NSW DEPARTMENT OF
PRIMARY INDUSTRIES

SOILpak – southern irrigators - 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-irrig

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

PART D. SOIL MANAGEMENT FOR THE MAIN FARMING SYSTEMS OF SOUTHERN NSW

Chapter D1.
Management for crop and pasture rotation systems

INTRODUCTION

Most crops are grown in rotation with other crops and pastures. This makes good sense since crop rotation is effective in:

- maintaining or improving soil fertility
- reducing the incidence of crop disease and weed competition
- improving soil structure in some instances

Soil management must therefore take into account differences in soil condition, and land use when crops are rotated.

ASSESSMENT OF SOIL AND ITS POTENTIAL

The most important assessment relating to soil is its inherent yield potential for given enterprises that are being considered. This manual uses five main soil groups. Each of these has different properties and therefore different uses for the particular soils are recommended.

Soil tests that can be conducted by users of the manual are included in Section C. These are referred to throughout SOILpak as they provide extra information regarding the condition of your soil. Knowing this information will allow SOILpak users to:

(i) Assess the suitability and yield potential of each of the soils examined. This is important since some crops will not perform satisfactorily on some soils.

(ii) Determine the management required to maximise yield from the soils you are examining.

FARMING SYSTEMS COVERED IN THIS SECTION

The major farming systems considered in this manual are:

(i) Rice rotations — farming systems where rice is the main crop grown.

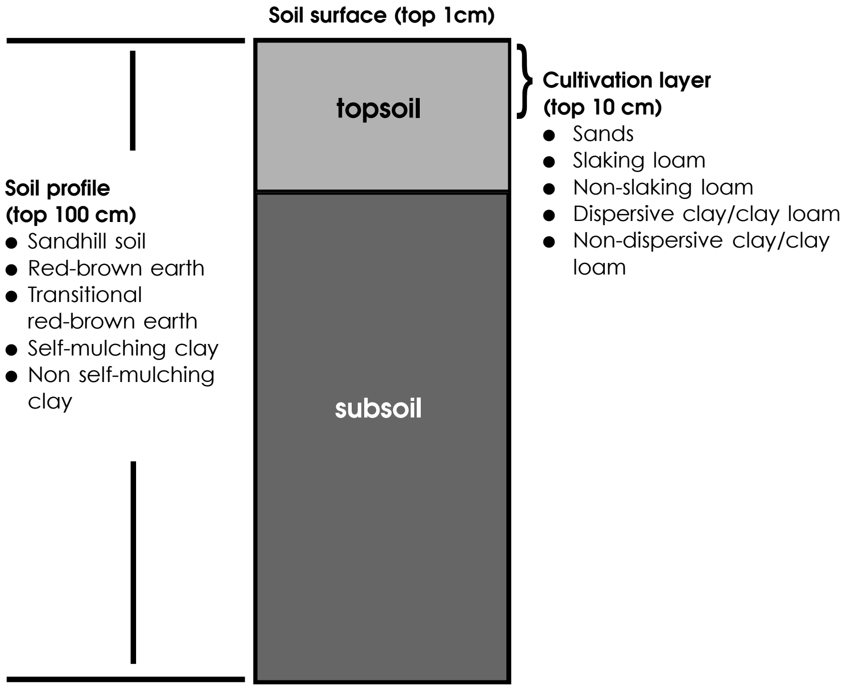
(ii) Summer cropping other than rice — maize, soybeans, etc., including double cropping.

(iii) Winter cropping — cereals, canola, faba beans, etc.

(iv) Pasture

Management options in SOILpak are discussed in terms of cultivation layer (top 10 cm) and soil profile (to about 1 metre). The top 10 cm is most important for crop establishment, while the whole soil profile influences water movement, aeration, and root growth. Therefore the soil profile influences land use, and crop growth after establishment has been achieved.

This chapter indicates how the information provided in previous chapters can be integrated with agronomic practices to provide soil management systems for the main irrigated crops of southern NSW.


Soil surface (top 1cm)
topsoil
subsoil
Soil profile
(top 100 cm)
● Sandhill soil
● Red-brown earth
● Transitional red-brown earth
● Self-mulching clay
● Non self-mulching clay
Cultivation layer
(top 10 cm)
● Sands
● Slaking loam
● Non-slaking loam
● Dispersive clay/clay loam
● Non-dispersive clay/clay loam

Chapter D2. Management for rice rotation systems

The following decision guides (rice after pasture and rice after rice) focus on the most important soil-influenced factors in decision-making for each option. References are made to the diagnosis and information sections of the manual.

DECISION GUIDE FOR PASTURE/RICE ROTATIONS

Rice is generally grown in rotation with legume-based pastures. This enables soil N to build up in the pasture phase for use by rice in the cropping phase. Rice will help to control many weeds, and diseases of non-rice plants.

Important considerations

The following are important issues to consider when growing rice after pasture:

i) Plant residue management

ii) Cultivation and structural problems

iii) Gypsum application to dispersive topsoils

Table D1. Rice after pastures calendar of operations

Calendar	Conventional	Reduced tillage
winter	Graze or spray pasture[1].	Graze or spray pasture[1].
spring	Cultivate (usually once with an offset disc plough followed by one pass with a scarifier). Urea application (usually drilled into the soil using a combine). Level soil/break down clods[2]. Flood bays. Sow rice.	Cultivate once (usually with a chisel plough)[3]. Urea application (usually drilled into the soil using a combine)[3]. Ridge roll[3]. Flood bays. Sow rice.

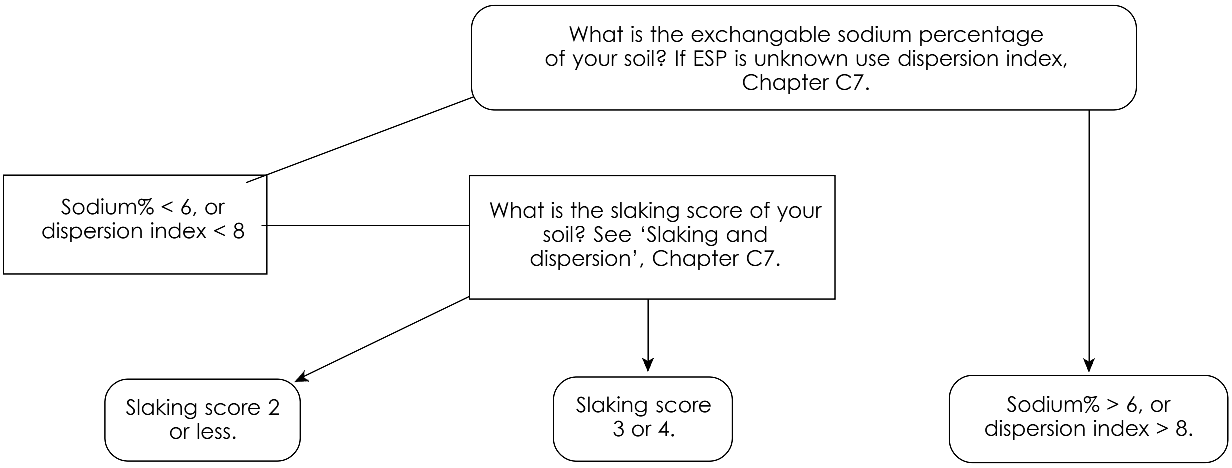
[1] Too much plant residue can reduce rice seedling growth. However some plant residue may assist in reducing structural problems such as muddy water.
[2] Wide-boards, landplanes, offset disc ploughs or ridge rollers are used to achieve a relatively even surface free from large clods.
[3] These operations can be combined to form a one- or two-pass preparation system, eg., fitting a fertiliser box to a chisel plough, with a trailing ridge roller.

(i) Plant residue management

Too much plant residue left at the soil surface at sowing can reduce rice seedling establishment. This is particularly common with residues of fresh clover. Experience shows that grass residues do not cause problems to the same degree that clover residue does. However, some plant residue may reduce establishment problems associated with slaking and dispersion of the surface soil, eg., muddy water.

To determine how your soil may behave after flooding you should calculate the dispersion score of the soil, or use the exchangeable sodium percentage of the soil (both in Chapter C7), as given in most soil tests.

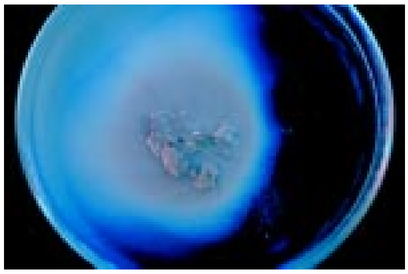
Figure D1. Assessing slaking and dispersion



stable soil

These soils are unlikely to have structural problems, unless excessively cultivated. Reduce plant residues as much as possible. Aim to have surface cover of < 10% plant residue after cultivation.

slaking soil



dispersive soil

These soils are likely to have structural problems such as muddy water, seedling burial or wind damage. This is more likely when over cultivated. A cover of plant residue (about 5 cm high clover stand) should be roughly incorporated using minimum tillage. After cultivation the soil surface should be left with a 10–20% cover of plant residue. This will help reduce structural problems at sowing.

Options for reducing the volume of plant residue before rice are:

- spray early (August)
- cultivate early (August)
- heavy grazing
- cut for hay

(ii) Cultivation

Stable soils (ESP < 6, dispersion score <6)

These soils can usually cope with extra cultivation. Choose either the conventional type cultivation (from calendar of operations) or reduced tillage.

Reduced tillage is a good management practice when rotating rice with other crops, since compaction at the base of the cultivation layer is less likely.

Where rice is to be grown in self-mulching soils which have a history of high water use, the fields should be puddled.

Dispersive soils (ESP > 6, dispersion score >6)

These soils are prone to dispersion, and therefore establishment problems such as muddy water and seed movement are likely. Reduced tillage is critical for these soils (see calendar of operations). Remember to cultivate at the appropriate moisture content (see Chapter C8: *Assessing soil moisture*).

Slaking loams

Conventional cultivation is acceptable on soils if they do not slake after cultivation. This can be assessed using the slaking score (see Chapter C7). If the topsoil is likely to slake, reduced cultivation (see calendar of operations) is recommended.

(iii) Gypsum application

Gypsum use is likely to increase water use under rice. The use of gypsum should only be considered where paddocks have a history of low water use, and muddy water problems which cannot be overcome with other management practices.

- Gypsum should be only applied to bays with problem soils and not applied to the whole paddock.
- Paddocks/bays where muddy water occurs should be managed using reduced cultivation, plant residue cover, ridge rolling and shallow water management. This will help to reduce the rate of gypsum, or may even eliminate the need for it.
- As muddy water problems are less likely when rice follows rice, this rotation may reduce the need for gypsum.
- Gypsum should only be used where other management procedures have been adopted and if problems are still experienced.

Slaking soils

Gypsum is not required.

Dispersive clay/clay loam

Gypsum should be only used where exchangeable sodium percentage exceeds 10% or dispersion score is greater than 6 (see Chapter C7). Apply at 1.25–2.0 t/ha, with an upper limit of 2.5 t/ha on the bottom bay.

Stable soils

Gypsum is not required.

DECISION GUIDE FOR RICE/RICE ROTATIONS

Important considerations

The following are important points to consider when growing rice-on-rice:

(i) Managing wet soils

(ii) ‘Cloddy’ soils following cultivation

(iii) Muddy water management

Table D2. Rice after rice calendar of operations

Calendar	Conventional	Reduced cultivation
autumn	Harvest rice. Burn stubble[1]. Reform banks and clean out toe furrows[2].	Harvest rice. Burn stubble[1]. Reform banks and clean out toe furrows[2].
winter	Cultivate twice (usually one pass with an offset disc followed by one pass with a scarifier). Predrill urea. Breakdown large clods[3].	Cultivate once with a chisel plough or scarifier[4] Predrill urea[4]. Ridge roll[4].
spring	Sow rice.	Sow rice.

[1] Stubble should be burnt as early as possible, allowing the soil to dry faster.
[2] Toe furrows should be cleaned out as soon as possible after harvest allowing good drainage of winter rain.
[3] Clods can be broken down with a wide-board, offset discs, or a ridge roller, depending on the soil structure.
[4] Two or all of these operations can be combined to reduce the number of passes required.

(i) Managing wet soils

Soils are likely to be wet following rice. If the winter period is wet, as is often the case, then cultivation and sowing may be delayed. It is therefore important to burn stubble as soon after harvest as possible to allow the soil to dry out. Cleaning out of toe furrows and early reforming banks is recommended to aid surface drainage over winter.

Wet soils have the potential to delay sowing, even with good management. It is therefore desirable to spread the risk of delays by choosing to sow some paddocks previously growing pasture. Early harvested paddocks should be the first considered for rice-on-rice, since there is more time for paddocks to dry out following harvest.

(ii) Cloddy soils following cultivation

Soils following rice often produce large ‘clods’ when cultivated. These can cause problems because:

- an even cover of shallow water is required to get good establishment, and reduce weed growth
- large clods may slake and bury rice seedlings resulting in seedling death.

It is therefore desirable to break down clods and produce a level surface before sowing. This can be done with a wide-board, an offset disc plough, or a ridge roller. Ridge rollers are more gentle on the soil than other implements, and therefore are recommended for soils where muddy water and seedling burial are a problem.

(iii) Muddy water management

Rice sown following rice rarely has muddy water problems where reduced tillage is used (see calendar of operations). If you did have muddy water problems in the previous rice crop, then reduced cultivation is critical to prevent muddy water in the following crop. Gypsum is rarely required when rice is sown following rice.

Chapter D3. Management for summer cropping/double cropping rotation systems

ROTATION CONSIDERATIONS

The following decision guides focus on the most important soil issues critical for high yields of summer crops. Growing a summer crop after rice, summer crop following winter crop, and summer crop following summer crop are discussed. References are made to the diagnosis and information sections of the manual.

While this chapter concentrates on soils issues relevant to summer cropping on raised beds, the general soil management principles also apply to row cropping (furrow irrigated hills) and growing on-the-flat.

SUMMER CROP AFTER RICE

Important considerations

The following are important issues to consider when growing a summer crop after rice, especially on raised beds:

(i) Compaction/plough pans may be a problem in soils following rice.

(ii) Soils following rice are likely to be deficient in phosphorus and nitrogen, and soil pH may also be low.

(iii) Bed dimensions to use.

(iv) Bed forming, and establishment of first crop.

Calendar of operations

(i) Plough pans and compaction of rice soils

Preparing land for rice often involves many cultivations, some of which may be conducted at a moisture content likely to damage soil structure. Machinery driven on rice fields when the soil is wet may also cause compaction. Both of these factors are likely to result in the formation of a compaction layer at and/or just below the surface. This layer will severely restrict the growth of crops which follow rice. The following steps may be useful in detecting and managing compaction layers:

- Burn stubble (if not incorporating) and clean out toe furrows as soon as possible after harvest. This will help soil to dry faster.
- Check soil for layers/plough pans.
- As deep tillage is needed for bed formation, it should be carried out to the depth required for hilling up or to just below the depth of the compaction layer, whichever is deepest. Remember that cultivation at an incorrect moisture content (usually too wet in this situation) will cause structural damage to the soil. Soil moisture for cultivation should be checked to cultivation depth before proceeding with the operation (see Chapter E4: *Cultivation and soil structure*)

Table D3. Summer crop after rice calendar of operations

Calendar	Fallow/winter crop	Long fallow/summer crop	Rice/summer crop
autumn	Rice harvest	Rice harvest	Rice harvest
	Burn stubble and clean out furrows[1]	Burn stubble and clean out clean out furrows[1]	Burn stubble and clean out furrows[1]
winter	Pull down old rice banks	Pull down old rice banks	Pull down old rice banks and soil test
spring	Soil test for pH, phosphorus and exchangeable sodium percentage (ESP)	Soil test for pH, phosphorus and exchangeable sodium percentage (ESP)	Deep tillage (cross worked)[2] Gypsum application, hilled up and bed shaping
summer	Deep tillage (cross worked)[2]	Deep tillage (cross worked)[2]	Sow summer crop
autumn	Gypsum application (if required)	Gypsum application (if required)	
	Hilling up/bed shaping[3]	Hilling up[5]	
	Pre-irrigation[4]		
	Sow winter crop		
winter		Knock down herbicide	
		Bed shaping	
spring		Pre-irrigation	
		Sow summer crop	

[1] This allows faster drying of soil.
[2] Deep tillage will break up any compacted layers and provide enough loose soil for bed forming or hilling up.
[3] Beds can be left in a reasonably rough condition. Pre-irrigation and sowing will assist in breakdown of large clods.
[4] Helps to consolidate beds, and provides moisture for good establishment.
[5] Beds should be left in a rough condition over winter, allowing weather to break down large clods rather than cultivation which may damage soil structure.

(ii) Phosphorus, pH and exchangeable sodium percentage of soil following rice

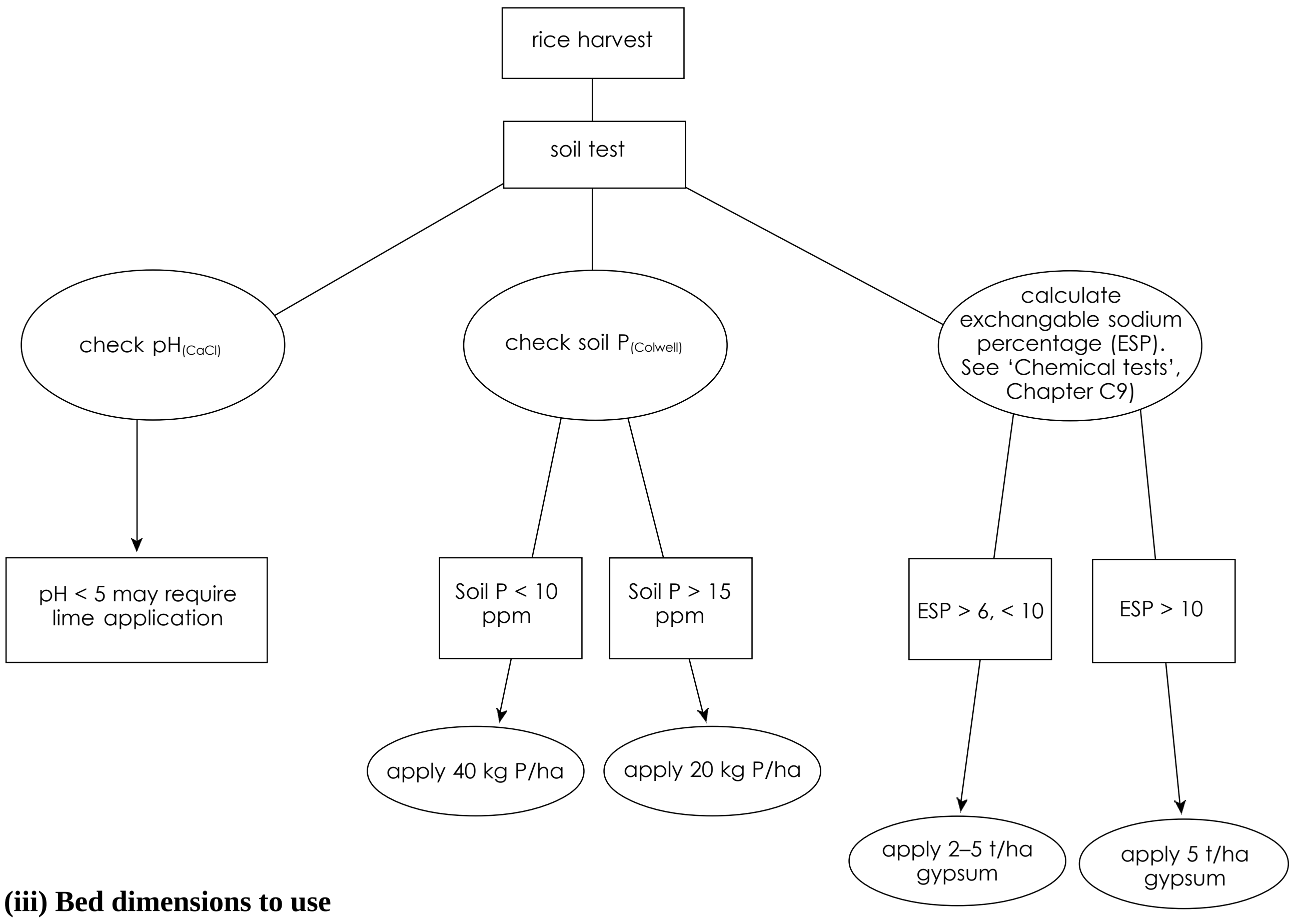
When a soil is flooded for rice production, soil phosphorus becomes much more available to the rice plants. Application rates of phosphorus for rice are therefore relatively low compared to other crops. However, when the soil is drained it may be left in a severely phosphorus deficient state. Soil in this condition can ‘tie-up’ much of the applied phosphorus, causing reduced plant growth.

A summer crop after rice should receive ample phosphorus. It is best ‘banded’ at or just prior to sowing to avoid phosphorus ‘tie-up’.

Soil pH will often be low following extended periods of rice production. Lime application may be needed if soil tests indicate a soil $pH_{(CaCl)}$ of less than 5.

Soil tests will usually give enough information to calculate exchangeable sodium percentage (see Chapter C9: *Other chemical tests*). If gypsum is required it should be spread before bed forming or hilling up.

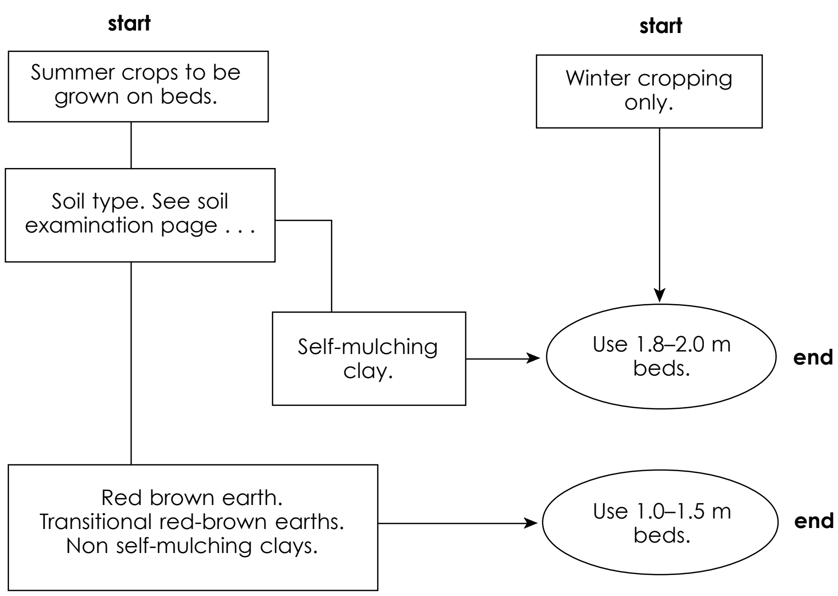
Figure D2. Phosphorus, lime and gypsum application guide



(iii) Bed dimensions to use

Actual bed dimensions will depend largely on machinery. However soil type will influence the maximum bed dimensions. Some soils such as red-brown earths do not 'sub' well and therefore should be narrower to allow the whole bed to wet up.

Figure D3. Bed dimensions guide



Note: Beds that do not sub well should be flooded (water over tops of beds) when irrigating in spring. Furrows act as drains that reduce yield losses due to waterlogging in winter.

(iv) Bedforming and establishment of first crop

Physical condition of beds after hilling up

After hilling-up beds may be in a rough condition, consisting of large clods and fine material. Rather than cultivating beds, it is preferable to allow pre-irrigation and sowing operations to break down large clods.

Phosphorus application

Fertiliser should be deep-banded just prior to or at sowing, to avoid phosphorus 'tie-up' after rice.

Crop selection

Ideally the first crop to grow after rice should be a winter cereal such as wheat or barley. Barley is a better option if a summer crop is to be sown directly after harvest, since it has a shorter growing season.

If a winter crop is not sown the paddock should be just left, with no cultivation carried out, provided surface drainage is effective. Volunteer grasses should be allowed to grow over the winter, as they will help to consolidate the beds, assist in the recovery of soil structure, and use some of the winter rainfall which may otherwise percolate to the watertable.

WINTER CROP AFTER RICE

The general principles of soil management for growing winter crops after rice are much the same as described above for summer crops. However, when using beds for winter cropping only, wider beds may be used on all soil types. If subbing is a problem, the beds can be flooded.

The main benefits of beds for winter cropping on heavy rice soils are:

- Decreased compaction and fuel costs, since wheels run in furrows only (with the possible exception of harvest time).
- Enhanced drainage since furrows act as drains. For this reason beds for winter crops are a good option on relatively flat ground (flatter than 1:1200).
- Less risk of waterlogging from spring irrigation, and safer pre-watering opportunities in subsequent years.

WINTER CROP AFTER SUMMER CROP (DOUBLE-CROPPING)

The most likely situation where this option should be successful is following a soybean crop. It should also work where other summer legumes or sunflowers are grown. The main advantages in following soybeans with a winter crop is that the soybeans are usually harvested in the early autumn period, and the soil is left in better condition than after rice. Soil compaction is less likely after soybeans than after rice. Stubbles of soybean and other grain legume are easier to handle than rice or maize.

Where the summer crop has been grown on beds, there are normally few problems in direct drilling of the winter crop. The soil management aspects described above also apply when winter crops are sown soon after a summer crop is harvested.

SUMMER CROP AFTER WINTER CROP (DOUBLE-CROPPING)

In this farming system a summer crop is planted soon after harvest of a winter crop on beds. The summer crop is usually always direct drilled.

Summer crops grown in a double cropping rotation have relatively short growing season, and hence soybeans are generally sown.

Important considerations

(i) Soil compaction — headers running on beds at winter crop harvest are likely to cause compaction.

(ii) Stubble management — stubble retention or burn?

Table D4. Summer crop after winter crop calendar of operations

Calendar	Conventional	Stubble retention	Wet harvest/compaction
October	• Schedule irrigations to dry soil by harvest.	• Schedule irrigations to dry soil by harvest.	
November	• Harvest winter crop.	• Harvest winter crop.	• Harvest winter crop. • If soil is compacted a surface cultivation should be carried out if time and soil moisture allow.
December	• Burn stubble. • Sow summer crop (usually soybeans).	• Sow soybeans[1] • Mulch stubble[1] • Clean furrows[2]	• Sow soybeans. Increased irrigation frequency may be required, if compaction is evident in the root zone.
	Soybeans sown after December will yield poorly		

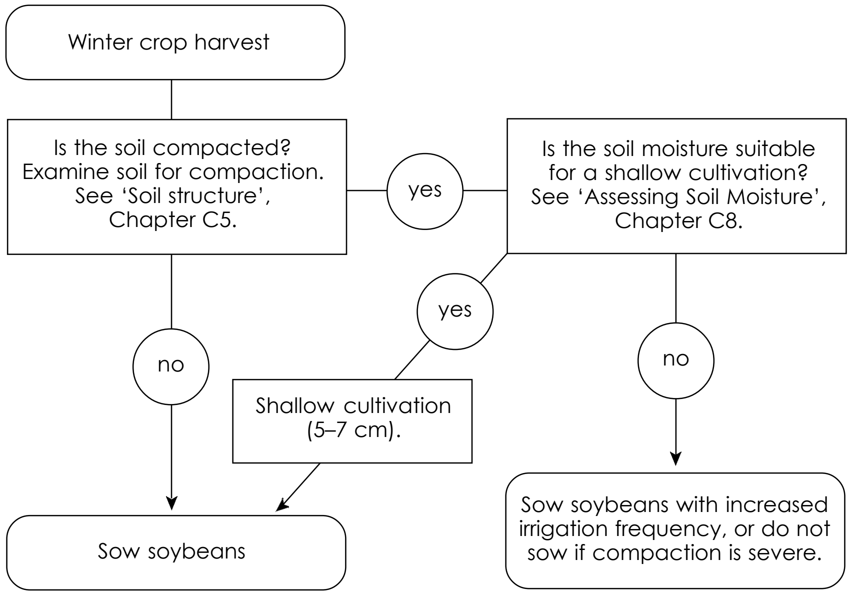
[1] When sowing soybeans after winter cereals, good trash flow and less blockages may result when the crop is sown into standing stubble, and mulched after sowing.

[2] Furrows should be cleaned out using a rake or power furrow cleaner.

(i) Compaction

If harvesting equipment is driven on beds compaction is likely. If the soil is moist to wet then compaction will almost certainly restrict growth of the following crop. There is no time to dry and/or deep rip the soil, however a surface cultivation may help to improve establishment.

Figure D4. Soil compaction rectification guide

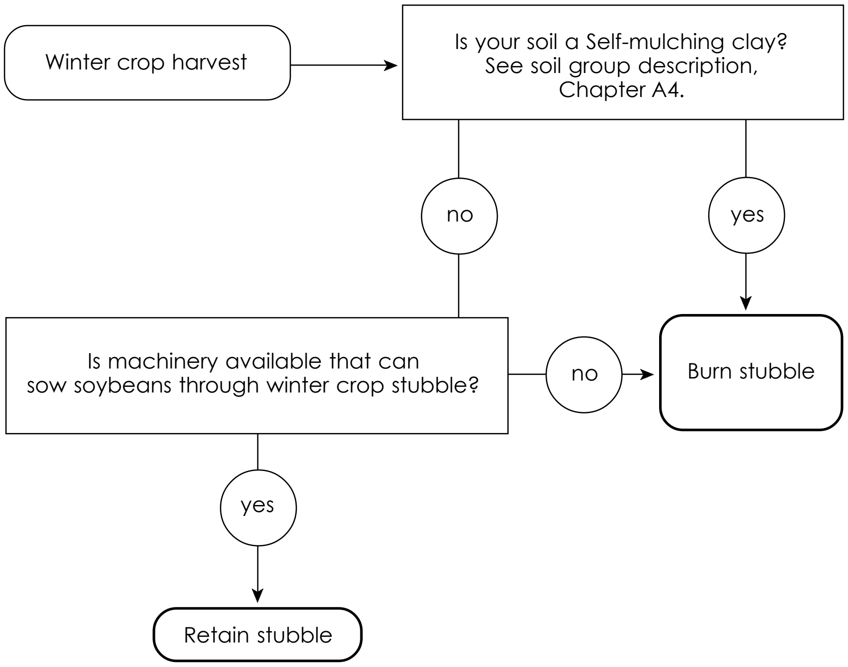


After soybeans the soil should be checked for compaction and ripped if it is evident, when soil moisture is suitable. For more information on deep ripping see Chapter E4.

(ii) Stubble management

Stubble can either be burnt, or retained on the surface, when double cropping on beds. Time constraints do not allow stubble incorporation. Stubble retention may help improve the structure of loamy topsoils of red-brown earths and transitional red-brown earths.

Figure D5. Stubble management guidelines



SUMMER CROP AFTER SUMMER CROP

Important considerations

The following management issues are important when following a summer crop with another, especially on raised beds:

(i) Soil compaction

(ii) Cultivation

(iii) Stubble management

(iv) Most suitable soil types

Table D5. Summer crop after summer cropping calendar of operations

Calendar	Conventional	Reduced tillage/stubble retention	Stubble incorporation*
autumn	Schedule irrigations to dry soil by harvest. Harvest. Mulch and burn stubble. Clean furrows. Rip plant lines/bed renovate[1].	Schedule irrigations to dry soil by harvest. Harvest[2] (wheels of harvesting machinery to run in furrows only). Mulch stubble[3]. Clean furrows.	Schedule irrigations to dry soil by harvest. Harvest. Mulch stubble. 'Split' beds using a left and right mouldboard. This will bury stubble and form a new bed, centered over the old furrow.
winter	Cultivate soil. Knockdown herbicide in late winter (if required)	Knockdown herbicide.	Breakdown clods using a rotary hoe.
spring	Pre-plant herbicide application, incorporated with banding of N and P fertiliser. Pre-irrigation. Sow.	Pre-plant herbicide application, incorporated with banding of N and P fertiliser. Pre-irrigation. Sow.	Pre-plant herbicide application, incorporated with banding of N and P fertiliser. Pre-irrigation. Sow.

[1] This operation will help to alleviate compaction and remove crowns of corn plants, allowing easier sowing. Not necessary for crops other than corn.
[2] Soil compaction and neccessary cultivation can be avoided by adapting machinery to run in furrows.
[3] Stubble should be directed to the centre of the bed away from sowing lines.
[4] Machinery is required that can cut through heavy stubble burdens eg; Agrowplow Agrowplant unit or Band rotary hoe units as used in the Tatura permenent bed system.
* The stubble incorporation system is still in the experimental phase. The long term benefits/disadvantages have yet to be assessed. Compaction under beds may be a problem with this farming system. This system has been shown to be useful on Non-sodic Transitional red-brown earths (especially where the topsoil is hardsetting and subbing is poor).

(i) Compaction

Compaction is likely to be a major problem in summer crops where beds have been driven on while moist, or cultivated when too wet. Any compaction is visible as a very poorly structured ‘platey’ layer in the soil that will restrict air, water, and root movement. Yields are decreased since the effective rooting depth of crops is substantially decreased.

If machinery has been driven on the top of the beds when soil is moist to wet, compaction may result, causing waterlogging and stunted plant growth with yellowing leaves. The best way to check for evidence of compaction is to dig a hole and look for ‘platey’ aggregates in the soil.

Compaction should be repaired using one of the following methods:

(a) Drying the soil

(b) Deep ripping.

(a) Drying the soil

In a clay soil, compacted layers can be repaired by growing a crop to dry it, so that the layer cracks. If this procedure is to be successful then the following points must be considered:

- Winter cereals are usually best suited to drying a soil profile.
- Cracks will form on drying, only if the soil is of a clay texture. Check the soil’s texture if it is not already known (see Chapter C6: *Soil texture*).

A good technique for drying and cracking the soil effectively is as follows:

- Sow a winter cereal crop as normal. The crop should be adequately fertilised and sown on time.
- The crop should be irrigated for maximum yield up until about flowering. At this point the root depth of the crop will be at a maximum.
- The crop should not be irrigated after flowering, allowing the plant roots to dry the soil, and cracking to take place. The higher the yield potential at flowering, the greater the soil drying and consequent cracking will be.

(b) Deep ripping

Deep ripping will break the compacted layer, allowing air, water and roots to penetrate the soil more deeply. Depth to the compacted layer should be checked, as well as soil moisture to the cultivation depth. Soil should be deep ripped only at the correct soil moisture content to avoid damaging soil structure further. If possible cultivation should not invert the soil.

Soil should be deep ripped to about 10 cm below the compacted layer to allow for variation in the depth of the layer across the paddock.

(ii) Cultivation

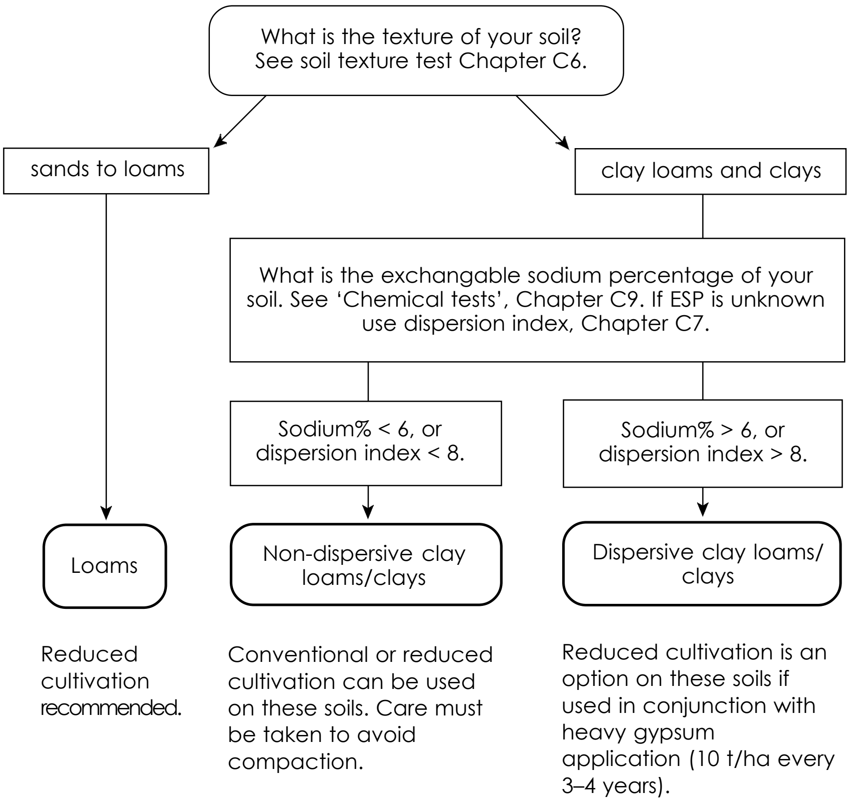
Reducing tillage is an important way of improving the structure of most soils, particularly loams. Reduced tillage is therefore more likely to benefit red-brown earths than other soil groups. As the structure of self-mulching clays is quite resilient, they can handle more cultivation than other soil groups.

> ***Soil organic matter* is the key to structure in loamy soils. Cultivation is largely responsible for reducing soil organic matter. It may only take one cultivation to cause a substantial reduction in soil organic matter and soil structure.**

Reducing soil disturbance can be achieved by the following:

- Deep band fertiliser and sow in the one pass using narrow points.
- Use herbicides where possible.
- When sowing a crop into maize stubble, adjust the seeder so that sowing points avoid the crowns of the old plants (ie. adjust row spacing). This will eliminate the need to rip the plant lines.

Figure D6. Cultivation decision guide



(iii) Stubble management

The three stubble management options are:

- Burn
- Stubble retention
- Incorporation

Burning

Burning is a recommended practice only when all or some of the following situations apply:

- Soil is a self-mulching clay.
- Stubble handling equipment is unavailable.
- The stubble is from a particularly heavy crop.
- Reduced tillage is not practiced.

Stubble retention

This system offers benefits for loamy and dispersive clay and clay loam surface soils. The stubble will protect the soil from raindrop impact, and reduce crust formation. Stubble retention systems do require some specialised machinery.

Stubble retention is recommended where the following situations apply:

- The cultivation layer (top 10 cm) is loamy or a dispersive clay/clay loam.
- Machinery with suitable stubble-handling capacity is available.
- Reduced tillage is practised.

Stubble incorporation

The key to this system is 'splitting' beds down the centre and reforming a new bed over the old furrow. Prior to splitting, stubble from the previous crop is mulched onto the soil surface. This system has been found to be useful where hardsetting loam topsoils restrict subbing into the centre of the bed.

Once the stubble has been buried by forming the new bed, water movement into the centre of the bed is thought to improve. This could be due to the layer of buried stubble acting as a 'channel' for irrigation water to move through.

This system is still in the experimental phase, and has some drawbacks. Compaction problems may develop since beds are reformed over old furrows. Machinery costs may also be high.

(iv) Most suitable soil types

Summer crops have a higher water requirement than winter crops. The soil must therefore be able to store high amounts of available water (see Chapter E7: *Irrigation scheduling*). Soils with sodic (dispersive) layers are least suitable for production of summer crops since water storage is low, necessitating frequent irrigations. The most suitable soil types are:

- Self-mulching clays
- Non-sodic transitional red-brown earths
- Red-brown earths

For more information on soil types see Chapter A4: *Soils of the Riverina landscape.*

Chapter D4. Management for winter cropping rotation systems

INTRODUCTION

The following are examples of typical rotations used with winter crops. Important soil issues are considered and management ideas are suggested as examples. It is acknowledged that many management variations are possible.

WINTER CROP AFTER WINTER CROP ROTATIONS

Important considerations

Important questions when growing a winter crop after a previous winter crop are:

(i) When is direct drilling an option?

(ii) Stubble management?

(iii) How do I manage poorly structured soils?

(iv) Should I consider using beds?

Table D6. Winter crop after winter cropping calendar of operations

Calendar	**Conventional**	**Reduced cultivation**[1]	**Direct drill/stubble retention**
Summer	Harvest winter crop	Harvest winter crop[2] Burn or mulch stubble, depending on stubble burden and machinery Pre-irrigation	Harvest winter crop[2] Slash or harrow stubble to shatter straw and reduce stubble length Pre-irrigation
Autumn	Burn stubble Cultivate after first rain Pre-irrigation Harrow or secondary cultivation Herbicide incorporation if required Sow winter crop	Knockdown herbicide if required Cultivate after first autumn rain, using non-inversion tillage[3] Herbicide incorporation if required Sow winter crop	Knockdown herbicide if required Sow winter crop[4]

[1] This is a good option where soils are hardsetting or poorly structured. Direct drilling is suited to better structured soils.
[2] A straw spreader fitted to the rear of the header is a good idea when stubble is to be retained.
[3] A tined implement with narrow points is ideal for this operation. A trailing roller may assist in breaking down clods (see Chapter E4).
[4] Deep banding fertiliser may assist crop growth.

(i) Is direct drilling an option?

Direct drilling is the best option for improving or maintaining good soil structure. If possible machinery that has high tine break-out pressure, and narrow sowing points should be used.

Direct drilling should be considered in the following situations:

1) cereal crops following canola
2) grain legumes following cereals

(ii) Stubble management

The three stubble management options are:

- Burn
- Stubble retention
- Incorporation

Burning

In environments such as the Riverina Plain, where water and wind erosion are not issues, research has shown no production benefit in stubble retention and incorporation relative to burning. Burning is a recommended practice where all or some of the following situations apply:

- Stubbles are particularly heavy and difficult to handle.
- Stubble handling equipment is unavailable.
- Reduced tillage is not practised.

Of the above three situations, it is the reduced tillage which gives the greatest benefit, regardless of whether the stubble has been burnt or not. However, in some dry seasons, stubble on the soil surface will aid moisture retention.

Stubble retention

This system offers benefits for loamy and dispersive clay/clay loam surface soils, since the stubble will protect the soil from raindrop impact, and reduce crust formation. If the situation permits, retaining the stubble over the hot summer months, and burning in the early autumn is an acceptable option.

Stubble incorporation

This system may offer benefits of increased soil nitrogen from stubble breakdown. However, stubble may be slow to break down over the dry summer months, causing problems at sowing. Nitrogen ‘tie-up’, and toxicity from stubble breaking down may reduce seedling growth. Additionally soil structure can be damaged severely trying to incorporate stubble. Implements that are more ‘gentle’ on the soil are best. If the upper subsoil is dispersive (see Chapter C7: *Slaking and dispersion*), then inverting the soil with a mouldboard plough or a disc implement is not recommended.

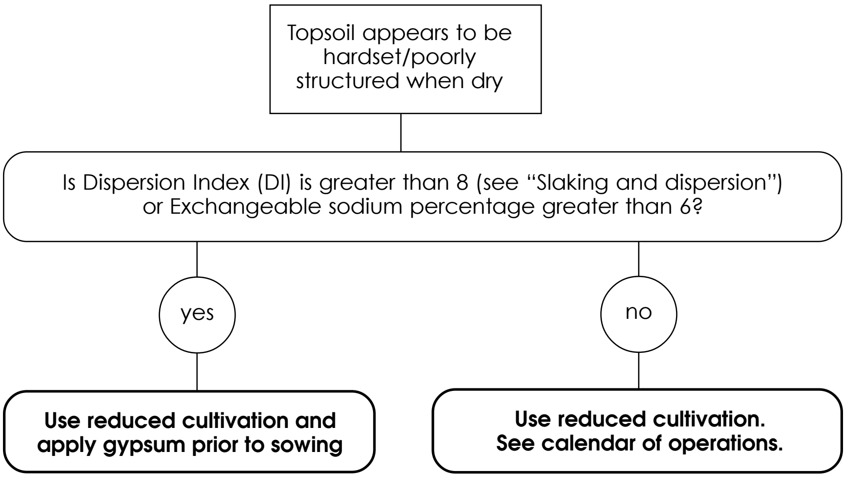
(iii) Managing poorly structured soils

A poorly structured soil presents problems in achieving good crop establishment. Direct drilling is less likely to be successful in soils with poor structure.

Identifying poor topsoil structure

Poor topsoil structure can be identified as a thick (around 1 cm or more) crust, pugged soil (damaged and compacted by stock) or hardset when dry. A good test is to drag the heel of your boot along the dry surface of the soil. If your boot easily forms a groove then the soil is still quite friable, and probably well suited to direct drilling. If a groove cannot be formed with your boot then the soil is hardset, and cultivation may be required.

Figure D7. Management guide for hardsetting topsoils



(iv) Should I consider using beds?

Raised beds are an excellent option for improving yields. Beds improve yields mainly through improving drainage. Research has shown that even with short bay lengths, winter crop yields are higher using beds.

Even where soils are poorly structured and do not sub well, beds can be used for winter crop production. In this situation beds are constructed within border check bays. When irrigated, the beds are flooded (rather than keeping water in furrows) allowing water to reach the centre of the bed.

Beds are the most favoured system for growing summer crops. However, summer crops have high demand for water, and require soils that sub well. For more information, see Chapter B9: *Is my soil suitable for raised bedfarming?*

WINTER CROP AFTER RICE DECISION GUIDE

Important considerations

The following are important issues to consider when growing winter crops following rice:

(i) Is sod sowing cereals into burnt rice stubble an option?

(ii) Soils following rice are likely to be deficient in phosphorus and nitrogen, and also low soil pH.

(iii) Plough pans or compacted layers are common in soils used for rice.

(iv) Cultivation of, and traffic on wet soils after rice will cause soil compaction.

(v) Rice stubble incorporation may be an option.

Table D7. Winter cropping calendar of operations

Calendar	Conventional	Stubble incorporation	Cereal sod sown into rice stubble
autumn	Rice harvest	Rice harvest Mulch stubble or run stock on stubble	Rice harvest Burn stubble
winter	Burn stubble[1]	Shallow mouldboard or offset disc[5]	Sow cereal[6] Top dress N if crop has good yield potential[7]
spring	Cultivation[2] Grading/levelling[3]		
summer		Level (if required)	Harvest cereal
autumn	Weed control[4] Sow winter crop	Sow winter crop	

[1] Earlier burning allows soil to dry allowing earlier cultivation.
[2] May help to break up "plough pans" after rice, as well as kill weeds and level out damage from a wet harvest.
[3] May be required after a wet harvest.
[4] If weed control is necessary, herbicide is preferred to cultivation.
[5] This cultivation should be conducted as soon as possible after harvest, allowing time for 'mellowing' of soil/clods before cereal sowing takes place.
[6] Higher sowing rates are required for direct drilling and earlier sown the better.
[7] If crop has a good establishment, topdress N as required.

(i) Fallow or direct drill cereal into rice stubble?

Direct drilled or sodsown cereals can take advantage of high levels of soil moisture after rice. Since little or no cultivation takes place, the high volume of plant material in the form of rice roots are preserved, potentially improving soil structure. However, slower growth due to waterlogging and hard, uncultivated soil may mean yields are up to 40% lower than fallowed wheat.

Direct drilling wheat into rice stubble soon after rice harvest is likely to be a good option when:

- Rice is harvested by mid-April.
- Few severe wheel ruts in the paddock.

- Successful flag burn of rice stubble is achieved soon after rice harvest.
- Paddock is adequately fertilised.
- High sowing rates are used (around 120 kg/ha).
- Favourable wheat prices.

If any of the above criteria are not met, then the paddock should be fallowed over the winter.

(ii) Phosphorus, nitrogen and pH status following rice

When a soil is flooded for rice production, soil phosphorus becomes much more available to the rice plants. Application rates of phosphorus for rice are therefore relatively low compared to other crops. However, when the soil is drained, it may be become severely phosphorus deficient. The soil can "tie up" much of the applied phosphorus in this state, causing plant growth problems.

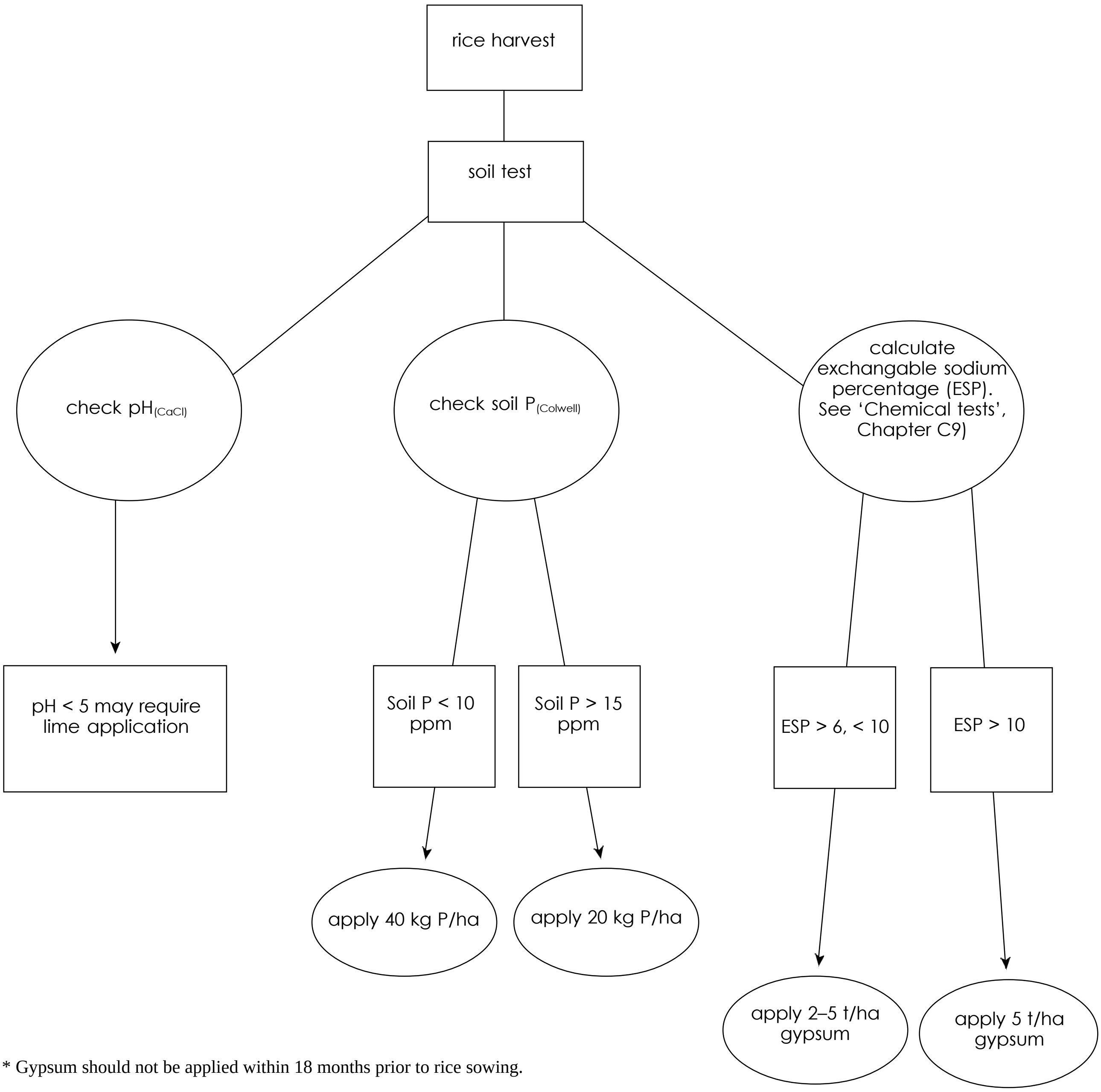
Nitrogen status of soils following rice may also be low. High rates of N are recommended especially where paddocks have wheat sown into burnt rice stubble.

Soil pH will often be low following extended periods of rice production. Lime application may be needed if soil tests indicate a soil $pH_{(CaCl)}$ of less than 5.

Table D8. Nitrogen requirement for wheat grown after rice

Fallow/wheat	Wheat sodsown into rice stubble
40–50 kg N/ha	80–100 kg N/ha (split application recommended) OR 20 kg N/ha at sowing and tissue test (NIR or sap N) for nitrogen requrement at late tillering (6-8 weeks after sowing)

Figure D8. Phosphorus, lime and gypsum application guide



* Gypsum should not be applied within 18 months prior to rice sowing.

(iii) Plough pans and soil compaction of rice soils

Rice growing usually involves several cultivations, some of which may be conducted when soil moisture content is likely to damage soil structure. Machinery driven on rice soils when the paddock is wet may cause severe compaction. Both of these factors are likely to result in the formation of a compaction layer at and/or just below the surface. This layer will severely restrict the growth of following crops (excluding rice).

If you decide to fallow the rice paddock before sowing a winter crop the following steps are recommended:

- Burn stubble (if not incorporating) and clean out toe furrows as soon as possible after harvest. This will help soil to dry faster.
- Check soil for compaction layers/plough pans.

- If a plough pan or compaction layer is detected, then a cultivation to below the depth of that layer will be needed. Remember that cultivation should be conducted at the appropriate moisture content (see Chapter C8: *Assessing soil moisture*).

(iv) Structural damage by cultivating or traffic on wet soils

When cultivating paddocks just after rice harvest, soils are likely to be wet, and therefore structural damage and compaction are likely. The following steps should be taken to avoid structural damage.

- Burn stubble and clean out toe furrows as soon as possible after harvest.
- Check soil moisture to cultivation depth (see Chapter C8). If soil is too moist structural damage is likely and cultivation should be delayed if possible.

(v) Incorporation of rice stubble

Incorporating rice stubble offers advantages such as increased soil organic matter, and increased soil nitrogen in the long term. However, in the short term (stubble needs approximately three months of good soil moisture to break down), ‘nitrogen tie-up’ may be a problem. It is therefore advisable to incorporate the stubble as soon as possible to reduce N deficiencies in the following year’s wheat crop.

Additionally, if several cultivations are needed to incorporate the stubble, soil structure will be damaged, reversing the beneficial effects of stubble in the soil. These problems can be overcome by:

- Reduce stubble burden with stock or mulch. Mulching is of benefit since it will aid incorporation and stubble breakdown.
- Incorporate stubble as soon as soil moisture allows. A mouldboard plough (less than 10–12 cm deep) could be used if available.
- Once cultivated, allow the soil and clods to mellow over the winter to summer period.
- Avoid multiple cultivations when incorporating stubble. Excessive cultivation will cause damage to soil structure.

Chapter D5. Management for irrigated pastures

SOIL MANAGEMENT FOR PASTURES

Whilst this chapter concentrates on irrigated pastures, much of the information also applies to dryland or non-irrigated pastures. The aspects of soil management for pastures discussed are in relation to the following yield-influencing factors:

(a) pasture establishment

(b) pasture growth (after establishment)

SOIL REQUIREMENTS FOR PASTURES

Soil requirements for pastures are generally the same as for most crops. All plants prefer a well-drained soil that stores large amounts of plant available water. However, such soils are rare and are usually targeted for high input crops. It is therefore important that species be well matched to the soil and drainage characteristics of the field.

Some species have different requirements, and adaptations to others. It is useful to group pastures into four broad groups for discussing their soil requirements.

(i) Perennial pastures (perennial ryegrass, paspalum, phalaris, white clover, strawberry clover and lucerne)

(ii) Winter pastures (sub-clover, annual grasses)

(iii) Pastures for poorly drained situations (Persian and Shaftal clovers, Balansa clover, Berseem clover and some sub-clovers)

(iv) Pastures for saline areas (Berseem clover, strawberry clover, perennial ryegrass, tall wheat grass, Puccinellia)

(i) Perennial or summer pastures

Perennial pasture species require good to very good drainage, and hence best production comes from the following soil types:

- Red-brown earths, especially those with a deep loam topsoil (> 25 cm).
- Self-mulching clays.
- Sandhill soils (mainly for lucerne).

Irrigation layouts should permit fast watering and drainage. Border check layouts and beds will generally allow best drainage. Border check bays should have slopes around 1:750, while bay length should generally not exceed 400m.

On sandhill soils and the lighter types of red-brown earths, it is preferable that deep rooted perennials such as lucerne and phalaris are grown, instead of the shallow rooted species. Water which quickly percolates below the root zone of the shallow rooted species is a major cause of accessions to the watertable in very well drained soils.

(ii) Winter pastures

Winter pasture species include sub-clover, and annual grasses such as ryegrass. These species can be grown successfully on all soil groups covered in this manual. As production will be better where drainage is good, the highest production will come from layouts that allow fast watering and drainage (border check is superior to contour layouts). Crop establishment and growth are likely to be better where gypsum is used on sodic soils, such as non self-mulching clays and sodic transitional red-brown earths.

(iii) Pastures for poorly drained situations

Some soils, particularly transitional red-brown earths and non self-mulching clays, are naturally poorly drained, and are poor environments for plant growth. This can be aggravated by poor irrigation layouts which will not drain quickly, leading to waterlogging. As fast watering and complete drainage is hard to achieve in contour layouts, pastures grown in rotation with rice often suffer from waterlogging.

In poorly drained situations it is important to choose pasture species that will have some tolerance of waterlogged conditions. Suitable species include paspalum, strawberry clover, Balansa clover, Persian and Shaftal clovers, and Berseem clover. The Yanninicum sub-clovers, such as Trikkala, Gosse and Riverina, are more tolerant of waterlogged conditions than most of the others.

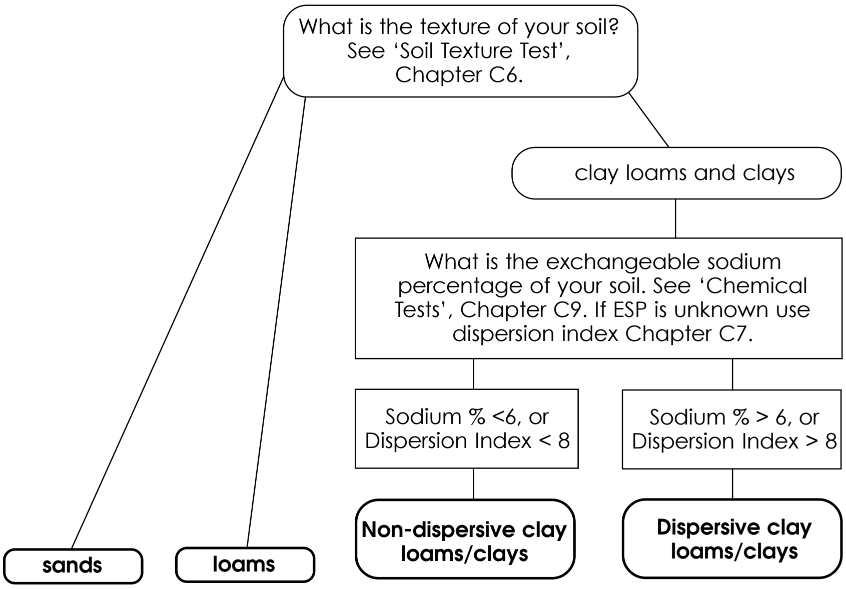
(iv) Pastures for saline soils

Soils are classified as saline when soil salinity levels exceed 2 dS/m (saturation extract). In these situations it is advisable to grow salt tolerant pasture species. Some of the more tolerant species which can grow in moderately saline land (EC_{se} 2–4 dS/m) include perennial ryegrass, strawberry clover and Berseem clover, whilst for severely saline conditions (EC_{se} > 4 dS/m) Puccinellia, tall wheat grass and some saltbushes are suitable. For more information contact your District Agronomist.

(a) Pasture establishment

Before trying to establish a pasture it is wise to know the properties of the soil in question. The following flow diagram is a guide to diagnosing soil characteristics of the top 10 cm of soil.

Figure D9. Soil characteristics guide



The most popular methods of establishing pasture are:

- *Sowing seed into a cultivated seedbed.* This method is suited to the better soils (sands, non-crusting loams and non-dispersive clays/clay loams)
- *Sodsowing (*often using a triple disc). A good option in hardsetting, crusting soils (slaking loams and dispersive soils).
- *Broadcasting the seed* (usually aerial-sown) onto the soil surface. This is an option where pasture is to be sown following rice, or where good soil 'tilth' is hard to achieve.

Some general rules apply for all sown pastures:

- Sow between 15 March and 30 May. Sowing prior to mid April will mean that one or two irrigations are required to ensure establishment.
- Ensure that layouts allow fast watering and drainage (< 12 hours). Areas where water lies will be slow to establish and will yield poorly.
- When undersowing clover pastures into cereal crops, ensure that cereal sowing rates are reduced. Sowing the crop seed through every second row is a good option. Sow the pasture seed on or close to the surface — do not bury it with the crop seed. Ensure that the seedlings are protected from Red Legged Earth Mites and other pests, and both pasture and crop are well supplied with water at least until the clover has set seed.

Sowing into a cultivated seedbed

This method involves sowing the pasture seed into the soil, similar to crop establishment. Implements such as bandseeders and combines fitted with a small seeds box are commonly used. Success has also been achieved with broadcasting seed onto a cultivated seedbed followed by a light harrowing.

A common method of establishment is undersowing pasture in a cereal crop. This is a less favoured method of establishment, since the cereal crop competes with the pasture for light, water, and nutrients.

To achieve successful pasture establishment in a cultivated seedbed it is important to achieve the following:

- correct sowing depth
- good seed/soil contact
- no to insignificant soil crusting
- good soil moisture at sowing depth
- a minimum amount of plant residue at the soil surface.

Correct sowing depth

Pasture seed is generally very small. It is therefore important that pasture seed be sown as shallow as possible. Soil texture and structure will also have an influence on the optimal sowing depth. Sowing depths on loose sands and non-dispersive clays can sometimes be slightly deeper since these soils are softer, with a surface that dries quite quickly.

Figure D10 shows the effect of sowing depth and soil texture on lucerne establishment.

Most pastures are sown using a combine fitted with a bandseeder, or a triple disc seed drill. When undersowing using a combine, a levelling bar should be fitted behind the last row of cultivating tines. This will allow more accurate placement of seed by the bandseeder.

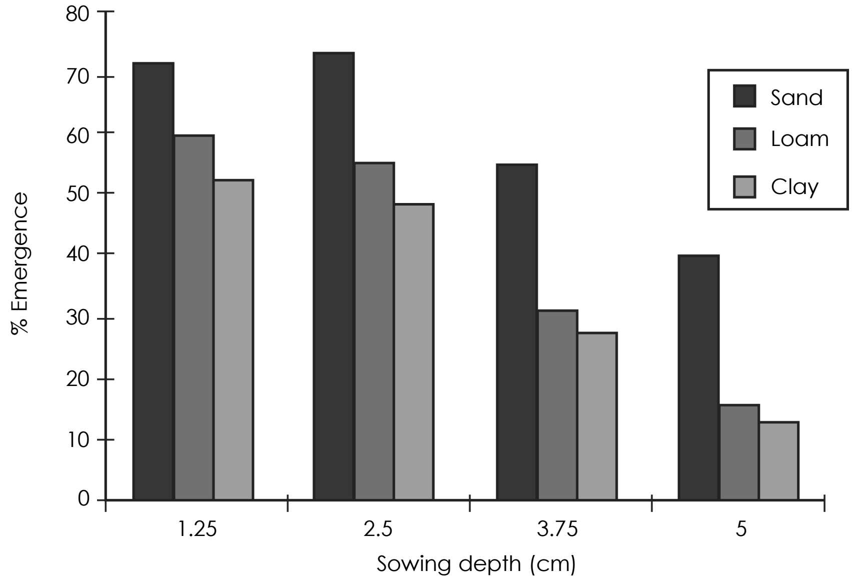
In hardsetting soils (loams and dispersive clays/clay loams) soil 'tilth' may be difficult to achieve. Pre-irrigation will help to 'soften' the soil, as well as providing good soil moisture for germination.

If soils are dispersive gypsum should be applied prior to sowing to help produce a better seed bed. For more information on gypsum use, see Chapter E1: *Sodicity and soil management.*

Good seed/soil contact

Good seed/soil contact relies on producing a relatively fine seedbed, without pulverising the soil. The best way of achieving this is to cultivate at the correct moisture content (see Chapter C8). Where soils

Figure D10. Percentage emergence of lucerne vs sowing depth and soil texture (Sund *et al.* 1963)



slake or disperse gypsum should be applied prior to sowing to improve soil 'tilth'.

Rollers and light covering harrows are recommended to improve seed/soil contact.

Crusting problems

Crusting (caused by rain or irrigation soon after sowing) is likely to restrict emergence of pasture species significantly. Crusting is a particular problem in slaking and dispersive soils.

Management options for soils where crusting is anticipated (slaking and dispersive soils) are:

- Irrigate 5–7 days after sowing, aiming to keep the topsoil moist.
- Sow later than normal. The soil surface is likely to stay moist when sowing in cooler weather. Moderate amounts of stubble or plant residue may assist in keeping the topsoil moist.
- Sodsow pasture.
- Broadcast seed and gypsum (2.5–5 t/ha) and follow with a light harrowing.
- When establishing pasture after rice, aerial sow after flag burning stubble (see section on aerial-sown pastures).

Good soil moisture at sowing depth

Pasture establishment will be most successful where moisture is in contact with the seed throughout the germination and early growth period. Loose sands and "crumbly" non-dispersive clays may dry slightly quicker than other soils.

Management strategies that will assist in keeping the topsoil moist are:

- pre-irrigation
- retention of a moderate amount of trash/plant residue at the soil surface
- later sowings (late March–April)

Minimise cover of trash/plant residue

While some plant residue is beneficial to pasture establishment, large amounts can be detrimental. Where soil is unlikely to have any crusting problems (sands, non-slaking loams, and non-dispersive clays), trash cover should be reduced as much as possible.

Sodsowing pasture

Sodsowing pasture is a suitable method where soils are likely to crust or hardset (loams and dispersive clays/clay loams). Triple disc combines are the most commonly used implements, but there are many others available.

To successfully establish a sodsown pasture attention must be paid to all issues that will affect pasture sown into a cultivated seedbed (with the exception of crusting). When sown with a triple disc or similar implement that creates a groove, a crack usually remains above the sowing line through which seedlings can emerge.

For successful sodsowing it is advisable to pre-irrigate before sowing. A modest shower of rain will usually establish a sodsown pasture. See Prime Pastures manual for more information on direct drilling pastures.

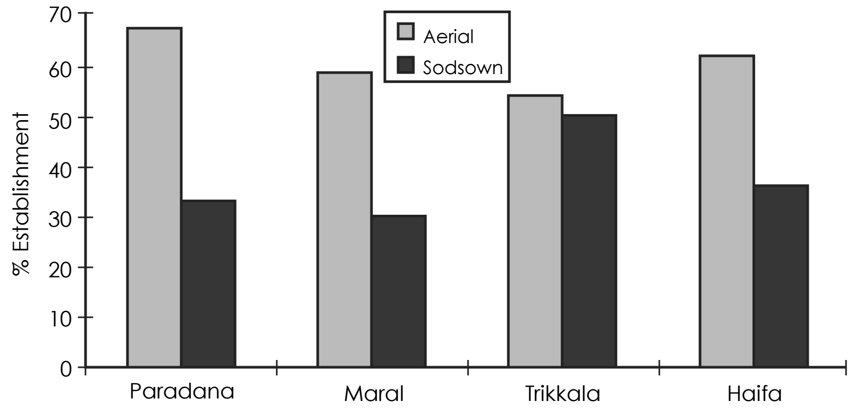
Broadcasting/ aerial sowing of pastures

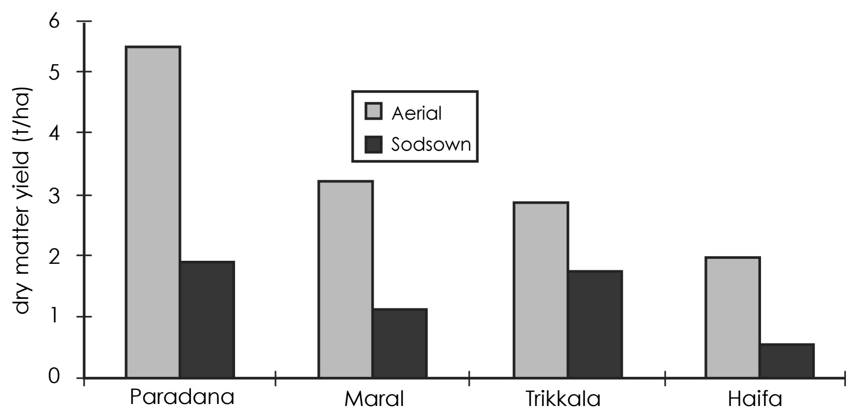
Aerial sowing is a very successful method of establishing pastures after rice. Research has shown that aerial-sown pastures establish better and produce more growth in their establishment year than sodsown pasture or pasture established in a cultivated seed bed (all immediately following rice).

Aerial sowing after rice is an excellent method of establishing pasture on heavy soils, especially dispersive clays, and also slaking loams, where crusting and hardsetting are often a problem.

Figure D11 shows a clear advantage in aerial sowing several clovers after a flagburn as opposed to sodsowing.

Figure D11. Establishment and yield of pastures established by aerial sowing and sod sowing into rice stubble after a flagburn (Beecher and Lattimore, 1990)





To achieve a successful establishment using aerial sowing after rice the following points need to be considered:

- A flagburn will improve establishment considerably when compared to paddocks that are not burnt.
- Sowing should be completed before the end of April for best establishment and yields.
- Pasture species such as Balansa, Persian and Berseem clovers should be included in the pasture mix for best results.

(b) Conditions for optimal pasture growth

Like any plant, pasture plants will grow best when they are supplied with adequate:

- air
- water
- nutrients (nitrogen, phosphorus, etc.)
- suitable soil pH

All of these are supplied via the soil. It is therefore valuable to have an understanding of how to improve/modify the supply of each input.

Air supply

Plants need oxygen to survive, and they obtain it from the air. However, as plants take up oxygen via their roots, the soil needs to contain air for them to survive. When a soil becomes waterlogged, there is no air available in the soil and plants become stressed. Swamp plants such as rice are an exception since they can supply the plant with oxygen through the leaves.

To maximise plant production, it is necessary to minimise the period of waterlogging a plant will experience every time the soil is irrigated (flood irrigation), or during extended wet periods.

Irrigation layouts must allow the pasture to be irrigated quickly (watered and drained in less than 12 hours) if maximum growth is to be achieved. Some pasture species can cope with waterlogging better than others (strawberry clover, Persian clover, Balansa clover and Berseem clover). They should be used where layouts are such that water will not drain very quickly and remains wet for extended periods in winter.

For more information of irrigation design and waterlogging, see Chapter B2: *Reducing waterlogging.*

Water supply

One of the requirements for plant growth is water. The soil acts as a reservoir for water. Some soils will not hold as much as other soils due to differences in texture and the rate at which water infiltrates into the soil. Irrigation water must be applied so that the soil never becomes too dry, with plant growth suffering accordingly. Alternatively if waterings are more frequent than needed, plant growth may suffer through waterlogging (insufficient air in the soil). Irrigation scheduling is a technique that aims to keep the plants well supplied with water while minimising waterlogging. For more information on irrigation scheduling see Chapter E7: *Irrigation scheduling.*

Nutrients

Plants need to be well supplied with nutrients if they are to produce high yields. The most important of these nutrients are: nitrogen, phosphorus, potassium, sulfur, and molybdenum.

For more information on pasture nutrition contact your District Agronomist and/or refer to Sub-check or Prime Pastures manual.

Soil pH

Soil pH is an important factor in determining the growth of pasture species. It is very important to match pasture species and varieties to soil pH. For example lucerne is more likely to perform in neutral to alkaline soils, whereas most varieties of sub-clover (*T. subterraneum*

L.) are suited to slightly acidic soils. Most pasture species are intolerant of highly acid soils (pH_{CaCl2} < 4.5), and liming is recommended in this situation (for more information see Chapter B5: *Is my soil acid*?

Productive legume-based pastures are likely to acidify soil. Paddocks that are lighter (sandier) in texture are likely to acidify at a faster rate than heavy (clayey) textured soils. Soil pH should be monitored regularly (every 3–4 years), to see if lime is required. If soil is not limed soon after an acid topsoil develops, subsoil acidity may develop. This is a much more serious problem, since lime is best incorporated into the acidic layer. This can be very costly when liming subsoils.