Guide to Best Practice in Water Management
ORCHARD CROPS
Guide to Best Practice in Water Management

First Edition
October 2002
ISBN 1 74106 313 2

Authors
Dr Anne-Maree Boland, Angelika Ziehrl and Jennifer Beaumont
Department of Natural Resources and Environment
621 Burwood Highway
Private Mail Bag 15
Ferntree Gully Delivery Centre
VIC 3156
Ph: (03) 9210 9222
Fax: (03) 9800 3521

Produced & Printed by Highway Press, Knoxfield, Victoria

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Acknowledgements

The authors wish to acknowledge the funding provided by the Murray–Darling Basin Ministerial Council for this work, under the Strategic Investigations and Education (SI&E) Program and the Department of Natural Resources and Environment.

We also thank the extensive number of people who contributed to the project “Development of Benchmarks and Best Management Practices for Perennial Horticulture”, and therefore the content of the manual. In particular:

- The project team, which included: Dr Anne-Maree Boland, Jacinta Corrie, Denise Bewsell and Dr Peter Jerie
- The steering committee members of the project: Dr Peter Jerie (NRE, Tatura), Henry Schneider (NRE, Cobram), Denise Bewsell (NRE, Tatura), Shane Hall (grower, Ardmona), Dominic Nardi (Northern Victorian Fruit Growers Association, Shepparton), Robert Hoogers (NSW Agriculture, Yanco), Bruce Cumming (NRE, Tatura), George Themilis (grower, Shepparton East), Lloyd Tremellen (grower, Ardmona), Caroline Welsh (NRE, Swan Hill), Ian Bolitho (grower, Ardmona), Max Cornish (grower, Cobram), Clive Noble (NRE, MDBC representative), Sandy Robinson (MDBC representative), Peter Alexander (MDBC representative), Terry Walker (AFFA, MDBC representative). This committee was established at the inception of the project and offered valuable input into the direction and outcomes. The growers input was particularly valued providing insights into extension strategies and adoption processes.
- The 200 growers involved in the initial survey
- The 40 growers involved in the monitoring program who contributed freely and hopefully received in return
- Mark Jenkins and Debbie Dellar for their excellent technical assistance
- Ian Bolitho and Max Cornish for the use of their orchards for demonstrations
- The Winter family, Tresco, for the provision of the orchard field sites
- Goulburn–Murray Water for the data for grower surveys
- Dr Leigh Callinan (NRE) for biometric advice
- All growers who participated in interviews and completed questionnaires for the market segmentation work
- Rob Hoogers for acting as the NSW contact for the market segmentation work
- Heather Cook (NRE), Ian Goodwin (NRE), Denise Bewsell and Harold Adem (NRE), for providing information and comments on the manual.
Management of water resources in the Goulburn/Murray Valleys is an increasingly important component of an orchard business – both from a production and environmental aspect. This issue has been emphasised in recent years with low water allocations and the intention of most growers to do the best for the environment. However, as water is not a significant cost of fruit production, good water management must embrace other aspects of productivity and sustainability. This project aimed to develop practices for both environmental sustainability and productivity that fitted with the farms general management and made good business and environmental sense. To achieve these aims, the project also focussed on developing a clear understanding of growers current practices and their needs and aspirations through survey and market segmentation studies.

To achieve efficient irrigation, an understanding of the current practices and the adoption of Best Management Practice (BMP) is critical. BMPs for orchard irrigation involve many factors including irrigation scheduling, nutrient management, leaching for salinity control, vigour management and knowledge of crop development stages. BMPs must integrate these factors within the physical and practical constraints of the orchard and the business. BMP strategies are based on current technology and the best available information and are expected to change over time.

The project aimed to:
• Benchmark current management practices
• Monitor the input of these practices, and
• Determine the Best Practices.

To establish Benchmarks and Best Practice in Water Management, we undertook a project with 40 growers to test on-farm practices and demonstrate practical production methods. These growers include pear, apple and stonefruit producers of fresh and canning produce, located in the Ardmona, Shepparton East, Cobram and Swan Hill districts. Growers and Department of Natural Resources and Environment (NRE) staff worked together to monitor crop yield, productivity, irrigation, nutrient movement, soil moisture, salinity and water table depths, and solve on-farm problems.

Best Practice Water Management was developed and tested through the monitoring programs, discussions with growers and any additional information available. This guide contains information to help you adopt these Best Practices.

The project was funded by NRE and the Murray-Darling Basin Commission (MDBC) and was supported by growers in the Goulbourn–Murray region.

Foreword

Management of water resources in the Goulburn/Murray Valleys is an increasingly important component of an orchard business – both from a production and environmental aspect. This issue has been emphasised in recent years with low water allocations and the intention of most growers to do the best for the environment. However, as water is not a significant cost of fruit production, good water management must embrace other aspects of productivity and sustainability. This project aimed to develop practices for both environmental sustainability and productivity that fitted with the farms general management and made good business and environmental sense. To achieve these aims, the project also focussed on developing a clear understanding of growers current practices and their needs and aspirations through survey and market segmentation studies.

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Introduction

This guide is for You – the grower. It will focus on Best Practice in Water Management to help:
• Improve production efficiency
• Produce good quality fruit
• Manage the orchard in a sustainable way for fruit production and the environment

This guide has been developed to be practical and easy to use. The information is provided to help you understand Best Practice and be able to apply it to your orchard. These practices have been tested on orchards, so they do work.

This guide enables you to measure the performance of your orchard and compare it with that of other orchards. The sections which relate to Best Practice Management are:
• Production
• Irrigation Management
• Salinity Management
• Nutrient Management
• Soil Management

How did we develop these Best Practices?

To establish Best Practice we undertook a project with 40 growers to test on-farm practices and demonstrate practical production methods. These growers included pear, apple and stonefruit producers of fresh and canning produce, located in the Ardmona, Shepparton East, Cobram and Swan Hill districts.

Growers and Department of Natural Resources and Environment (NRE) staff worked together to monitor crop yield, productivity, irrigation, nutrient movement, soil moisture, salinity and water table depths, and solve on-farm problems.
Good water management involves making informed decisions. Consider the following when managing your water:

**Irrigation Scheduling**

The main aim of irrigation scheduling is to apply the right amount of water at the right time (traditionally decided through experience and observation). This means:

- understanding the changes in tree water use over the season
- measuring soil moisture
- making informed decisions on when and how much water to apply.

With flood and furrow irrigation – there is little control over the efficiency of water application. Micro-irrigation allows greater control over the water, but when and how much becomes more critical.
**Salinity Management**

Stone and pome fruit are sensitive to salt! Leaching is the way to manage saline irrigation.

Where irrigation water is saline [greater than 600 Electrical Conductivity (EC) or 0.6 deciSiemens per metre (dS/m)] an additional leaching component is important to:

- flush salt from the soil profile and
- prevent build-up in the tree rootzone.

However, it is important to consider the following:

- Leaching can cause waterlogging on heavy soils.
- Leaching should never be more than 10–15% of normal irrigation.
- A leaching component should not be included with fertiliser application as nutrients will be washed past the rootzone.

The effectiveness of leaching will depend on:

- soil type
- whether you have ground-water pumps installed
- whether tile drains are in place.

**Water Table Control**

Fruit trees don't like being waterlogged. This can occur from over-irrigation leading to perched water tables, or from shallow regional water tables.

Shallow water tables during the irrigation season indicate over-irrigation, which can be controlled by irrigating for less hours and monitoring soil moisture.

Shallow water tables in winter and spring are due to rainfall and can be decreased by surface drainage and hilling in the tree row.

- Ground-water pumps and tile drains will protect orchards from shallow water tables.
- Test wells can be used to measure the water table depth.
- Saline water tables are particularly bad for tree health and productivity.
A well managed high-denisty orchard

“We need to measure it in order to manage it”.

A good monitoring system:
• will cost a fraction of the establishment cost of a new high-density orchard
• will make the difference in getting the best performance out of that orchard
• can help improve water management and orchard performance even for conventional flood irrigated orchards
• needs to be simple, practical and measure the correct parameters.

This guide provides information for the grower to monitor the performance of their orchard and compare this against results from Goulburn and Murray Valley growers and some industry standards.

Nutrient Management
Nutrients must be applied where and when the roots can use them.

How you irrigate and when fertiliser is applied during irrigation is critical when trying to keep nutrients in the rootzone, rather than being washed past. Nitrogen fertilisers are often very soluble (eg. urea) and will move past the rootzone very quickly. Using larger doses to compensate, is not an answer – this can acidify soil and in the long term pollute drainage water.

Vigour Control
Regulated Deficit Irrigation (RDI) was developed to reduce the amount of shoot growth of stone and pome fruit by cutting back the water early in the season when fruit are growing slowly.

RDI controls too much vigour, particularly in high-density orchards, and results in increased productivity and fruit quality.

Monitoring
– The Key to Good Management

‘We need to measure it in order to manage it’.

A good monitoring system:
• will cost a fraction of the establishment cost of a new high-density orchard
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This guide provides information for the grower to monitor the performance of their orchard and compare this against results from Goulburn and Murray Valley growers and some industry standards.
CASE STUDY

ADOPTING BEST PRACTICE FOR WATER MANAGEMENT

A grower in Ardmona runs a small pear orchard. The orchard is traditionally planted (mostly 17 feet by 17 feet) and is irrigated by knocker sprinklers that were installed in 1967. Initially this grower was irrigating the pears fortnightly. This matched the demands of other orchard jobs – for example, spraying. The routine was adjusted if the weather was warmer than normal or if it rained. Run times averaged 16 hours or more. Although he was happy with the performance of his trees when the opportunity came to join the project he decided "taking a look at his irrigation practices" would be worthwhile.

Over the three years of the project this grower gradually decreased the run time of the sprinklers. He is now confident that eight to 10 hours gives the trees sufficient water. He used the tensiometers to check what was happening and see how deep the irrigations went. He also decreased the interval between irrigations – now between once a week and 10 days depending on weather conditions and other management decisions like spraying. The grower feels that it was being part of a group discussing possible changes to his irrigation management and hearing about the experiences of others that gave him the confidence to change what he was doing. He says, "Confidence grew in the group. There was no feeling that the information was too far ahead of us."

The grower's newer, closer – planted blocks are under micro-irrigation. He feels that this gives more control over the water, but having been part of the project doesn't feel that his older knocker sprinklers (or himself!) are past it. The ability to make a living from an orchard is hampered by rising costs and this grower feels that changing his irrigation management can help manage this. He's pleased he joined in initially and is now talking to his neighbour "over the fence" about the changes and benefits he gained from looking at his irrigation practices.
Summary of Best Practice for water management

GROWTH CYCLE
• Record growth cycle dates for each variety

PRODUCTION
• Measure and record production and quality for each variety

IRRIGATION MANAGEMENT
• Select the most efficient irrigation method
• Assess the soil using a soil pit and determine how long to run the system
• Monitor and record the irrigation system’s performance
• Keep records of irrigation events
• Measure and record the amount of water applied over the season
• Calculate the water use efficiency tonnes per Mega Litre (t/ML) for each variety
• Schedule irrigation using the most appropriate techniques
• Measure and record soil moisture
• Apply Regulated Deficit Irrigation for vigour control and/or water savings

SALINITY MANAGEMENT
• Measure and record salinity of irrigation water and the water table
• Monitor and record the depth of the watertable
• Take soil samples for salinity measurement Electrical Conductivity (saturation extract) \( (EC_e) \)
• Take leaf samples for salinity (sodium and chloride) measurements

NUTRIENT MANAGEMENT
• Apply the most efficient form of fertiliser
• Record the amount and timing of fertiliser applied
• Ensure that fertiliser is applied at the most effective time
• Monitor plant nutrition using leaf nutrient analysis
• Measure efficiency of nitrate application (amount of leaching) using soil water samplers
• Take soil samples for measurement of soil pH

SOIL MANAGEMENT
• Ensure adequate surface drainage (eg. hilling and/or laser grading inter-rows)
• Incorporate a surface mulch
• Check crusting of soil and water infiltration
• Record the amount and timing of any gypsum or lime applied (gypsum for soil structure problems and lime for pH problems)
Living and growing trees need air, sunshine and water in regular and appropriate quantities. They also need good soil, good husbandry and good nutrition.

There are 5 events/stages that are important in the growth cycle of fruit crops; these are depicted diagrammatically below (with a full size lift-out over the page).

The guide focuses on these growth stages throughout all sections of this manual.

Figure 3.1 Fruit Growers Guide to Irrigation: The Growth Cycle
Figure 3.1 Fruit Growers Guide to Irrigation: The Growth Cycle
The tree growth cycle

Budburst and flowering

Floral budburst is the beginning of flowering. This may occur before or after vegetative budburst (depending on the tree variety) and signifies the beginning of stage 1.

Vegetative budburst occurs when buds reach the green tip stage and leaves start to develop.

Flowering completes this cycle and fruitlets start to form. The number of cells that form the fruit are determined at this stage of the growth cycle. Enlargement of the fruit will then rely on these cells getting bigger, i.e. no additional cells will be produced.

| STAGE 1 | Budburst and flowering | → | Beginning of rapid shoot growth |

Beginning of rapid shoot growth

The beginning of rapid shoot growth signifies the start of stage 2 of the growth cycle which is when both rapid shoot growth, and spring root growth occurs. The fruit grows slowly. In stonefruit this stage commences at tip change (stone hardening).

To determine tip change you need a sharp knife and a piece of immature fruit. Start slicing off the tip end of the fruit. If there is some resistance to this, tip change has occurred.

There is no similar or obvious point, for when this stage of fruit growth starts for apples or pears. However, growers can observe known dates for specific varieties.

For stonefruit, the time of tip change to the start of fruit fill depends on the variety.

| STAGE 2 | Beginning of rapid shoot growth | → | Beginning of fruit fill |
Beginning of fruit fill
Stage three of the cycle starts when the fruit cells begin to fill with water and sugars and the size of the fruit increases rapidly. Shoot and root growth is slow and bud formation for the following season’s fruit begins.

STAGE 3  Beginning of  →  Harvest fruit fill

Harvest
At the end of fruit fill, mature fruit are picked (usually based on colour and size). This completes the third stage of the growth cycle and leads into leaf fall.

For early varieties shoot growth often starts here. Root growth occurs once the fruit is removed. Leaves turn and some nutrients are stored in the tree.

STAGE 4  Harvest  →  Leaf fall

Leaf fall
The tree enters a dormancy phase. Leaves fall from the tree.

STAGE 5  Leaf fall  →  Budhurst & Flowering
How do the growth cycle stages relate to water management?

The five growth stages and tree development events allow us to work out soil moisture requirements for the crop.

Monitoring of these stages is straightforward. It involves recording when your crop blossoms, when tip change (for stonefruit) occurs, when rapid fruit growth starts and when you harvest the fruit. A general growth curve is shown in Figure 3.2 and growth curves for peach, apple and pear are shown in Chapter 5. Blank sheets are provided in Chapter 9 to record growth events of your own crops.

The growth cycle and water management

This section introduces how the tree growth cycle, crop factors and soil moisture relate to water management (including RDI). For more detail on irrigation management and growth stages, see Chapter 5.

Stage 1 – Budburst and flowering to beginning of rapid shoot growth

This stage of the growth cycle is critical for cell division and the formation of the fruit, and it is recommended that soil moisture tension be kept between 8 and 40 kilopascals (kPa). Spring rain will generally provide adequate moisture.

Stage 2 – Beginning of rapid shoot growth to beginning of fruit fill

At the second stage of the growth cycle, fruit growth is slow and shoot growth is rapid. Irrigation is not critical, but soil moisture tension should remain between 8 and 40 kPa. If RDI management is used here to reduce vegetative vigour, soil moisture can be dried to 200 kPa.
Stage 3 – Beginning of fruit fill to harvest
Stage three is the time of rapid fruit growth, lasting anywhere from four to eight weeks to harvest. It is important to keep soil moisture tension between 8 and 40 kPa at this time.

Stage 4 – Harvest to leaf fall
In this final stage of growth after harvest, the amount of water applied can be reduced. However, if you are applying post harvest fertiliser, there must be sufficient water in the soil to allow trees to take up these nutrients. Soil moisture tension should be kept between 8 and 200 kPa.

Stage 5 – Leaf fall to budburst and flowering
The tree is dormant and generally does not need irrigation.

RDI – Regulated Deficit Irrigation
What is it and how do we use it?

Regulated Deficit Irrigation is an irrigation management method designed:
- to reduce vigour, or shoot growth, of stone and pome fruit early in the season and therefore
- increase yield and fruit quality.

Note: It is important to provide full irrigation when fruit begins to grow quickly.

For more detail:
- refer to the section on RDI in Chapter 5 and
- ‘Irrigation scheduling for Regulated Deficit Irrigation (RDI) – Agricultural Note – see further reading.'
Production management

In order to understand the performance of your orchard, you will need to measure production factors from individual blocks. Differing seasonal and/or environmental conditions that occur from one year to the next, affect the productivity of the trees. This effect on productivity varies from block to block – each block will therefore need to be monitored and the following type of information recorded:

- tree variety
- tree age
- rootstock
- planting system
- planting area.

This information will clearly identify each orchard block and allow you to measure productivity, irrigation requirements and fertiliser and chemical spray applications for individual blocks.

It is also important to record management practices performed on individual blocks such as, pruning and tree training times. This will generally be part of your normal record keeping requirements for Quality Assurance.

Keeping records of crop productivity is critical in understanding the effects of different irrigation practices (see Figure 9.1). For each block, you will need to record:

- yield
- fruit size, and
- packout.

Refer to Chapter 9 (Benchmarking and Monitoring) for productivity record sheets.

A whole farm plan is often the best way to easily identify each block and record the correct information. This whole farm plan should include:

- aerial photos
- irrigation lines and shifts
- traffic lines and channels
- block boundaries
- number of trees on each block (or area)
- planting spacing.
Irrigation management

Irrigation management in orchards aims to attain the full production potential of the crop and to ensure long term production with the most efficient use of irrigation water.

Most importantly, the fruit tree needs water to grow to its full potential.

You need to keep records of when you irrigate

Certain questions need to be answered and records kept to manage irrigation and achieve full production potential, see Figure 5.1:

• How much water does a tree use?
  - water use varies with seasonal conditions
  - the water needs of a tree change with different growth stages.

• How to schedule?
  - when to irrigate
  - how much water is required.

Do you know how much water you apply to each block over a season? You will need to measure it.

• Which system?
Some of the questions that need to be asked when considering a new system are:

Labour and time
• Do you have the time to switch things on and off?
• Is automation available?

Water supply
• Is water available on demand?
• Volume and timing – how much, how often?
• Quality of water – are there problems with salinity?
The system
- What is the accuracy and efficiency that you require?
- What is the potential for damage to irrigation laterals and emitters due to layout?
- Do you want to use RDI?
- Is this a high-density planting?
- What is the cost of installation and maintenance?
- How easy or difficult is it to manage?

Fertiliser
- How will you apply fertiliser?

Choose a system that you can control and fits the needs of your crop

Water Use Efficiency (WUE)
WUE is calculated by the amount of fruit produced from 1 ML of irrigation water applied. This indicates how efficiently the water is being used.
Irrigation management strategy

To decide on an irrigation strategy you need to understand the basic water needs of the tree. For a certain crop at a particular time of the season, this can be determined by:

1. Tree Water Use (mm) = Crop Factor x Pan Evaporation (Epan) (mm)

Water use in mm as calculated here refers to the entire block or orchard planted with this crop.

To calculate water use of individual trees (litres) you need to estimate the tree spacing or planting square (m²) and multiply this by water use (mm).

1 mm of water used over 1 m² = 1 litre of water use, ie. 1 litre of water poured over an area of 1 square metre will create a depth of 1 millimetre

2. Tree Water Use (L/tree) = Crop Factor x Pan Evaporation x Planting Square (m²)

When irrigation scheduling, one can use either (1) mm or (2) L/tree. For sprinklers of flood irrigation it is best to use mm while for micro-irrigation, L/tree is the easiest method. Examples are presented for both types of systems later in this chapter.

When you have determined tree water use, you can decide if other management strategies are necessary, for example:
- to control tree vigour with RDI (refer to later in this chapter)
- to control salinity with leaching (see ‘Management of Water Tables and Salinity’ Chapter 6).

Once you have decided on your irrigation strategy, you can then work out how much you need to apply and when to apply it to each block. This is irrigation scheduling.

Crop Factors
Crop Factors are values used to relate tree water use, at a particular growth stage, to Pan Evaporation (Epan) (see below).

Crop Coefficients
You may see numbers that are similar to crop factor numbers, but are called crop coefficients. The crop coefficient relates tree water use to reference crop evapotranspiration (ET₀) as calculated by a weather station. These are slightly different to crop factors, but can be used in the same way for the purpose of irrigation management. It is important to know whether Epan or ET₀ has been used.

Pan Evaporation (Epan)
Pan evaporation is the amount of water lost from a Class A pan. Refer to:
- ‘Evaporation and crop factors’ in this chapter

Pan evaporation figures are also available from the Bureau of Meteorology.
How to schedule irrigation is discussed in detail later in this chapter.

You will also need to measure soil moisture throughout the season to either check on Crop Factors or use as your main decision tool.
Tree water use

The following section describes the water needs of different trees at different times. Refer to Figures 5.2 to 5.4 and Tables 5.1 to 5.3 in conjunction with the text.

Stone fruit

Stage 1 – Budburst and flowering to beginning of rapid shoot growth
Tree water needs increase as cell division occurs and the canopy starts to leaf-up. At the end of this stage you will have a Crop Factor of 0.6. Soil moisture tension should be kept between 8 and 40 kPa. Spring rain will often maintain soil moisture at this level.

Stage 2 – Beginning of rapid shoot growth to beginning of fruit fill
Fruit growth is slow, shoot growth is fast and water use is stable – so Crop Factors stay at 0.6.

Soil moisture tension should be kept between 8 and 40 kPa. If you are using RDI (refer section later this chapter), the Crop Factor will be 0.3 and soil moisture should be allowed to dry to 200 kPa.

Stage 3 – Beginning of fruit fill to harvest (4–8 weeks)
The fruit grows rapidly and needs large amounts of water to reach its potential size. Remember that the fruit still has the same number of cells and these have to be filled for the fruit to enlarge. Your tree needs more water, fast. The Crop Factor will now be 1 – 1.2 and soil moisture tension should be maintained between 8 and 40 kPa.

Stage 4 – Harvest to leaf fall
Once fruit is taken off the tree, water use drops and evaporation declines. But, water is still needed especially for healthy leaves. The Crop Factor will be around 0.4. Soil moisture can be allowed to dry to 200 kPa.

Stage 5 – Leaf fall to budburst and flowering
The trees no longer need irrigation as they have entered the dormant phase. Soil moisture monitoring will need to commence in Spring to determine when to apply the first irrigation.
Pears

As with stonefruit, the majority of fruit growth occurs 6–8 weeks before harvest.

**Stage 1 – Budburst and flowering to beginning of rapid shoot growth**

Tree water needs increase as cell division occurs and the canopy starts to leaf-up. At the end of this stage you will have a Crop Factor of 0.6 and soil moisture tension should be kept between 8 and 40 kPa. The first irrigation will depend on the amount of spring rain.

**Stage 2 – Beginning of rapid shoot growth to beginning of fruit fill**

At this stage of the tree cycle, fruit growth is slow and shoot growth rapid and the Crop Factor will be between 0.6 and 0.8. Soil moisture tension should be kept between 8 and 40 kPa. If you are using RDI management (refer section later this chapter), the Crop Factor will be 0.2 and soil moisture should be allowed to dry to 200 kPa.

**Stage 3 – Beginning of fruit fill to harvest**

Irrigation is critical at this stage to allow the fruit to grow rapidly and reach its potential size. The Crop Factor is between 1.0 and 1.1 and soil moisture tension needs to be between 8 and 40 kPa.

**Stage 4 – Harvest to leaf fall**

After harvest, tree water needs decline, but water is still needed to maintain the health of the tree. The Crop Factor should be 0.4 and soil moisture can be allowed to dry to 200 kPa.

**Stage 5 – Leaf fall to budburst and flowering**

As the trees enter dormancy, they no longer require water. But, soil moisture will need to be monitored at the start of spring to determine when the first irrigation is required for the next stage of growth.

**Figure 5.3**

**Pear Growth Stages**

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<thead>
<tr>
<th>Month</th>
<th>Pear Growth</th>
<th>Crop Factor</th>
<th>RDI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sept</td>
<td>Slow fruit growth</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>Oct</td>
<td>Slow fruit growth</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Nov</td>
<td>Slow fruit growth</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>Dec</td>
<td>Slow fruit growth</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>Jan</td>
<td>Rapid fruit growth</td>
<td>1.0</td>
<td>0.2 (to mid Dec)</td>
</tr>
<tr>
<td>Feb</td>
<td>Postharvest</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>March</td>
<td>0.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>April</td>
<td>0.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.2

Suggested crop factor values for pear in the Goulburn Valley
Apples

Stages 1 and 2 – Budburst and flowering to beginning of fruit fill
From the start of flowering and as the tree starts to leaf–up until the beginning of fruit fill, crop factors increase to 0.6. Soil moisture tension should be between 8 and 40 kPa. There is no real time when the fruit grows slowly (apple fruit growth rate is steady from about 6–7 weeks after budburst to harvest). This means that Crop Factors will not vary as sharply as for pears. It also means that there is little time to apply RDI (ie. either the fruit cells are dividing or the fruit is growing).

Stage 3 – Beginning of fruit fill to harvest
Fruit continues to grow at a steady rate. The crop factor will increase to 0.8 before harvest. Soil moisture tension should be kept between 8 and 40 kPa.

Stage 4 – Harvest to leaf fall
Following harvest, tree water requirements decline. The Crop Factor should be 0.4. The health of the leaves still requires that soil moisture tension be kept between 8 and 40 kPa.

Stage 5 – Leaf fall to budburst and flowering
The tree no longer requires irrigation as it enters dormancy. But, as for stonefruit and pear, soil moisture will need to be monitored at the start of spring to determine when the first irrigation is required for the next stage of growth.

<table>
<thead>
<tr>
<th>Month</th>
<th>Apple Crop Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sept</td>
<td>0.2</td>
</tr>
<tr>
<td>Oct</td>
<td>0.5</td>
</tr>
<tr>
<td>Nov</td>
<td>0.6</td>
</tr>
<tr>
<td>Dec</td>
<td>0.6</td>
</tr>
<tr>
<td>Jan</td>
<td>0.8</td>
</tr>
<tr>
<td>Feb</td>
<td>0.8</td>
</tr>
<tr>
<td>March</td>
<td>0.8</td>
</tr>
<tr>
<td>April</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Table 5.3
Suggested crop factor values for apple in the Goulburn Valley
To accurately schedule irrigation, we need to know how much and when to irrigate. How much will depend largely on the amount of water the soil can hold, and what the specific aim of the irrigation is. The specific irrigation strategy can include RDI to reduce vegetative vigour or use of extra water to flush salts from saline soil. When, will depend on how quickly water is used by the tree at a particular time of the growth stage.

Knowing how much to irrigate relies on knowing the amount of water held in the rootzone. Knowing when to irrigate relies on knowing the crop factors and evaporation and monitoring soil moisture.

There are three steps involved in scheduling:

1. **Knowing the amount of water held in the rootzone** allows you to determine the amount of water to apply, ie. **HOW MUCH TO IRRIGATE**

2. **Knowing Crop Factors and evaporation** allows you to determine how much water your tree uses and how frequently water must be applied, ie. **WHEN TO IRRIGATE**

3. **Soil moisture monitoring** helps you to check how much water to apply with each irrigation and when you need to irrigate, ie. **CHECK ON HOW MUCH AND WHEN TO IRRIGATE**

The following points will provide more detail on how to schedule irrigation using these methods.

**1. How much to irrigate**

Knowing the amount of water held in the rootzone

The maximum amount of water that should be applied with each irrigation, will depend on the amount of water that is held in the irrigated rootzone and is readily available. Before we start calculating this value you will need some general information.
Soil Moisture

Not all the water you’ve put on, or pre-existing water in the soil, is available to your tree. Some water is held very tightly in the soil and the tree hasn’t enough energy to suck it up! How tightly the water is held is referred to as soil moisture tension.

If you think of the soil as a water filled sponge – the amount of water held in the sponge is the total soil water. When you squeeze the sponge water is released – but not all of it! More pressure is needed to release more water. In this same way, a tree would need to suck harder to get more water from the soil.

Some important points to remember:

• Field Capacity is when the soil has drained (imagine no squeezing of the sponge, its just left to run out naturally). Soil moisture tension is approximately 8 kPa.

• Permanent Wilting Point is where the tree can not take up any more water even though there is still some left in the soil. Soil moisture tension is approximately 1500 kPa.

• Total Plant Available Water is between these two points. Refer to Figure 5.5.

But what you are interested in is Readily Available Water.

• Readily Available Water (RAW) is the amount of water that is easily available to the tree. This is between field capacity and when the plants start to have difficulty sucking up water – between a soil moisture tension of 2–8 and 40–60 kPa.

• Deficit Available Water (DAW) is water that is less available to the tree. DAW is important when applying RDI management (between 40–60 kPa and 200–400 kPa).

Figure 5.6 describes the available soil water and the corresponding soil moisture tensions (kPa). RAW is between 2–8 and 40–60 kPa, whilst Deficit Available Water is between 40–60 kPa and 200–400 kPa.
The amount of water that is held at different tensions is referred to as soil water content (%). The soil water content varies for different soils depending on the amount of sand, silt and clay particles. Refer Figure 5.7.

**Readily Available Water – how much to apply with each irrigation.**

To calculate the amount of RAW you will need to dig a soil pit next to a tree. You will need to note where most of the roots are growing (depth and width) and the wetting pattern of the emitter. In other words you are figuring out the volume of the wetted roots. Refer Figure 5.8 page 31.

Once the volume of the wetted roots has been determined we can estimate the RAW. As a general guide, RAW is approximately 6% of the total soil volume for sandy loam and clay soils and 8% for clay loam soils.

If you know how much RAW you have in the root–zone, you can then calculate the maximum amount of irrigation (the most water) that can be applied to the tree. If excess water is added it just goes out the bottom of the root zone.

**Calculating system run time**

There are two methods to calculate the system run time:

a. For sprinklers or flood irrigation it is easiest to consider RAW as mm over the wetted rootzone depth.

   For example, you may have a sandy loam soil and want to maintain soil moisture tension between 8 and 40 kPa to a depth of 60 cm. If we calculate that rootzone RAW is 35 mm (from soil texture assessment as calculated by Wetherby 1996 – see further reading), and the sprinklers are wetting the whole orchard floor, then the maximum amount of water that can be applied is 35 mm or 35 litres/m².

   If the planting square is 6 m x 6 m then each tree will be able to receive a maximum of 1260 litres with one irrigation.

   \[ (6 \text{ m} \times 6 \text{ m} \times 35 \text{ litres/m}^2 = 1260 \text{ litres}) \]

How long to run the system

This means that if the output of sprinklers is 210 litres/hr, and there is one sprinkler per tree, the system can run for a maximum of 6 hours

\[ (1260 \text{ litres} \div 210 \text{ litres/hr} = 6 \text{ hrs}) \]
b. For micro-irrigation, you need to consider the RAW as a percentage of the total wetted root volume. Therefore, you need to know:
- the wetting pattern of your irrigation system
- the depth of the rootzone

To estimate wetted root volume, this formula can be used:

Estimated wetted root volume

= wetted area of microjet x rootzone RAW

For example, to maintain the soil moisture tension between 8 and 40 kPa, at a rootzone depth of 60 cm, a sandy loam soil can hold 36 mm (60 cm x 6%) of RAW which is equal to 36 litres/m².

Estimated wetted area (Figure 5.8)

= 2.4 m x 2.4 m (ie. wetted strip)
= 5.76 m²

Estimated water held in the rootzone between 8 and 40 kPa

= 5.76 m² x 36 litres/m²
= approximately 210 litres/tree

How long to run the system

If the system delivers 45 litres per tree per hour, maximum run time will be roughly 4.5 hours.

(45 litres x 4.5 hours = 202.5 litres)

<table>
<thead>
<tr>
<th>Month</th>
<th>Maximum irrigation to apply</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Micro-irrigation litres/tree</td>
</tr>
<tr>
<td>Oct</td>
<td></td>
</tr>
<tr>
<td>Nov</td>
<td></td>
</tr>
<tr>
<td>Dec</td>
<td></td>
</tr>
<tr>
<td>Jan</td>
<td></td>
</tr>
<tr>
<td>Feb</td>
<td></td>
</tr>
</tbody>
</table>
A grower and his orchard manager in the Goulburn Valley were very concerned about a particular block of apples irrigated with microjets. The block was sloping and the trees on the higher end of the block were very healthy. At the lower end of the block however, the trees looked sick and were going backwards.

We dug a soil pit at the top end of the block. The top soil was 45 cm deep, a sandy clay loam. Underneath was a light medium clay. The roots went down to 70 cm. We worked out the soil held about 260 litres in the rootzone (between 8 and 40 kPa). A seven to eight hour irrigation would fill up the rootzone.

We dug another pit at the bottom of the slope. Here we had 25 cm of a clay loam top soil. Immediately underneath was a medium clay. The depth of the rootzone was 50 cm. We worked out the soil held about 180 litres of water in the rootzone (between 8 and 40 kPa). A four to five hour irrigation would fill the rootzone. We also noticed that you could smell rotting roots when you got into the pit.

We talked with the grower and the manager and found that they were irrigating the whole block for eight hours. The bottom half of the block was getting almost double the amount of water the soil could hold! They decided to put in a tap and halve the block. They began irrigating the block differently giving the top half the usual eight hours, but only giving the bottom half four to five hours.

When we were last out there, talking to the grower and the manager they were happy with the apples at the end of the block. They still had a long way to go before they caught up with the top end, but they were looking healthier and had a crop.
2. When to irrigate
Knowing how quickly the water in the rootzone is used

To determine tree water use and how frequently to irrigate, you need to know Crop Factors and evaporation. Before we start working this out, some general information is again required.

Pan Evaporation
Pan Evaporation ($E_{pan}$) is the amount of water lost from a standard Class A Pan. You can buy or make one and measure this yourself (refer to Goodwin 2000, “Construction of an evaporation pan for irrigation scheduling” mentioned in further reading), or obtain figures and information from the Bureau of Meteorology.

Crop Factors
Crop Factors are values that relate tree water use, at a particular stage of growth, to the amount of pan evaporation. For example, if the pan evaporation is 10 mm and the Crop Factor is 0.8, plant water use is $0.8 \times 10 = 8$ mm. This can also be described as a percentage, i.e. 80% of the evaporation.

The crop factor changes as the growth stages of the plant changes. Early in the season crop factors are generally low and peak just before harvest.

Crop Factors for stonefruit, pear and apple are presented in the previous section. These crop factors are suggested for the Goulburn Valley, however, values will vary between orchards. The right crop factor for your orchard will need to be determined through trial and error. Begin with these values and then check the soil moisture before an irrigation. If the soil is too dry or too wet adjust the crop factor and irrigation frequency accordingly. Growers in other districts can also use these crop factors as a starting point and then check soil moisture.
How much water your tree uses

You need to work out how much water to apply, taking into account that some of it will be lost through the evaporation process. The following formula (also shown on page 23) illustrates how to work out water use for a block or over the entire orchard.

\[ \text{Tree Water Use (mm)} = \text{Crop Factor} \times \text{Pan Evaporation (E_{pan}) (mm)} \]

This formula is fine for flood or knocker sprinklers which wet the whole orchard floor. However, for micro-irrigation, we need to work out how much water each tree is using so we can work out how much to irrigate through the system.

Look at your “average” tree – you don’t want to drown your young trees. The formula (also shown on page 23) to calculate water use in litres per tree is:

\[ \text{Tree water use (L/tree)} = \text{Crop Factor} \times \text{Pan Evaporation} \times \text{Planting Square (m²)} \]

Take a look at the table below. This is an example of how to calculate the approximate daily water use in a peach orchard (Golden Queen) which is planted at 4 m between rows and 2 m between trees. The evaporation information for the past ten years was obtained from weather stations.

### Table 5.5 Calculating how much water your tree uses

<table>
<thead>
<tr>
<th>Month</th>
<th>Planting Square (m²)</th>
<th>Crop Factor</th>
<th>Long term average daily evaporation (mm/day)</th>
<th>Average daily water use (L/day) per tree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2m x 4m</td>
<td>A</td>
<td>B</td>
<td>D=AxBxC</td>
</tr>
<tr>
<td>Oct</td>
<td>8</td>
<td>0.4</td>
<td>4.0</td>
<td>12.8</td>
</tr>
<tr>
<td>Nov</td>
<td>8</td>
<td>0.4</td>
<td>5.6</td>
<td>17.9</td>
</tr>
<tr>
<td>Dec</td>
<td>8</td>
<td>0.6</td>
<td>6.9</td>
<td>33.1</td>
</tr>
<tr>
<td>Jan</td>
<td>8</td>
<td>0.8</td>
<td>7.3</td>
<td>46.7</td>
</tr>
<tr>
<td>Feb</td>
<td>8</td>
<td>1.0</td>
<td>6.7</td>
<td>53.6</td>
</tr>
<tr>
<td>March</td>
<td>8</td>
<td>1.0</td>
<td>4.8</td>
<td>38.4</td>
</tr>
<tr>
<td>April</td>
<td>8</td>
<td>0.4</td>
<td>2.8</td>
<td>9.0</td>
</tr>
</tbody>
</table>
Once the maximum irrigation to apply and the tree water use have been calculated you can then estimate how frequently the orchard or block will need to be irrigated. Using the previous example for sprinklers, the maximum amount to irrigate is 210 litres. During peak demand (February), water use will be 54 litres/tree/day. Each tree will take less than four days to use the water held in the rootzone, so you will need to irrigate every three days.

The calculations for this orchard can then be used as a season irrigation plan as shown in table 5.6.

**Table 5.6 Frequency between irrigations**

<table>
<thead>
<tr>
<th>Month</th>
<th>Maximum irrigation</th>
<th>Daily water use</th>
<th>Average days between irrigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oct</td>
<td>210</td>
<td>12.8</td>
<td>16</td>
</tr>
<tr>
<td>Nov</td>
<td>210</td>
<td>17.9</td>
<td>11</td>
</tr>
<tr>
<td>Dec</td>
<td>210</td>
<td>33.1</td>
<td>6</td>
</tr>
<tr>
<td>Jan</td>
<td>210</td>
<td>46.7</td>
<td>4</td>
</tr>
<tr>
<td>Feb</td>
<td>210</td>
<td>53.6</td>
<td>3-4</td>
</tr>
<tr>
<td>March</td>
<td>210</td>
<td>38.4</td>
<td>5</td>
</tr>
<tr>
<td>April</td>
<td>210</td>
<td>9.0</td>
<td>23</td>
</tr>
</tbody>
</table>

REALITY CHECK. We know that this is an ideal scenario and that watering schedules are limited by your on-farm conditions of time, money, power and water availability.
3. Check on how much and when to irrigate

Monitoring soil moisture

Irrigation scheduling that relies solely on estimated RAW, evaporation and Crop Factors will run into problems.

Firstly, values of RAW are difficult to estimate and the amount of water applied with each irrigation may need to be modified.

Secondly, Crop Factors may vary between orchards. Soil moisture monitoring will allow the Crop Factor values to be adjusted for each orchard and will help you to irrigate each block in a more specific way.

Finally, soil moisture monitoring is also very important for deciding on the first irrigation and when to irrigate after rainfall.

We can measure:
- Total soil water content, OR
- Soil moisture tension (suction)

Different measurement tools are listed below.

**Table 5.7 Comparison of main soil moisture monitoring systems**

<table>
<thead>
<tr>
<th>System</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
</table>
| 1. Monitoring Soil Moisture Tension (kPa) | • Relatively cheap  
• Easy to install yourself  
• Can be read by yourself  
• Allows continuous monitoring | • Labour intensive to collect and record data  
• Requires regular maintenance  
• Can be inaccurate in extremely wet or dry soil |
| Tensiometers             | • Relatively cheap  
• Easy to install yourself  
• Can be read by yourself  
• Continuous monitoring possible | • Labour intensive to collect and record data  
• Requires a digital meter to be brought to each sensor site to take readings  
• Can be inaccurate in extremely wet soil |
| Gypsum blocks            | • Relatively cheap  
• Easy to install yourself  
• Can be read by yourself  
• Continuous monitoring possible | • Labour intensive to collect and record data  
• Requires a digital meter to be brought to each sensor site to take readings  
• Can be inaccurate in extremely wet soil |
| Neutron probe            | • Portable, can be moved around sites  
• Very reliable and accurate | • Not suitable for continuous monitoring  
• As equipment is expensive and containing radioactive material, generally used by a consultants  
• Less accurate in the top 10 cm of soil |
| Capacitance probes eg. Enviroscan® | • Continuous monitoring  
• Accurate at all depths  
• Enables rapid reading and recording of results | • Expensive  
• Need skill in interpreting data |
The choice of measuring system will also be based on the range you need to measure. A tensiometer, for example, only measures between 0 and 70 kPa, whereas gypsum blocks read between 30 and 600 kPa - the drier end of the scale.

To know what is happening throughout the orchard, you will need to have more than one set of sensors.

Where should you place them? The sites should represent the “average” soil type, tree health and tree size within each block.

To help decide where to put the sensors it is always good to dig under the emitter to see the wetting pattern!

Put your sensors in the right spots –

- In the middle of the root zone
- Near the bottom of the main fibrous root zone and
- Below the root zone

As a guide, we found that for the forty blocks monitored, 30, 60 and 90 cm were good depths of measure. The information from your sensors is important to calculate the irrigation requirements of each block and adjust your system accordingly.
Now that we have some background understanding and know how to do the calculations, we can concentrate on how to schedule irrigation.

**How Much to Irrigate**

Knowing the amount of water held in the rootzone allows you to determine the amount of water to apply.

**Step 1.** Determine the wetted root volume from the wetting pattern and root distribution.

If the microjet wets an area of approximately 2.4 x 2.4 m² and has a rootzone depth of 0.6 m, then the wetted root volume is 3.5 m³.

**Step 2.** Estimate the maximum amount of water to apply with each irrigation from the wetted root volume and the RAW.

If the soil is a sandy loam then the RAW is approximately 6% of the total soil volume. The amount of water held in the rootzone is therefore 6% of 3.5 m³ or 210 litres/tree (6% x 3500 litres). This means that the maximum amount of water to apply in one irrigation is 210 litres per tree. If the system delivers 45 litres per tree per hour, the maximum run time will be roughly 4.5 hrs.

**When to Irrigate**

Knowing crop factors and evaporation allows you to determine how much water your tree uses and therefore how frequently water must be applied.

**Step 3.** Create an irrigation plan that estimates the number of days between irrigations.

This irrigation plan will be based on the amount of water used by the tree (calculated from long term average evaporation data and Crop Factors), the maximum amount of irrigation and the planting square. For example:

If the planting square is 16 m² (4 x 4 m) and the Crop Factors are those for Golden Queen Peach in the Goulburn Valley (Table 5.5); it is estimated that during peak demand, the daily tree water use will be 107 litres (16 m² x 1.0 x 6.7 mm) The trees will take 2 days to use up the stored water of 210 litres. Expressed another way, they will need to irrigated roughly every 2nd day in January and February and every 3rd day in December and March.
Step 4. The frequency of irrigation will be as in step three, but the amount of water applied with each irrigation is dependent on the weather.

The irrigation plan is based on average evaporation for the month, but the evaporation will vary from day to day. In January the average evaporation is 7.3 mm and from the plan we would be irrigating every 2nd day (for 16 m²). If we have two warm days where the evaporation is 8 mm each day, we would need to apply approximately 205 litres. If this period is then followed by two milder days of 6 and 5 mm evaporation, we would need to apply only 140 litres.

If the weather is very hot for two days (10 and 10 mm evaporation), then the water is more than the maximum irrigation value (210 litres) the frequency of irrigation would need to be reduced (1 to 1.5 days) for a short time or a "top up" irrigation could be applied on the "in between" day.

Check on how much and when to irrigate

Step 5. Monitoring soil moisture before and after irrigation to check irrigation amount and crop factors.

Soil moisture monitoring will allow you to determine if the estimated maximum irrigation amount is reasonable and also if the Crop Factors are accurate for this site. If the soil is too wet or dry before or after an irrigation, then the crop factors can be modified.

An example is as follows:
Three sets of tensiometers have been placed at 30, 60 and 90 cm at the top middle and bottom of a block. Prior to irrigation the 30 and 60 cm tensiometers read between 30 and 40 kPa and the 90 cm ones are dry. After irrigation, the 30 and 60 cm readings drop to between 4 and 10 kPa and the 90 cm readings drop to 12 kPa. This means that water has travelled well past the rootzone and is wasted. It will be necessary to reduce the run time and the irrigation interval. If the tensiometers are still wet prior to the next irrigation the Crop Factor which was 0.8 will need to be reduced to 0.6 for this block.

Actual irrigation amount (litres/tree) = crop factor x evaporation x planting square
Following the next irrigation the 30 and 60 cm tensiometer readings drop to between 4 and 10 kPa, while the 90 cm readings stop at 40 kPa. This irrigation is then reasonable.

The following table summarises example calculations for irrigation scheduling.

**Table 5.8 Irrigation scheduling** (planting square = 5 x 4m)

<table>
<thead>
<tr>
<th>Month</th>
<th>Max Irrigation (L/tree)</th>
<th>Max Run time (hrs)</th>
<th>Planting Square</th>
<th>Crop factor</th>
<th>Average evaporation</th>
<th>Average daily water use (L/tree)</th>
<th>Average days between irrigation</th>
<th>Evaporation</th>
<th>Water use (L/tree)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>210</td>
<td>4.5</td>
<td>16</td>
<td>0.8</td>
<td>7.3</td>
<td>93.4</td>
<td>2</td>
<td>16</td>
<td>205</td>
</tr>
<tr>
<td>Feb</td>
<td>210</td>
<td>4.5</td>
<td>16</td>
<td>1.0</td>
<td>6.7</td>
<td>107.2</td>
<td>2</td>
<td>11</td>
<td>140</td>
</tr>
<tr>
<td>Mar</td>
<td>210</td>
<td>4.5</td>
<td>16</td>
<td>1.0</td>
<td>4.8</td>
<td>76.8</td>
<td>2.5 – 3</td>
<td>20</td>
<td>256</td>
</tr>
<tr>
<td>April</td>
<td>210</td>
<td>4.5</td>
<td>16</td>
<td>0.4</td>
<td>2.8</td>
<td>17.9</td>
<td>12</td>
<td>16</td>
<td>205</td>
</tr>
<tr>
<td>May</td>
<td>210</td>
<td>4.5</td>
<td>16</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>June</td>
<td>210</td>
<td>4.5</td>
<td>16</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
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<tr>
<td>July</td>
<td>210</td>
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<td>16</td>
<td>–</td>
<td>–</td>
<td>–</td>
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<td>–</td>
</tr>
<tr>
<td>Aug</td>
<td>210</td>
<td>4.5</td>
<td>16</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Sep</td>
<td>210</td>
<td>4.5</td>
<td>16</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Oct</td>
<td>210</td>
<td>4.5</td>
<td>16</td>
<td>0.4</td>
<td>4.0</td>
<td>25.6</td>
<td>8</td>
<td>3</td>
<td>205</td>
</tr>
<tr>
<td>Nov</td>
<td>210</td>
<td>4.5</td>
<td>16</td>
<td>0.4</td>
<td>5.6</td>
<td>35.8</td>
<td>6</td>
<td>11</td>
<td>140</td>
</tr>
<tr>
<td>Dec</td>
<td>210</td>
<td>4.5</td>
<td>16</td>
<td>0.4</td>
<td>6.9</td>
<td>66.2</td>
<td>3</td>
<td>20</td>
<td>256</td>
</tr>
</tbody>
</table>

A (see below)
Best approach for irrigation scheduling –

Evaporation and Crop Factors, and soil moisture monitoring

The recommended irrigation scheduling system will utilise crop factors and evaporation, together with soil moisture monitoring to determine and adjust both the amount and timing of irrigations. A summary of the steps is as follows:

HOW MUCH TO IRRIGATE

Step 1 Determine the irrigated root volume, from:
• the wetting pattern and
• the root distribution

Step 2 Estimate the maximum amount of allowable irrigation, from:
• the irrigated root volume and
• the percentage of RAW

WHEN TO IRRIGATE

Step 3 Calculate the maximum number of days allowable between each irrigation for each month of the season based on:
• maximum amount of allowable irrigation, and
• average daily evaporation and Crop Factors

Step 4 Irrigation occurs after the number of days calculated in step 3, with volumes as calculated below

For flood and knocker sprinklers

Irrigation Requirement (mm) = Pan Evaporation (mm) x Crop Factor

For micro-irrigation

Irrigation requirement (litres/tree) = Pan Evaporation (mm) x Crop Factor x Planting square (m²)

CHECK ON HOW MUCH TO IRRIGATE AND WHEN TO IRRIGATE

Step 5 Monitor soil moisture before and after irrigation and:
• adjust maximum irrigation amount
  – if soil is wet below the rootzone or
  – if soil is dry after irrigation
• adjust Crop Factor (and therefore maximum number of days between irrigations) if
  – soil becomes too dry or
  – remains too wet before a scheduled irrigation.
Regulated Deficit Irrigation

What is it and what do we use it for?

Regulated Deficit Irrigation (RDI) is a method of managing irrigation to get better yield and/or quality by irrigating less at certain stages of tree development.

How do we do it?

We apply less water in order to stress the tree because we want to:

• reduce the amount of vegetative growth and
• save water

We need a balance between production and vegetative growth. RDI is particularly important for high-density orchards where this balance is difficult to maintain. Early in the season, shoots grow quickly and the fruit grows slowly. In the last 6-8 weeks before harvest, fruit grows quickly and shoot growth almost ceases.

RDI reduces the amount of water applied during rapid shoot growth. It is important that water stress is only applied at this time, when the fruit is growing slowly.

The best way to apply RDI is to reduce the amount of water applied, but maintain the frequency it is applied at. (Crop Factor of 0.6 – then reduce it to 0.3).

Note! When fruit begins to grow quickly you must maintain full irrigation.

For fruit that is harvested early (cherries, fresh market nectarines, peaches) often there is only a very short period of slow fruit growth before harvest. However, less water can be applied after harvest when shoots grow quickly.

Figure 5.10

Regulated Deficit Irrigation
Example of how RDI is used in relation to fruit and shoot growth

Trees under full irrigation

Control of vigour under RDI
Scheduling RDI

Two things to remember – Crop Factors and Soil Moisture –
- Crop Factors need to be reduced (look at the table below!)
- Maintain irrigation frequency
- Measure soil moisture to adjust Crop Factors
- Soil moisture levels should be allowed to dry to 200 kPa.

Table 5.9  Suggested irrigation Crop Factors for the application of RDI to late-season peach, pear and apple

<table>
<thead>
<tr>
<th>Fruit Crop</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>March</th>
<th>April</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-harvest</td>
<td>Post-harvest</td>
<td>Pre-harvest</td>
<td>Post-harvest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peach</td>
<td>0.4</td>
<td>0.6</td>
<td>0.6</td>
<td>0.8</td>
<td>1.0</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>RDI</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.4 (early)</td>
<td>1.0</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Pear</td>
<td>0.6</td>
<td>0.6</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>RDI</td>
<td>0.3</td>
<td>0.3</td>
<td>0.5</td>
<td>1.0</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Apple</td>
<td>0.6</td>
<td>0.6</td>
<td>0.7</td>
<td>0.9</td>
<td>0.9</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>RDI</td>
<td>0.3</td>
<td>0.3</td>
<td>0.4 (early)</td>
<td>0.9</td>
<td>0.9</td>
<td>0.4</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Table 5.10  RDI times for some canning peaches and pears in the Goulburn Valley

<table>
<thead>
<tr>
<th>Fruit Crop</th>
<th>RDI</th>
<th>Normal Irrigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canning Peaches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tatura 204</td>
<td>Nov – 5th Dec</td>
<td>5th Dec – Harvest</td>
</tr>
<tr>
<td>Tatura Noon</td>
<td>Nov – 20th Dec</td>
<td>20th Dec – Harvest</td>
</tr>
<tr>
<td>Orrvale Queen</td>
<td>Nov – 27th Dec</td>
<td>27th Dec – Harvest</td>
</tr>
<tr>
<td>Golden Queen</td>
<td>Nov – 4th Jan</td>
<td>4th Jan – Harvest</td>
</tr>
<tr>
<td>Taylor Queen</td>
<td>Nov – 18th Jan</td>
<td>18th Jan – Harvest</td>
</tr>
<tr>
<td>Pears</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WBC</td>
<td>Nov – 7th Dec</td>
<td>7th Dec – Harvest</td>
</tr>
<tr>
<td>Packham</td>
<td>Nov – 15th Dec</td>
<td>15th Dec – Harvest</td>
</tr>
</tbody>
</table>
CASE STUDY

IRRIGATION SCHEDULING AND RDI

Joe manages an orchard in Ardmona growing a mix of stone fruit, apples and pears. His whole orchard is under micro-irrigation because it suited the lighter soil types on the property. Soil moisture monitoring offered the chance to check his irrigations and to see what was happening in these lighter soils. Joe had tensiometers installed in a block of late harvested peaches. Weekly monitoring of the tensiometers began and Joe soon realised that the 10 to 12 hour runs were pushing water below the rootzone of the trees. So Joe reduced his maximum run time to six hours.

In the meantime Joe had also been concerned with excessive tree growth in his orchard resulting in large trees with lots of shading. This can affect fruit quality and it adds to the amount of pruning that needs to be done. In discussions with a group of growers involved in irrigation trials Joe heard about Regulated Deficit Irrigation or RDI. RDI is a technique that cuts back the irrigations during the time fruit growth is slow. For Joe’s later harvested peaches this was during November and December. With some caution, and some help setting up an irrigation schedule using weather information, Joe began to trial RDI.

During November and December Joe kept the interval between irrigations the same but cut back the run time. Instead of the normal six hours Joe would irrigate for only three to four hours. “It was hard to watch that first season,” says Joe, “as the peaches actually started to wilt a few times over November and December.” In that first season of trying RDI Joe relied on the fruit growth measurements that were being taken to reassure himself that fruit size wasn’t being affected.

At harvest Joe found fruit sizes were no different between the trees that had been put through RDI and the trees that had been irrigated normally. Importantly, there appeared to be less vegetative growth on trees grown under RDI. It gave him the confidence to try again and he has been very happy with the results. “I went from no monitoring to monitoring my irrigations with tensiometers. They’re a cheap way to check what is going on in a block. “Moving to RDI was another step again. "Using some weather information was really helpful to set up an irrigation schedule," says Joe. "It's still important to check the soil moisture though because the schedule won't be set in concrete."

Joe will be using his experiences to continue on with RDI. However for soil moisture monitoring he's not sure if tensiometers will be the most useful tool in future. "They take time to check," he says. There are many other options on the market including automatic systems that can be linked to a computer. This would reduce the amount of time needed to check each site. In the end it comes down to the system that best suits the situation.

And Joe's final thoughts on his experiences? "You can always learn!" he says.
System maintenance

System Check
You have installed your irrigation system, the supplier/designer has given you recommendations and you think that the correct and consistent amount of water is being delivered across your orchard.

Have you checked?
A new car gets a service where all components are checked. Your irrigation system probably costs at least as much as your car and deserves the same amount of attention.

If you want your system maintained to deliver what it promises – you’ll need to service the system.

Measure! Monitor! Maintain!

What should you check?

1. Flow Rate Variation
It is important to know that the system is putting out the same amount of water at all points. A blockage in the line or emitter results in uneven watering and stressed trees.

a) For microjets, minisprinklers and drippers
Place a 2 litre (500 ml for drippers) measuring jug under the emitter. Record the amount of water after one minute. Repeat this process for a number of emitters. Make sure you include emitters from the top, bottom and middle of the block.

b) For knocker sprinklers
Flow rate can be checked in the same way except that a hose is attached to the nozzle so that no water is lost during measurement. A larger bucket for collecting the water will be needed!
Table 5.11 Calculating flow rate

<table>
<thead>
<tr>
<th>Emitter No.</th>
<th>B Minutes</th>
<th>C Volume</th>
<th>D ml per hour (B x C x 60)</th>
<th>Litres per hour D ÷ 1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example</td>
<td>1</td>
<td>800 ml</td>
<td>48000 ml/hr</td>
<td>48 L/hr</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Calculating average flow rate

Example
To calculate average flow rate, add up all the flow rates and divide by the number of flow rates measured.

<table>
<thead>
<tr>
<th>Emitter 1</th>
<th>Emitter 2</th>
<th>Emitter 3</th>
<th>Emitter 4</th>
<th>Emitter 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>42.5 L/hr</td>
<td>44.4 L/hr</td>
<td>45.2 L/hr</td>
<td>44.9 L/hr</td>
<td>46.9 L/hr</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>223.9 L/hr</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average (total ÷ 5)</td>
<td></td>
<td></td>
<td></td>
<td>44.8 L/hr</td>
</tr>
</tbody>
</table>

Calculating flow rate variation

To calculate flow variation we first need the midpoint flow rate, and the difference between the lowest point and the midpoint.

1. Midpoint – add the highest and lowest discharge and divide the result by 2.
   For example:
   \[(46.9 + 42.5) ÷ 2 = 44.7 \text{ L/hr}\] midpoint flow rate

2. Difference – subtract the lowest flow rate value from the midpoint.
   ie. \[44.7 - 42.5 = 2.2 \text{ L/hr}\]

3. Then – divide the difference by the midpoint and multiply by 100 to get a percentage.
   ie. \[2.2 ÷ 44.7 \times 100 = 4.9\%\]
   This is expressed as ± 4.9 % flow variation.

A flow rate variation of greater than ± 5% is unacceptable.
It means there has been poor design or there are problems such as blockages.
Table 5.12 Approximate operating pressures of various irrigation systems.

<table>
<thead>
<tr>
<th>Emitter type</th>
<th>Optimum pressure range</th>
<th>Flow rate range (litres/hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drippers (non pressure compensating)</td>
<td>80–120 kPa  11–14 psi</td>
<td>2–8</td>
</tr>
<tr>
<td>Microjets</td>
<td>100–200 kPa  14–21 psi</td>
<td>25–200</td>
</tr>
<tr>
<td>Mini sprinklers</td>
<td>125–200 kPa  18–29 psi</td>
<td>25–200</td>
</tr>
<tr>
<td>Low throw sprinklers</td>
<td>200–300 kPa  29–43 psi</td>
<td>300–1200</td>
</tr>
<tr>
<td>Overhead sprinklers</td>
<td>250–400 kPa  35–57 psi</td>
<td>700–3000</td>
</tr>
</tbody>
</table>

CASE STUDY

FLOW RATE

A grower in Swan Hill had a trial site in his Maygrand nectarines orchard. There were three tensiometer sites down one row. The grower been wondering why there was such a difference between the tensiometer readings at the top of the row and the readings at the bottom of the row.

One of the issues the local grower’s group was interested in was checking the irrigation system. The group therefore went out to this grower’s Maygrand block and measured the flow rate over the block. We worked out that his system had a 20% variation in flow rate over the block. Certainly higher than the 5% recommended.

We discussed some reasons for this. His irrigation system is a double line of 4 L/hr drippers. They are not pressure compensating. The row length was commented on, it could be too long for the system to have an even flow rate down the whole row.

The grower now realises why the tensiometer readings were so different.

2. Pressure Variation

Pressure can be measured in:

Psi (pounds per square inch)

kPa (kilopascals) or cb (centibars)

1 centibar = 1 kilopascal (kPa)

1 psi = 7 kPa (approx)
Pressure can be measured at various points in the system using a manual portable gauge. You should also regularly check pressures at the headworks 10 minutes after start-up.

**Calculating the average pressure**

To calculate average pressure, add up all the pressure values collected at various points and then divide this total by the number of values (collection points).

eg. pressure was recorded at 6 points the total of these was 710 kPa

\[ 710 \div 6 = 118 \text{ kPa average pressure} \]

**Calculating the pressure variation**

As for flow variation, to calculate pressure variation we first need the midpoint and the difference between the lowest point and the midpoint.

1. Midpoint – add the highest and lowest pressure value and divide the result by 2.
   eg. \((125 + 110) \div 2 = 117.5 \text{ kPa midpoint.}\)

2. Difference – subtract the lowest pressure from the midpoint.
   ie. \(117.5 - 110 = 7.5 \text{ kPa}\)

3. Then – divide the difference (7.5) by the midpoint (117.5) and multiply by 100 to get a percentage.
   ie. \(7.5 \div 117.5 \times 100 = 6.4 \%\)
   This is expressed as ± 6.4 % pressure variation.

A pressure variation of greater than ± 10% is unacceptable. It means there has been poor design or there are problems such as blockages.
3. a) Checking for problems

It is important to visually check the system when in the orchard. This should be done every couple of weeks during the irrigation season. You need to be on the lookout for blockages, broken pipes and emitters and/or missing emitters.

b) Flushing and cleaning the system

Even with a good filtration system, blockages can occur and it is a good idea to regularly flush out filters, mainlines and laterals. The frequency of flushing will depend on the quality of water and the filtration system.

As a good rule of thumb aim to flush the system at least once during the season.

### Procedure for Flushing

The mainline should be flushed, with submains and laterals closed, for at least 2 minutes, and until water runs clean. Close the opening of the mainline and start flushing the submain for at least 2 minutes. The drip laterals should then be flushed plot by plot for at least 2 minutes. Only open 2 or 3 laterals at one time to ensure sufficient velocity to remove all dirt. Shaking the lines will help to clear them. Close the ends of the laterals in consecutive order, then check all microjets are working.

Refer also "Maintenance of trickle irrigation systems" Ashcroft 1994, in “Further reading”.

A more detailed description of chemical treatments for flushing can be found in Mitchell & Goodwin 1996.
Salinity management

Both crops and the environment suffer from salinity, especially in the Murray Darling Basin. By putting in place a salinity management program you can minimise damage to production which also has benefits for the environment.

Fruit trees are generally sensitive to:
• waterlogging
• saline irrigation, and
• salinity under waterlogged conditions.

Waterlogging and water tables

Waterlogging can occur from either excessive surface irrigation (perched water table) or from shallow regional water tables.

Salinity

There are two major sources of salinity damage in orchards:
• high salt concentration in irrigation water
• increased soil salinity from rising saline water tables.

Waterlogging and salinity results in rapid uptake of salts to toxic levels which badly damages or kills trees.

Fruit trees, as mentioned above, are generally sensitive to salt and a reduced yield can be experienced even at fairly low salt levels, because:
• water is naturally attracted to higher salt levels – if the soil is high in salt, it binds the water strongly and becomes difficult for the tree to extract (ie. in effect, saline soil reduces available water)
• excesses of some salts (eg. sodium + chloride) can poison the tree
• excess salts taken up by the tree are stored in the woody tissue.
Symptoms of salt damage include:
- leaf burn
- leaf drop
- reduced vigour, yield and size
- trees may appear wilted (despite moist soil)
- chloride and sodium in leaves

The table below shows the sensitivity of fruit trees to salt.

**Table 6.1 Sensitivity of various crops to salt**

<table>
<thead>
<tr>
<th>Sensitive</th>
<th>Moderate</th>
<th>Tolerance</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple</td>
<td>Grapes</td>
<td>Squash</td>
<td>Salt bush</td>
</tr>
<tr>
<td>Apricot</td>
<td>Potato</td>
<td>Zucchini</td>
<td>Olives</td>
</tr>
<tr>
<td>Cherry</td>
<td>Tomato</td>
<td>Ryegrass</td>
<td>Date Palms</td>
</tr>
<tr>
<td>Citrus</td>
<td>Lucerne</td>
<td>Strawberry Clover</td>
<td></td>
</tr>
<tr>
<td>Peach</td>
<td></td>
<td></td>
<td>Barley</td>
</tr>
<tr>
<td>Pear</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plum</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Maximum tolerable levels for salinity**

The salt tolerance levels shown in the following tables should only be used as a guide and may require adjustment depending on management and salinity response measured by regular monitoring of irrigation salinity, soil salinity and salt uptake by the tree (leaf Na and Cl).

**Water**

Irrigation scheduling and soil moisture monitoring will be vital in the management of saline irrigation water. As a rough guide irrigation water for stone and pome fruit should not exceed 1 dS/m (1000 EC) and should include a leaching strategy.

**Soil**

Soil salinity levels should generally be kept below 2.0 dS/m (ECe) for fruit trees.
Laboratories use similar methods for the measurement of soil salinity; EC$_{1:5}$ or EC$_e$. The two methods measure salt in the soil but EC$_e$ takes into account your soil type – see Table below and page 105.

Table 6.4 Recommended maximum soil EC levels for fruit production

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>EC$_{1:5}$ (dS/m) Quick measurement</th>
<th>EC$_e$ (dS/m) Standard measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium Clay</td>
<td>0.27</td>
<td>2.0</td>
</tr>
<tr>
<td>Loam</td>
<td>0.21</td>
<td>2.0</td>
</tr>
<tr>
<td>Sandy Loam</td>
<td>0.14</td>
<td>2.0</td>
</tr>
</tbody>
</table>

(Mass and Hoffman, 1977 and Reuter, 1999)

Laboratories use similar methods for the measurement of soil salinity; EC$_{1:5}$ or EC$_e$. The two methods measure salt in the soil but EC$_e$ takes into account your soil type – see Table below and page 105.

Table 6.3 Salt tolerance for fruit trees

<table>
<thead>
<tr>
<th>Fruit species</th>
<th>Salinity at initial yield decline (threshold) ($EC_e$)</th>
<th>Yield decrease per unit increase in salinity beyond threshold (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple</td>
<td>1.0</td>
<td>18</td>
</tr>
<tr>
<td>Almond</td>
<td>1.5</td>
<td>19</td>
</tr>
<tr>
<td>Apricot</td>
<td>1.6</td>
<td>24</td>
</tr>
<tr>
<td>Grape</td>
<td>1.5</td>
<td>9.6</td>
</tr>
<tr>
<td>Orange</td>
<td>1.7</td>
<td>16</td>
</tr>
<tr>
<td>Peach</td>
<td>1.7</td>
<td>21</td>
</tr>
<tr>
<td>Plum</td>
<td>1.5</td>
<td>18</td>
</tr>
<tr>
<td>Pear</td>
<td>1.0</td>
<td>–</td>
</tr>
</tbody>
</table>

(Peach tree yield response to soil salinity)

Figure 6.1

Salt damage to trees
Salt in the tree
Toxic levels of salts measured in the leaves differ for various crops. For example, leaf sodium (Na) is toxic to peaches at levels greater than 0.5% and leaf chloride (Cl) at levels greater than 1.0% (refer to table below). Peach Na and Cl should therefore be kept below these toxic levels.

Table 6.5 Toxic levels of sodium and chloride in leaves of fruit trees

<table>
<thead>
<tr>
<th>Fruit Crop</th>
<th>Toxic Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf Na (%)</td>
<td>Leaf Cl (%)</td>
</tr>
<tr>
<td>Apple</td>
<td>&gt;0.5</td>
</tr>
<tr>
<td>Peach</td>
<td>&gt;0.5</td>
</tr>
<tr>
<td>Pear</td>
<td>&gt;0.2 – 0.5*</td>
</tr>
<tr>
<td>Apricot</td>
<td>&gt;0.5</td>
</tr>
<tr>
<td>Plum</td>
<td>&gt;0.5</td>
</tr>
<tr>
<td>Grape</td>
<td>&gt;0.5</td>
</tr>
</tbody>
</table>

* dependent on aeration and other stress factors

(Reuter and Robinson, 1997)

CASE STUDY
MANAGING A WATERTABLE

A couple with a small orchard found that they had a severe watertable problem on about half of the property, which affects the fresh market stone fruit. Over a number of years they converted the orchard to micro-irrigation. After the first few years they realised that having micro-irrigation did not mean the watertable problem disappeared. They needed to manage the water applied during the season even with the new irrigation system. In the last two years the couple put in three sets of tensiometers – one in an early block, the second in a mid-season block and the last in a late season variety.

They now read the tensiometers just before irrigating – the reading tells them if the block is due for water. The couple often find that while their experience is generally right, the tensiometers are a check to make sure! Often they also check the tensiometers after irrigation. This tells them how efficient the irrigation has been. There is still a watertable problem on their property, but now they are able to manage it during the season by managing the irrigation.
Management of water tables and salinity

In your orchard you can manage salinity by being aware of/understanding the following:
• sensitivity of the fruit tree species
• soil type
• irrigation management including
  - system type (micro-irrigation, furrow or flood)
  - quality of irrigation water
  - drainage
• water tables (saline and non-saline)

Water tables
Before you start, measure the depth and salinity of the water table.

To manage rising salty water tables and prevent waterlogging, you need to grow fruit trees on well-drained soils and have good surface drainage.

Perched water tables (temporary water tables above the main regional water table) or areas not protected from the regional water table by ground water pumps or tile drains, will only require enough irrigation to meet the amount of water used by the tree. Too much irrigation will result in recharge to the groundwater and increase the possibility of waterlogging.

Increased sensitivity to salinity under waterlogged conditions and nutrient leaching are additional costs.

Saline irrigation water and leaching
Soil moisture monitoring (eg. by tensiometers or neutron probes) is needed to help irrigation practices and prevent waterlogging. The amount of irrigation should generally closely match the water use needs of the tree.

In areas with no water table problems and highly saline irrigation water, the strategy will be sensible leaching to flush the salts through the soil. Leaching is good in areas with tile drainage or areas such as the Goulburn Valley, where groundwater pumps are installed to lower water tables by pumping water from the aquifers. Leaching must be managed for different soil types – for example it may not be possible to leach

Leaching means adding more water to flush salts past the root zones (10%–20%)

No one really irrigates so efficiently that water equals tree water use so there is always some leaching.
heavy soils without causing waterlogging. In areas not protected by groundwater pumps or areas with heavy soils, the addition of excessive water for leaching may cause waterlogging. Leaching should only include about 10% more water than is used by the tree.

- It is vital that leaching irrigations are separate to fertiliser application to ensure that nutrients are not washed through the soil.
- If the water is of good quality (less than 0.2 dS/m or 200 EC) and there is no existing soil salinity problem, there is no need to leach (leaching will waste water and nutrients!).

**General Management**

For all situations, successful management for orchards under saline conditions requires regular monitoring of three things:

1. Irrigation water
2. Soil salinity
3. Salt in the plant

Sample regularly and observe your orchard

- Measure salinity
- Shandy salty water where practical
- Watch for tree symptoms

**Experience with monitoring is the key**

Experience and good accurate records of soil and leaf analysis and yield response will increase the knowledge of salinity effects in a particular environment. Regular monitoring will increase understanding and improve management decisions for individual situations.

See also the next page "Quick reference guide to salinity results for fruit trees", and "Installation and monitoring of testwells", and "Soil and water salinity" at the back of Chapter 9, Benchmarking and monitoring.
# QUICK REFERENCE GUIDE TO SALINTITY RESULTS FOR FRUIT TREES

*remember to convert your EC$_{1:5}$ result to EC$_e$ by taking into account the soil texture*

* Remember that 1 µS/cm = 1000 mS/cm = 640 ppm = 1000 EC units

<table>
<thead>
<tr>
<th>Water EC µS/cm (ie EC units)</th>
<th>Result</th>
<th>Soil EC$_e$ dS/m</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very low 0-200</td>
<td>Good quality water for the production of all crops</td>
<td>0-0.5</td>
<td>Very low soil salinity; all crops will grow</td>
</tr>
<tr>
<td>Low 200-600</td>
<td>Adequate for the production of most fruit trees</td>
<td>0.5-2.0</td>
<td>Low soil salinity; level is generally safe for fruit trees</td>
</tr>
<tr>
<td>Medium 600-1000</td>
<td>Production of fruit trees must consider salinity management including leaching strategies; maximum level for human consumption is recommended at 830</td>
<td>2.0-3.0</td>
<td>Soil salinity slightly above threshold for fruit trees; leaching management to reduce salinity</td>
</tr>
<tr>
<td>High &gt;1000</td>
<td>Not generally recommended for fruit trees unless specific management is adopted; need to produce more salt tolerant crops; contact Agriculture Victoria for further information</td>
<td>&gt;3.0</td>
<td>High soil salinity for fruit trees; specific management needs to be adopted; grow more salt tolerant crops; contact Agriculture Victoria for further information</td>
</tr>
</tbody>
</table>

QQUUIICCKK  RREEFFEERREENNCCEE  GGUUIIIDDDEE  TTOO  SSAALLIINNIITTYY  RREESSUULLTTSS  FFOORR  FFRRUUIITT  TTRREEEESS

* remember to convert your EC$_{1:5}$ result to EC$_e$ by taking into account the soil texture

* Remember that 1 µS/cm = 1000 mS/cm = 640 ppm = 1000 EC units
Nutrient management

Managing nutrients is a key ingredient to successful fruit growing. The nutrients applied must be available for use by the tree to produce the desired quantity and quality of crop.

Nutrient loss to waterways, or groundwater, is wasted money and can cause off-farm damage such as toxic blue-green algae outbreaks. Nitrogen leaching also causes soil acidity problems.

Best practice includes:

- Applying nutrients at the right times (in relation to tree and irrigation event)
- Keeping records of amounts and times of application
- Selecting correct form of nitrogen depending on the pH of your soil
- Monitoring leaf analysis (take leaf samples)
- Measuring efficiency of nitrate application using soil water samplers.

Tree nutrition

The application of fertiliser aims to ensure that the tree has enough nutrients to grow. Standards are available which are based on analysis of leaves and show how well the tree is taking up the nutrients.
Soil pH has a very significant effect on the availability of nutrients for the tree. A soil pH close to neutral (pH 7) will maximise the availability and uptake of nutrients (refer to the diagram below). When the pH is too low or too high, some nutrients cannot be taken up by the tree (or only in low quantities), while others may be taken up at the desired rate. You must therefore sample soil for pH regularly. To maintain a good pH it is important to select the appropriate form of nitrogen as outlined in “Nutrient management” pp.64-65.

Presented in the table below are some standard nutrient values of fruit tree leaves, and the interpretation of these. These values are a guide only. Up-to-date information should be sought in respect to each crop and the interpretation of these values in relation to management and site aspect information.

Table 7.1 Plant nutrient concentrations and their effect

<table>
<thead>
<tr>
<th>Fruit tree</th>
<th>Nutrient</th>
<th>Deficient</th>
<th>Adequate</th>
<th>Excessive / Toxic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple</td>
<td>N</td>
<td>&lt;1.6</td>
<td>2.0 – 2.4</td>
<td>&gt;3.0</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>&lt;0.10</td>
<td>0.15 – 0.20</td>
<td>&gt;0.3</td>
</tr>
<tr>
<td></td>
<td>K</td>
<td>&lt;0.8</td>
<td>1.2 – 1.5</td>
<td>&gt;2.0</td>
</tr>
<tr>
<td>Apricot</td>
<td>N</td>
<td>&lt;1.7</td>
<td>2.4 – 3.0</td>
<td>&gt;4.0</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>&lt;0.09</td>
<td>0.14 – 0.25</td>
<td>&gt;0.4</td>
</tr>
<tr>
<td></td>
<td>K</td>
<td>&lt;1.0</td>
<td>2.0 – 3.5</td>
<td>&gt;4.0</td>
</tr>
<tr>
<td>Cherry</td>
<td>N</td>
<td>&lt;1.7</td>
<td>2.2 – 2.6</td>
<td>&gt;3.4</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>&lt;0.09</td>
<td>0.14 – 0.25</td>
<td>&gt;0.4</td>
</tr>
<tr>
<td></td>
<td>K</td>
<td>&lt;1.0</td>
<td>1.6 – 3.0</td>
<td>&gt;4.0</td>
</tr>
<tr>
<td>Peach</td>
<td>N</td>
<td>&lt;2.4</td>
<td>3.0 – 3.5</td>
<td>&gt;4.2</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>&lt;0.09</td>
<td>0.14 – 0.25</td>
<td>&gt;0.4</td>
</tr>
<tr>
<td></td>
<td>K</td>
<td>&lt;1.0</td>
<td>2.0 – 3.0</td>
<td>&gt;4.0</td>
</tr>
<tr>
<td>Pear</td>
<td>N</td>
<td>&lt;1.8</td>
<td>2.3 – 2.7</td>
<td>&gt;3.5</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>&lt;0.1</td>
<td>0.14 – 0.2</td>
<td>&gt;0.3</td>
</tr>
<tr>
<td></td>
<td>K</td>
<td>&lt;0.7</td>
<td>1.2 – 2.0</td>
<td>*</td>
</tr>
<tr>
<td>Plum</td>
<td>N</td>
<td>&lt;1.7</td>
<td>2.4 – 3.0</td>
<td>&gt;4.0</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>&lt;0.09</td>
<td>0.14 – 0.25</td>
<td>&gt;0.4</td>
</tr>
<tr>
<td></td>
<td>K</td>
<td>&lt;1.0</td>
<td>1.6 – 3.0</td>
<td>&gt;4.0</td>
</tr>
</tbody>
</table>

*trees behave normally over a wide range (Reuter & Robinson, 1997)

Soil pH

Soil pH has a very significant effect on the availability of nutrients for the tree. A soil pH close to neutral (pH 7) will maximise the availability and uptake of nutrients (refer to the diagram below). When the pH is too low or too high, some nutrients cannot be taken up by the tree (or only in low quantities), while others may be taken up at the desired rate. You must therefore sample soil for pH regularly. To maintain a good pH it is important to select the appropriate form of nitrogen as outlined in “Nutrient management” pp.64-65.
The figure below shows the effect of pH_{CaCl} on the availability of nutrients to plants. The width of the bars for each nutrient, indicates the relative amount that is available to plants at the pH_{CaCl} shown at the bottom of the table. A pH_{CaCl} of 6.1–7.1 is therefore the best pH_{CaCl} range.

(from Hollier et al., 1993)
Fertiliser application

Horticultural crops require a variety of nutrients, including nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, sodium, zinc, copper, manganese and iron. The major nutrients for fruit trees are nitrogen (N), phosphorous (P) and potassium (K).

Nitrogen and phosphorus have been identified as being the main nutrients causing problems for the environment through leaching and run off.

Nutrients are usually supplied as fertiliser in solid form, which is either broadcast and incorporated into the soil, or can be dissolved and applied with the irrigation water. This second method is called fertigation.

Applied nutrients are then held in the soil and taken up by the crop when needed. Some nutrients are returned to the soil at leaf drop.

Efficient fertiliser use requires:
- determining the correct rate
- selecting the correct time to run the irrigation system for and
- determining when to fertigate within an irrigation event.

Check Your Irrigation Management
Wet the rootzone only. Excessive run times will leach fertiliser and nutrients past the rootzone and cause soil acidity (low soil pH). Nutrients such as nitrate are continually released in the soil and are prone to leaching by long irrigation run times. Determine your maximum irrigation run time and vary the interval between irrigations to maintain optimal soil moisture. If saline irrigation water is applied, some controlled leaching could be required to prevent salt accumulation in the rootzone.
A grower in the Goulburn Valley has a medium sized orchard. He grows pears and apples with some canning stonefruit. Over the past few years he noticed a decline in one of his pear blocks. He called us in to investigate. We dug a soil pit and looked at the depth of the tree’s rootzone, what type of soil the pears were growing in and also conducted a field pH test. We found that from the middle to the bottom of the rootzone (between 40 cm and 60 cm) was a severe soil acidity problem.

Soil acidity is generally caused by leaching fertiliser through over irrigation. We therefore discussed the amount of water the grower applies to his pears. According to our calculations based on soil types found in the pit and the estimated RAW, the grower could reduce the number of hours he ran his system by about a third. While this will not reverse the soil acidity problem it will prevent it from becoming worse.
An important point for nitrogen management is selecting the best form of nitrogen for your soil. The following guide has been developed for Pome and Stonefruit Orchards in the Goulburn–Murray Valley.

### Nutrient loss

The stages with the most likelihood of loss from the orchard are:

- When excess water leaches nutrient (particularly nitrogen) below the rootzone to groundwater or to tile drains – the initial watering in of fertiliser is the most risky stage
- When excess surface water carries nutrients from the soil, or with soil that runs off to surface drainage systems.

In addition, if the soil pH of the water is strongly acidic (<5.5) or strongly alkaline (>8.0), added nutrients are leached, become fixed or lost to the atmosphere.

For orchards in the Goulburn and Murray Valleys, leaching is a bigger issue than run-off. Urea and nitrate are easily lost down past the roots with excessive irrigation or rainfall. Ammonium, potassium and phosphorus are not as easily leached out.

### Nutrient management

An important point for nitrogen management is selecting the best form of nitrogen for your soil. The following guide has been developed for Pome and Stonefruit Orchards in the Goulburn–Murray Valley.

#### Table 7.3 Nitrogen forms for different soil pH

<table>
<thead>
<tr>
<th>Your soil pH range</th>
<th>Suitable forms of nitrogen for the pH ranges shown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkaline soil pH (&gt;6.5 in CaCl₂)</td>
<td>Ammonium, urea, mixed, nitrate organic sources</td>
</tr>
<tr>
<td>Good soil pH (5.0–6.5 in CaCl₂)</td>
<td>Urea, ammonium, nitrate, mixed organic sources. (Avoid fertilisers containing nitrogen as ammonium only*)</td>
</tr>
<tr>
<td>Acid soil pH (4.2–5.0 in CaCl₂)</td>
<td>Urea, nitrate. (Avoid fertilisers containing nitrogen as ammonium only*)</td>
</tr>
<tr>
<td>Strongly acid soil pH (&lt;4.2 in CaCl₂)</td>
<td>Nitrate based fertilisers only. (Avoid fertilisers containing nitrogen as ammonium only*)</td>
</tr>
</tbody>
</table>

* Fertilisers that contain ammonium only will lower soil pH over time even if used efficiently.
More on Efficient Nitrogen use

The proportion of applied fertiliser taken up by fruit trees is typically low (ie. 30%), which is not very efficient. Nitrogen fertiliser can be lost by leaching due to heavy rainfall or poor irrigation management. Losses can also occur as gas and this is increased by waterlogging or failure to water fertiliser into the soil. Fertiliser uptake can be improved (ie. made more efficient) by careful timing to meet tree demand. Careful fertiliser application techniques, splitting larger fertiliser applications and good irrigation management are all important to maximise root uptake of fertiliser. The best case is 100% efficient where all fertiliser is taken up by the tree. The worst case is 0% efficiency where there is no tree uptake and all fertiliser is leached.

Efficient Nitrogen Application Techniques

Microjet or Drip
- **Fertigation**: apply in the last hour of a normal irrigation or in a special short run (1–2 hours) a day after an irrigation
- **Treeline**: Spread fertiliser a day or two after an irrigation and irrigate for 2 hours.

Sprinkler
- **Treeline**: Spread and irrigate for 2 hours
- **Fertigation**: Apply in the last 2 hours of an irrigation or in a short run 2 days after an irrigation.

Flood or Furrow
- Spread and irrigate or spread and cultivate.

Rainfall
- Choose the form of fertiliser carefully (avoid urea) and apply just before rainfall is forecast and at the correct time of year.

Allow sufficient time for fertiliser to clear from lines before ending the irrigation.
Most growers will have a fair idea of which blocks have what type of soil. You will also probably have done a soil analysis on all of your blocks at different times.

But, you need to understand the characteristics and behaviour of your soil to make irrigation decisions and achieve Best Practice. Some of the information required includes:

- soil type; sand, loam, clay etc.
- root volume and physical barriers
- general characteristics such as undulation, rocks, stones
- infiltration rates, ie. does the water run off quickly or slowly?

This will help you figure out how much water the soil can hold and how to manage the soil to maximise production (See the previous section – Irrigation Management).

Many soils in the Goulburn and Murray Valleys have been described and the following tables outline these soil types.
Table 8.1 Description of soil types available for growth of crops in Goulburn Valley

<table>
<thead>
<tr>
<th>Group</th>
<th>Description of Crops Suitable for Production</th>
<th>Soil Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>Very good soils for all horticultural crops, most vegetables, tomatoes and tobacco. Summer fodder crops, cereals, lucerne and perennial and annual pastures can be grown successfully</td>
<td>East Shepparton Fine Sandy Loam Grahamvale Sandy Loam Sandmount Sand</td>
</tr>
<tr>
<td>Group II</td>
<td>Good soils for all horticultural crops (except citrus), pumpkins, peas, beans, tomatoes, summer fodder crops, cereals, lucerne and perennial and annual pastures</td>
<td>Katamatite Loam Shepparton Fine Sandy Loam</td>
</tr>
<tr>
<td>Group III</td>
<td>Good soils for apricots, apples, pears, plums, summer fodder crops, cereals and perennial and annual pastures; fair soils for peaches, tomatoes, pumpkins, peas, beans and lucerne</td>
<td>Lemnos Loam Karook Loam</td>
</tr>
<tr>
<td>Group IV</td>
<td>Fair soils for pears and plums; good soils for summer fodder crops, cereals and perennial and annual pastures</td>
<td>Goulburn Loam Goulburn Clay Loam Orvale Loam Zeerust Fine Sandy Loam</td>
</tr>
<tr>
<td>Group V</td>
<td>Pears, plums and perennial pastures can be grown only if well drained; summer fodder crops, cereals and annual pastures can be grown</td>
<td>Congupna Clay Loam Coomboona Clay</td>
</tr>
<tr>
<td>Group VI</td>
<td>Soils not recommended for irrigation because of swampiness or uneven surface features making layout for irrigation impracticable</td>
<td>Congupna Clay</td>
</tr>
</tbody>
</table>

(from Skene and Poutsma, 1962)
Table 8.2 Description of soil types available for growth of crops in Murray Valley

<table>
<thead>
<tr>
<th>Group</th>
<th>Description of Crops Suitable for Production</th>
<th>Soil Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>Good and fair soils for citrus (except Murrawee sand, shallow phase), apricots, plums, vines, vegetables and lucerne, but doubtful soils for peaches, apples and shallow rooting crops.</td>
<td>Tyntynder Sand Murrawee Sand Murrawee Sand, Shallow Phase</td>
</tr>
<tr>
<td>Group II</td>
<td>Good and fair soils for apricots, plums, apples, pears, vines, vegetables, lucerne, summer fodder crops, cereals, perennial and annual pastures; the grey sandy clay is also fair for peaches.</td>
<td>Murrawee Sand Murrawee Sandy Loam Murrawee Sandy Loam, Shallow Phase Tresco Sandy Loam Tresco Sandy Loam, Shallow Phase</td>
</tr>
<tr>
<td>Group III</td>
<td>Good and fair soils for vegetables, lucerne, (except some areas), vines, summer fodder crops, cereals, and perennial and annual pastures; doubtful or unsuitable for most tree species.</td>
<td>Tatchera Sandy Loam Tatchera Sandy Loam, Deep Phase Tatchera Sandy Loam, Shallow Phase Venifera Sandy Clay Loam</td>
</tr>
<tr>
<td>Group IV</td>
<td>Good and fair soils for lucerne (except Speewa sand and Nyah Clay Loam), summer fodder crops, cereals, and perennial and annual pastures; mainly doubtful for vegetables.</td>
<td>Lake Baker Clay Speewa Clay Swan Hill Clay Nyah Clay Loam</td>
</tr>
<tr>
<td>Group V</td>
<td>Saline soils requiring appropriate reclamation measures and careful irrigation; when reclaimed the Kunat, Murrawee and Tatchera Sandy Clay Loam and Sandy Loam should support most of the Group III crops.</td>
<td>Kunat Sandy Clay Loam Murrawee Sandy Loam, Saline Phase Tatchera Sandy Loam, Saline Phase</td>
</tr>
<tr>
<td>Group VI</td>
<td>Soils generally not recommended for irrigation because of elevation above gravity supply level, liability to intermittent flooding, or high salinity.</td>
<td>Lunette Soils Saline Flats Swamps Watercourses</td>
</tr>
</tbody>
</table>

(from Skene and Sargeant, 1966)
To effectively manage nutrient supply and irrigation for your trees, you will need to understand and manage your soil. To do this you will need to consider:

- How the soil works (e.g. water infiltration rates)
- Soil particle size
- Soil texture (soil type) and depth of horizons
- Crusting (sodicity)
- Water holding capacity
- pH and adjustments required (e.g. addition of lime)
- Sodicity, slaking and dispersion (e.g. do you need to add gypsum and how much?)
- Soil salinity (what type of irrigation management is needed)
- Nitrate (is it being leached out?)

Now – how do you manage these things?

1. **Soil Structure**
   You can improve this by:
   - mulching/growing sward between rows
   - growing rye grass – to improve permeability
   - reducing the irrigation application rate.

2. **Drainage**
   You can improve this by:
   - hilling – to allow water to move away from roots
   - subsurface tile drains
   - surface drains between rows
   - improve surface soil structure to allow better infiltration
   - deep ripping of impermeable B horizon.
3. **Water Retention**
You can improve this by:
- mulch – to reduce surface evaporation
- mulch – to reduce weed growth (competition)
- hilling – to increase volume of soil and water available to trees.

4. **Soil Acidity**
You can manage this by:
- measuring pH accurately in each block
- irrigating with appropriate fertilisers (refer Chapter 7, Nutrient management)
- applying lime prior to planting.

**Table 8.3 Suggested amounts of lime (tonnes per hectare)**

<table>
<thead>
<tr>
<th>Soil texture</th>
<th>Soil pH 4.0 – 4.5</th>
<th>Soil pH 4.5 – 5.0</th>
<th>Soil pH 5.0 – 5.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sands</td>
<td>4.0</td>
<td>2.50</td>
<td>1.5</td>
</tr>
<tr>
<td>Loams</td>
<td>5.5</td>
<td>3.25</td>
<td>2.0</td>
</tr>
<tr>
<td>Clay sand</td>
<td>9.5</td>
<td>6.25</td>
<td>3.5</td>
</tr>
</tbody>
</table>

5. **Sodicity**
Sodicity means you have a lot of sodium (or salt) in the soil which causes a decline in soil structure and prevents drainage.

You can manage this by:
- taking a soil sample prior to planting
- applying gypsum – as required.

6. **Slaking and Dispersion**
Slaking and dispersion refers to a breakdown in the structure of the soil. The soil will crust, compact and erode easily.

You can manage this by:
- applying gypsum.

**Importance of Soils for Irrigation:**
- the texture of the soil (soil type) determines the water holding capacity
- the infiltration rate determines the wetting pattern of an irrigation system and will be influenced by slaking and dispersion.
Soils management

The Tatura System
In the ‘Tatura system’, to improve drainage and optimise land use the topsoil is hilled into a treeline bank approximately 0.5 m high. From soil tests, the specified amount of lime is incorporated and gypsum spread on the surface in a 2 m wide strip on the treeline. Ryegrass is sown over the entire orchard. To improve drainage through the soil profile, a ripper with a winged-tine is used to till the soil to a depth of 60 cm to create aggregates 1–10 mm in diameter in the subsoil. The fruit trees are planted, and the bare soil, created by the tillage operation is covered with a 2 m wide straw mulch. The following steps are suggested as a guide to setting up a new orchard.

1. In late summer/autumn, peg out the orchard treelines accurately and install the irrigation mains.

2. Use a road grader to move the topsoil from the centre of the traffic line to the treeline to create a bank approximately 0.5 m high.

3. For acid soils (pH < 6.0), apply lime (amount determined by a soil test) in a 2 m wide strip along the treeline, and incorporate with a rotary hoe.

4. Install irrigation laterals and microjet sprinklers (output 5 – 10 mm/hour) and irrigate for 2 – 3 hours.

5. When the soil has drained to around field capacity (2 – 3 days), cultivate the entire orchard with a tined implement, power hoe or a rotary hoe and smooth the soil surface.

6. For dispersive soils, apply gypsum (amount determined by a soil test) in a 2 m wide strip along the treeline.

7. Sow the orchard to ryegrass or a ryegrass and clover mix and irrigate for 2 – 3 hours.

8. In late winter, mow the grass/clover sward close to the ground.

9. Use a winged-tine ripper to a depth of 60 cm in three passes in increments of 20 cm.

10. Cultivate the 2 m wide strip with a tined implement, power harrow or a rotary hoe and smooth the soil surface.

11. Plant the trees without compacting the soil.

12. Apply a surface mulch of straw in a 2 m wide strip on the treeline.

13. In spring/summer, use herbicides to control weeds in a 2 m wide strip on the treeline.

14. Slash the orchard and deliver the clippings onto the treeline to supplement the straw mulch.
Benchmarking and monitoring

Having identified the Best Practices in the previous chapters – you now have to ask:

What’s In It For Me?  How Do I Do It?
We need to measure what we do – and then:
• Compare it to other people’s experiences
• Compare and analyse the differences and similarities
• Set Industry Standards
• Measure our own performance over time.

How do we know how well we’re doing?  What should you check?

This is vital for any Quality Assurance (QA) system we may need to be involved in, eg. SQF 2000, ISO 9002, Woolworth’s Vendor Quality Management System.

Some Best Management Practices applications and the resultant benchmarks are shown in the following sections 1 – 6 which are:
1. Growth cycle
2. Production
3. Irrigation management
4. Salinity management
5. Nutrient management
6. Soil management

You need to know what you want.
For each of the Sections you can fill in your own information and compare it with the grower benchmarks. These provide a good reality check.
The benchmark data is presented throughout the chapter and uses information collected from 40 growers in the Goulburn and Murray Valleys. The districts monitored were Shepparton East, Ardmona, Cobram and Swan Hill. For some measurements the information from Shepparton East and Ardmona are combined and referred to as Shepparton.

The crops monitored were pears, apples and peach/nectarines. Peach and nectarines are divided into early (harvested by end of December) and late (harvested after December). Monitoring took place over two seasons – 1997/98 and 1998/99.

Remember! In order to manage you need to measure!
1. Growth cycle

Best Practice
Record growth cycle dates for each variety

Growth cycle monitoring sheets are attached to record your own data

Below are examples of growth curves for fruit tree crops, including timing of the different growth stages.

Growth Stage – Golden Queen Peach

Figure 9.2 Example of a growth curve for peach trees
Growth Stage – Williams Pear

Figure 9.3 Example of a growth curve for pear trees

Growth Stage – Granny Smith Apple

Figure 9.4 Example of a growth curve for apple trees
# Growth Cycle Monitoring Sheet

<table>
<thead>
<tr>
<th>Tree details</th>
<th>Growth Cycle Events</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Season (year):</td>
<td>Floral Budburst / Flowering</td>
<td></td>
</tr>
<tr>
<td>Block:</td>
<td>Beginning of Shoot Growth</td>
<td></td>
</tr>
<tr>
<td>Crop:</td>
<td>Tip hardening (for Stonefruit)</td>
<td></td>
</tr>
<tr>
<td>Variety:</td>
<td>Beginning of Fruit Fill</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(rapid fruit growth)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Start of Harvest</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Finish of Harvest</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Leaf Fall</td>
<td></td>
</tr>
</tbody>
</table>

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<thead>
<tr>
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<th>Date</th>
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</tr>
<tr>
<td>Block:</td>
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<td></td>
</tr>
<tr>
<td>Crop:</td>
<td>Tip hardening (for Stonefruit)</td>
<td></td>
</tr>
<tr>
<td>Variety:</td>
<td>Beginning of Fruit Fill</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(rapid fruit growth)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Start of Harvest</td>
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<tr>
<td></td>
<td>Finish of Harvest</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Leaf Fall</td>
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</tbody>
</table>

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<th>Growth Cycle Events</th>
<th>Date</th>
</tr>
</thead>
<tbody>
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<td></td>
</tr>
<tr>
<td>Block:</td>
<td>Beginning of Shoot Growth</td>
<td></td>
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<tr>
<td>Crop:</td>
<td>Tip hardening (for Stonefruit)</td>
<td></td>
</tr>
<tr>
<td>Variety:</td>
<td>Beginning of Fruit Fill</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(rapid fruit growth)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Start of Harvest</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Finish of Harvest</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Leaf Fall</td>
<td></td>
</tr>
</tbody>
</table>
2. Production

Best Practice
Measure and record production and quality for each variety

*Production record sheets are attached to record your own data*

A whole farm plan assists you in keeping records for the whole orchard:
- photo of property
- record information on blocks
- map of blocks and roads
- identify irrigation outlets etc.

Figure 9.3 An example of a Whole Farm Plan showing some elements that need to be included
Benchmark data

The benchmark data shown in the following pages, uses information collected from 40 growers in the Goulburn and Murray Valleys. The districts monitored were Shepparton East, Ardmona, Cobram and Swan Hill. For some measurements the information from Shepparton East and Ardmona are combined and referred to as Shepparton. The crops monitored were pears, apples and peach/nectarines. Peach and nectarines are divided into early (harvested by end of December) and late (harvested after December). Monitoring took place over two seasons – 1997/98 and 1998/99.

Table 9.1 Yield benchmark data for 1997–98 and 1998–99

<table>
<thead>
<tr>
<th>Location</th>
<th>Crop</th>
<th>No. of sites</th>
<th>1997/98</th>
<th>1998/99</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>average</td>
<td>range</td>
</tr>
<tr>
<td>Shepparton</td>
<td>Pear</td>
<td>14</td>
<td>38.8</td>
<td>11–79</td>
</tr>
<tr>
<td></td>
<td>Apple</td>
<td>3</td>
<td>79</td>
<td>62–110</td>
</tr>
<tr>
<td></td>
<td>Peach</td>
<td>3</td>
<td>50.3</td>
<td>30–68</td>
</tr>
<tr>
<td>Cobram</td>
<td>Pear</td>
<td>1</td>
<td>52</td>
<td>52</td>
</tr>
<tr>
<td></td>
<td>Peach</td>
<td>4</td>
<td>48</td>
<td>23–62</td>
</tr>
<tr>
<td>Swan Hill</td>
<td>Peach/Nectarine</td>
<td>6</td>
<td>14.9</td>
<td>10–25</td>
</tr>
<tr>
<td></td>
<td>(early)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Peach/Nectarine</td>
<td>4</td>
<td>28.7</td>
<td>15.7–43</td>
</tr>
<tr>
<td></td>
<td>(late)</td>
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</table>

Table 9.2 Fruit size benchmark data for 1997–98 and 1998–99

<table>
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<tr>
<th>Location</th>
<th>Crop</th>
<th>No. of sites</th>
<th>1997/98</th>
<th>1998/99</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>average</td>
<td>range</td>
</tr>
<tr>
<td>Shepparton</td>
<td>Pear</td>
<td>8</td>
<td>76.6</td>
<td>69–87</td>
</tr>
<tr>
<td></td>
<td>Apple</td>
<td>1</td>
<td>70</td>
<td>70</td>
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<tr>
<td></td>
<td>Peach</td>
<td>3</td>
<td>72.7</td>
<td>63–90</td>
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<tr>
<td>Cobram</td>
<td>Pear</td>
<td>1</td>
<td>80</td>
<td>80</td>
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<tr>
<td></td>
<td>Peach</td>
<td>2</td>
<td>66.8</td>
<td>64–70</td>
</tr>
<tr>
<td>Swan Hill</td>
<td>Peach/Nectarine</td>
<td>6</td>
<td>60.3</td>
<td>57–67</td>
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<tr>
<td></td>
<td>(early)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Peach/Nectarine</td>
<td>2</td>
<td>65</td>
<td>60–70</td>
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<tr>
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<td>(late)</td>
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### Production Record Sheet

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<td>.........................................................</td>
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<td>Rootstock:</td>
<td>.........................................................</td>
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<tr>
<td>Planting System:</td>
<td>.........................................................</td>
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<tr>
<td>Planting Area:</td>
<td>.........................................................</td>
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</table>

<table>
<thead>
<tr>
<th>Year/Date</th>
<th>Tree Age</th>
<th>Yield</th>
<th>Fruit Size</th>
<th>Packout</th>
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</tr>
</tbody>
</table>
3. Irrigation management

**Best Practice**
Select the most efficient irrigation method

Discuss suitability of a system with irrigation designers and DNRE extension staff

**Best Practice**
Assess the soil using a soil pit and determine how long to run the system

Follow the practices outlined in Chapter 5, Irrigation management, to assess your soil and determine how long to run the system.

Irrigation and WUE data in the following tables were collected from 40 growers in four regions, with Ardmona and Shepparton East combined as Shepparton.

**Table 9.3 Irrigation benchmark data; depth of rootzone and readily available water between 8 and 40 kPa for 1997–98**

<table>
<thead>
<tr>
<th>Location</th>
<th>Irrigation</th>
<th>Depth of rootzone (cm)</th>
<th>Readily available water (8-40 kPa)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>No. of</td>
<td>average</td>
<td>range</td>
</tr>
<tr>
<td></td>
<td>system</td>
<td>sites</td>
<td>sites</td>
</tr>
<tr>
<td>Shepparton</td>
<td>Micro</td>
<td>16</td>
<td>74</td>
</tr>
<tr>
<td></td>
<td>Sprinkler</td>
<td>2</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>Flood</td>
<td>4</td>
<td>74</td>
</tr>
<tr>
<td>Cobram</td>
<td>Micro</td>
<td>4</td>
<td>81</td>
</tr>
<tr>
<td></td>
<td>Sprinkler</td>
<td>2</td>
<td>73</td>
</tr>
<tr>
<td>Swan Hill</td>
<td>Micro</td>
<td>10</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td>Flood</td>
<td>1</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>–</td>
<td>1</td>
<td>85</td>
</tr>
</tbody>
</table>
How to calculate water use efficiency (t/ML)

Water use efficiency (t/ML) = Yield (t/ha) ÷ ML/ha

Record water use efficiency for your crops, alongside ML/ha on attached charts.
### Table 9.4 Water use efficiency benchmark data for 1997–98

<table>
<thead>
<tr>
<th>Location</th>
<th>Crop</th>
<th>Irrigation system</th>
<th>1997–98 Water Applied (ML/ha)</th>
<th>Water use efficiency (t/ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>No. of sites</td>
<td>average</td>
</tr>
<tr>
<td>Shepparton</td>
<td>Pear</td>
<td>Micro</td>
<td>11</td>
<td>6.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sprinkler</td>
<td>1</td>
<td>8.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flood</td>
<td>2</td>
<td>6.6</td>
</tr>
<tr>
<td></td>
<td>Apple</td>
<td>Micro</td>
<td>1</td>
<td>7.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sprinkler</td>
<td>1</td>
<td>8.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flood</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Peach</td>
<td>Micro</td>
<td>4</td>
<td>6.5</td>
</tr>
<tr>
<td>Cobram</td>
<td>Pear</td>
<td>Sprinkler</td>
<td>1</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td>Peach</td>
<td>Micro</td>
<td>4</td>
<td>6.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sprinkler</td>
<td>1</td>
<td>8.9</td>
</tr>
<tr>
<td>Swan Hill</td>
<td>Peach</td>
<td>Micro</td>
<td>4</td>
<td>5.4</td>
</tr>
<tr>
<td></td>
<td>Nectarine (early)</td>
<td>Micro</td>
<td>1</td>
<td>12.3</td>
</tr>
<tr>
<td></td>
<td>Peach</td>
<td>Micro</td>
<td>4</td>
<td>6.5</td>
</tr>
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</table>

### Table 9.5 Water use efficiency benchmark data for 1998–99

<table>
<thead>
<tr>
<th>Location</th>
<th>Crop</th>
<th>Irrigation system</th>
<th>1997–98 Water Applied (ML/ha)</th>
<th>Water use efficiency (t/ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>No. of sites</td>
<td>average</td>
</tr>
<tr>
<td>Shepparton</td>
<td>Pear</td>
<td>Micro</td>
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<td>5</td>
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<td>Sprinkler</td>
<td>1</td>
<td>6.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flood</td>
<td>3</td>
<td>6.8</td>
</tr>
<tr>
<td></td>
<td>Apple</td>
<td>Micro</td>
<td>1</td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sprinkler</td>
<td>1</td>
<td>9.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flood</td>
<td>1</td>
<td>11</td>
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<td></td>
<td>Peach</td>
<td>Micro</td>
<td>4</td>
<td>6.6</td>
</tr>
<tr>
<td>Cobram</td>
<td>Pear</td>
<td>Sprinkler</td>
<td>1</td>
<td>7</td>
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<tr>
<td></td>
<td>Peach</td>
<td>Micro</td>
<td>4</td>
<td>6.4</td>
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<td></td>
<td></td>
<td>Sprinkler</td>
<td>1</td>
<td>7.1</td>
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<tr>
<td>Swan Hill</td>
<td>Peach</td>
<td>Micro</td>
<td>5</td>
<td>5.7</td>
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<tr>
<td></td>
<td>Nectarine (early)</td>
<td>Micro</td>
<td>1</td>
<td>4.8</td>
</tr>
<tr>
<td></td>
<td>Peach</td>
<td>Micro</td>
<td>3</td>
<td>8.7</td>
</tr>
</tbody>
</table>
Best Practice
Schedule irrigation using the most appropriate techniques

Refer to Chapter 5 to determine the most appropriate technique/s

Talk to other growers to determine their experience with different techniques

Best Practice
Measure and record soil moisture

> Charts to record ML/ha for your crops are attached. These also include calculations of water use efficiency (refer end of this section).

Use other soil moisture monitoring methods if not using tensiometers. Refer to guide

Best Practice
Apply Regulated Deficit Irrigation for vigour control and/or water saving

Refer to Chapter 5 of this guide to determine how and when to apply Regulated Deficit Irrigation
Irrigation Monitoring Sheet

**Note:** If using a tensiometer, use the 'Tensiometer and watertable recording chart' included in the back of this manual.

<table>
<thead>
<tr>
<th>Block:</th>
<th>Variety:</th>
<th>System Type:</th>
<th>Season:</th>
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</table>

<table>
<thead>
<tr>
<th>Date</th>
<th>Run Time (hrs)</th>
<th>Date</th>
<th>Run Time (hrs)</th>
<th>Date</th>
<th>Run Time (hrs)</th>
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</table>
Seasonal Water Applied (ML/ha) & Water Use Efficiency (t/ML)

<table>
<thead>
<tr>
<th>Block</th>
<th>Variety</th>
<th>System</th>
<th>Season</th>
<th>Yield (t/ha)</th>
<th>Total Water Applied (ML/ha)</th>
<th>Yield (t/ha)</th>
<th>Water Use Efficiency (t/ML)</th>
</tr>
</thead>
</table>

100 mm = 1 ML/ha

Yield (t/ha) ÷ ML/ha = water use efficiency (t/ML)
4. Salinity management

Best Practice
Measure and record salinity of irrigation water and the water table

Charts to record your own water salinity data are attached.

Refer to quick reference guide in Chapter 6 about recommended levels of water salinity for fruit trees.

Best Practice
Monitor and record the depth of the watertable

Refer to the tensiometer chart (insert at back of manual) for recording water table depth.

Best Practice
Take soil samples for salinity measurement \((\text{EC}_e)\)

Soil sample results will give Electrical Conductivity \((\text{EC}_e)\) values, which is a measure of the soil salinity. The tables below show benchmark data collected from 40 growers in Ardmona, Cobram, Shepparton East and Swan Hill.

Refer to Chapter 6 of this guide about recommended levels for soil salinity.

Table 9.6 Soil \(\text{EC}_e\) benchmark data at 0–25 cm depth, for 1997–98 and 1998–99

<table>
<thead>
<tr>
<th>Location</th>
<th>No. of sites</th>
<th>Soil (\text{EC}_e) (dS/m) 0–25 cm depth</th>
<th>1997–98 average</th>
<th>1997–98 range</th>
<th>1998–99 average</th>
<th>1998–99 range</th>
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<tbody>
<tr>
<td>Ardmona</td>
<td>8</td>
<td>0.55</td>
<td>0.27–1.24</td>
<td>1.27</td>
<td>0.73–1.93</td>
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</tr>
<tr>
<td>Shepparton East</td>
<td>14</td>
<td>0.69</td>
<td>0.21–2.23</td>
<td>1.02</td>
<td>0.32–2.61</td>
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</tr>
<tr>
<td>Cobram</td>
<td>6</td>
<td>1.26</td>
<td>0.05–4.52</td>
<td>1.76</td>
<td>0.79–3.48</td>
<td></td>
</tr>
<tr>
<td>Swan Hill</td>
<td>12</td>
<td>1.67</td>
<td>0.48–4.65</td>
<td>1.03</td>
<td>0.82–1.35</td>
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</tr>
</tbody>
</table>

Table 9.7 Soil \(\text{EC}_e\) benchmark data at 25–45 cm depth, for 1997–98 and 1998–99

<table>
<thead>
<tr>
<th>Location</th>
<th>No. of sites</th>
<th>Soil (\text{EC}_e) (dS/m) 25–45 cm depth</th>
<th>1997–98 average</th>
<th>1997–98 range</th>
<th>1998–99 average</th>
<th>1998–99 range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ardmona</td>
<td>8</td>
<td>0.46</td>
<td>0.30–0.56</td>
<td>1.25</td>
<td>0.73–2.22</td>
<td></td>
</tr>
<tr>
<td>Shepparton East</td>
<td>14</td>
<td>0.59</td>
<td>0.21–2.27</td>
<td>0.93</td>
<td>0.32–2.58</td>
<td></td>
</tr>
<tr>
<td>Cobram</td>
<td>6</td>
<td>1.54</td>
<td>0.26–5.33</td>
<td>2.90</td>
<td>0.77–4.42</td>
<td></td>
</tr>
<tr>
<td>Swan Hill</td>
<td>12</td>
<td>1.47</td>
<td>0.51–4.31</td>
<td>0.98</td>
<td>0.58–1.59</td>
<td></td>
</tr>
</tbody>
</table>
A leaf sample analysis will show levels of chloride and sodium which indicate plant salinity. (Refer to nutrient management – Section 5).

Refer to page 54 of this guide about toxic levels for leaf sodium and chloride and symptoms of salinity damage.

Table 9.8  Leaf chloride (Cl) benchmark data from 40 growers in four regions for 1997–98 and 1998–99

<table>
<thead>
<tr>
<th>Location</th>
<th>Crop</th>
<th>No. of sites</th>
<th>Soil EC_e (dS/m) 25–45 cm depth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>average</td>
</tr>
<tr>
<td>Ardmona</td>
<td>Pear</td>
<td>4</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>Apple</td>
<td>2</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>Peach</td>
<td>2</td>
<td>0.04</td>
</tr>
<tr>
<td>Shepparton East</td>
<td>Pear</td>
<td>11</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>Apple</td>
<td>1</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>Peach</td>
<td>2</td>
<td>0.07</td>
</tr>
<tr>
<td>Cobram</td>
<td>Pear</td>
<td>1</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>Peach</td>
<td>5</td>
<td>0.08</td>
</tr>
<tr>
<td>Swan Hill</td>
<td>Peach &amp; Nectarine (early)</td>
<td>7</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>Peach &amp; Nectarine (late)</td>
<td>5</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Table 9.9  Leaf sodium (Na) benchmark data from 40 growers in four regions for 1997–98 and 1998–99

<table>
<thead>
<tr>
<th>Location</th>
<th>Crop</th>
<th>No. of sites</th>
<th>Soil EC_e (dS/m) 25–45 cm depth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>average</td>
</tr>
<tr>
<td>Ardmona</td>
<td>Pear</td>
<td>4</td>
<td>0.30</td>
</tr>
<tr>
<td></td>
<td>Apple</td>
<td>2</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Peach</td>
<td>2</td>
<td>0.07</td>
</tr>
<tr>
<td>Shepparton East</td>
<td>Pear</td>
<td>11</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>Apple</td>
<td>1</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>Peach</td>
<td>2</td>
<td>0.01</td>
</tr>
<tr>
<td>Cobram</td>
<td>Pear</td>
<td>1</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>Peach</td>
<td>5</td>
<td>0.01</td>
</tr>
<tr>
<td>Swan Hill</td>
<td>Peach &amp; Nectarine (early)</td>
<td>7</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>Peach &amp; Nectarine (late)</td>
<td>5</td>
<td>0.01</td>
</tr>
</tbody>
</table>
### Irrigation Water and Water Table Salinity Records

Block: .....................................................

Crop/Variety: .............................................

<table>
<thead>
<tr>
<th>Date</th>
<th>Irrigation Salinity</th>
<th>Water Table Salinity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5. Nutrient management

Best Practice
Apply the most efficient form of fertiliser

Refer to guide to determine the best form of fertiliser to apply to your orchard.

Best Practice
Record the amount and timing of fertiliser applied

Charts to record your own data are attached – when, how much and what was applied. These also allow for recording gypsum and lime applications (see end of this section).

FERTILISER RECORD SHEET
(One block per sheet)

BLOCK DETAILS

BLOCK NAME:
YEAR:
TREE AGE:
PLANTING DISTANCE:
TREES/HA:
TREES/acre:
IRRIGATION SYSTEM:
FERTIGATION: YES OR NO

CROP PRODUCTION

Bins
Half-Bins
No. of Trees
Tree Spacing
(acre)
(l/ha)
(l/acre)

ESTIMATED TREE VIGOUR

(water-shoot growth in the top third of the tree)

HIGH
growth longer than 1 metre
MODERATE
growth from 0.5 to 1 metres
LOW
growth less than 0.5 metres

FERTILISER RECORDS

These examples are assuming that the tree planting is 20’ x 20’ (6m x 6m) = 278 trees/ha

<table>
<thead>
<tr>
<th>DATE</th>
<th>FERTILISER</th>
<th>AMOUNT OF FERTILISER</th>
<th>UNITS OF NUTRIENT</th>
<th>HOW APPLIED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>kg/ha</td>
<td>kg/tree</td>
<td>Units of N</td>
</tr>
<tr>
<td>e.g. 5 March</td>
<td>Ammonium Nitrate</td>
<td>139</td>
<td>0.5 kg/tree</td>
<td>47 units of N</td>
</tr>
<tr>
<td>e.g. 5 March</td>
<td>NPK (10:6:6)</td>
<td>416</td>
<td>1.5 kg/tree</td>
<td>42 units of N</td>
</tr>
</tbody>
</table>

Date
Gypsum
Amount
kg/ha
kg/tree
How applied

Figure 9.5 Recording fertiliser information – an example sheet

Best Practice
Ensure that fertiliser is applied at the most effective time

Refer to Chapter 7 of this guide to determine when to apply fertiliser
Best Practice
Monitor plant nutrition using leaf nutrient analysis

Refer to the end of Chapter 9 Benchmarking and monitoring for a leaf sampling procedure.

Below is an example of a leaf nutrient analysis, which could be received from a laboratory. Chloride and sodium levels are also shown (refer to the salinity section).

Table 9.10  Leaf nutrient analysis – example only

<table>
<thead>
<tr>
<th>Element</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>2.7%</td>
</tr>
<tr>
<td>Phosphorous</td>
<td>0.18%</td>
</tr>
<tr>
<td>Potassium</td>
<td>2.7%</td>
</tr>
<tr>
<td>Chloride</td>
<td>0.22%</td>
</tr>
<tr>
<td>Sodium</td>
<td>0.010%</td>
</tr>
<tr>
<td>Calcium</td>
<td>2.59%</td>
</tr>
<tr>
<td>Magnesium</td>
<td>0.691%</td>
</tr>
<tr>
<td>Sulphur</td>
<td>0.18%</td>
</tr>
<tr>
<td>Manganese</td>
<td>82.4 mg/kg</td>
</tr>
<tr>
<td>Iron</td>
<td>164 mg/kg</td>
</tr>
<tr>
<td>Copper</td>
<td>8.8 mg/kg</td>
</tr>
<tr>
<td>Zinc</td>
<td>30.8 mg/kg</td>
</tr>
<tr>
<td>Boron</td>
<td>40.1 mg/kg</td>
</tr>
</tbody>
</table>

Make sure to record the variety, block and year on any leaf analysis report.

Refer to Chapter 7 of this guide about recommended levels for leaf nutrients.

The following tables show benchmark data from 40 growers for leaf nitrogen, phosphorous and potassium levels.

Table 9.11  Leaf nitrogen (N) benchmark data for 1997–98 and 1998–99

<table>
<thead>
<tr>
<th>Location</th>
<th>Crop</th>
<th>No. of sites</th>
<th>Leaf nitrogen (N) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>average</td>
</tr>
<tr>
<td>Shepparton</td>
<td>Pear</td>
<td>15</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td>Apple</td>
<td>3</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td>Peach</td>
<td>4</td>
<td>2.7</td>
</tr>
<tr>
<td>Cobram</td>
<td>Pear</td>
<td>1</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td>Peach</td>
<td>5</td>
<td>3.0</td>
</tr>
<tr>
<td>Swan Hill</td>
<td>Peach &amp;</td>
<td>7</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td>Nectarine (early)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Peach &amp;</td>
<td>5</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td>Nectarine (late)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 9.12 Leaf phosphorous (P) benchmark data for 1997–98 and 1998–99

<table>
<thead>
<tr>
<th>Location</th>
<th>Crop</th>
<th>No. of sites</th>
<th>Leaf phosphorous (P) (%)</th>
<th>1997–98</th>
<th>1998–99</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>average</td>
<td>range</td>
<td>average</td>
</tr>
<tr>
<td>Shepparton</td>
<td>Pear</td>
<td>15</td>
<td>0.12</td>
<td>0.11–0.14</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>Apple</td>
<td>3</td>
<td>0.16</td>
<td>0.13–0.19</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td>Peach</td>
<td>4</td>
<td>0.18</td>
<td>0.15–0.23</td>
<td>0.18</td>
</tr>
<tr>
<td>Cobram</td>
<td>Pear</td>
<td>1</td>
<td>0.12</td>
<td>–</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>Peach</td>
<td>5</td>
<td>0.13</td>
<td>0.11–0.16</td>
<td>0.14</td>
</tr>
<tr>
<td>Swan Hill</td>
<td>Peach &amp; Nectarine (early)</td>
<td>7</td>
<td>0.15</td>
<td>0.14–0.17</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>Peach &amp; Nectarine (late)</td>
<td>5</td>
<td>0.15</td>
<td>0.15–0.17</td>
<td>0.14</td>
</tr>
</tbody>
</table>

Table 9.13 Leaf potassium (K) benchmark data for 1997–98 and 1998–99

<table>
<thead>
<tr>
<th>Location</th>
<th>Crop</th>
<th>No. of sites</th>
<th>Leaf potassium (K) (%)</th>
<th>1997–98</th>
<th>1998–99</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>average</td>
<td>range</td>
<td>average</td>
</tr>
<tr>
<td>Shepparton</td>
<td>Pear</td>
<td>15</td>
<td>2.0</td>
<td>1.5–2.2</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>Apple</td>
<td>3</td>
<td>1.7</td>
<td>1.6–1.8</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>Peach</td>
<td>4</td>
<td>2.7</td>
<td>2.2–3.5</td>
<td>2.2</td>
</tr>
<tr>
<td>Cobram</td>
<td>Pearson</td>
<td>1</td>
<td>2.1</td>
<td>–</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>Peach</td>
<td>5</td>
<td>3.0</td>
<td>2.6–3.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Swan Hill</td>
<td>Peach &amp; Nectarine (early)</td>
<td>7</td>
<td>2.7</td>
<td>1.9–3.1</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td>Peach &amp; Nectarine (late)</td>
<td>5</td>
<td>2.7</td>
<td>2.2–3.2</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Best Practice
Measure efficiency of nitrate application (amount of leaching) using soil water samplers

Refer to end of Chapter 9 Benchmarking and monitoring to determine how to use soil water samplers.

Figure 9.6 shows an example of recording nitrate levels.
Date sample taken
22.12.97       21.1.98

Depth below
Soil surface
30 cm + + + +
60 cm + + + +
90 cm 0 0

Type of fertiliser used : Urea
Method of application : Spreader

Nitrate ppm
5 = -
5 – 250 = +
250 – 500 = ++
> 500 = +++
0 = No sample

Figure 9.6 The application efficiency for the nitrate fertiliser, one grower’s samples

Charts of the same format are attached to record your own data on nitrate presence.

Best Practice
Take soil samples for measurement of soil pH

Refer to the end of this chapter to determine how to sample soil for measurement of pH.

Soil analysis reports from the laboratory will provide pH data.

The tables below show benchmark data for soil pH.

Table 9.14 Soil pH benchmark data (0–25 cm depth) from 40 growers in four regions for 1997–98 and 1998–99

<table>
<thead>
<tr>
<th>Location</th>
<th>No. of sites</th>
<th>Soil pH 0–25 cm depth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>average</td>
<td>range</td>
</tr>
<tr>
<td>Ardmona</td>
<td>8</td>
<td>5.4 4.0–6.3</td>
</tr>
<tr>
<td>Shepparton East</td>
<td>14</td>
<td>5.9 4.7–7.2</td>
</tr>
<tr>
<td>Cobram</td>
<td>6</td>
<td>5.2 4.2–6.4</td>
</tr>
<tr>
<td>Swan Hill</td>
<td>12</td>
<td>7.4 5.9–8.1</td>
</tr>
</tbody>
</table>

Table 9.15 Soil pH benchmark data (25–45 cm depth) from 40 growers in four regions for 1997–98 and 1998–99

<table>
<thead>
<tr>
<th>Location</th>
<th>No. of sites</th>
<th>Soil pH 0–25 cm depth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>average</td>
<td>range</td>
</tr>
<tr>
<td>Ardmona</td>
<td>8</td>
<td>5.7 4.5–6.2</td>
</tr>
<tr>
<td>Shepparton East</td>
<td>14</td>
<td>5.7 4.5–7.0</td>
</tr>
<tr>
<td>Cobram</td>
<td>6</td>
<td>5.6 4.4–6.6</td>
</tr>
<tr>
<td>Swan Hill</td>
<td>12</td>
<td>7.6 6.5–8.1</td>
</tr>
</tbody>
</table>
## Nitrate Sampling Results

### Date sample taken

<table>
<thead>
<tr>
<th>Depth below Soil surface</th>
<th>30 cm</th>
<th>60 cm</th>
<th>90 cm</th>
</tr>
</thead>
</table>

### Type of fertiliser used:

### Method of application:

<table>
<thead>
<tr>
<th>Nitrate ppm</th>
<th>&lt; 5 = -</th>
<th>5 – 250 = +</th>
<th>250 – 500 = ++</th>
<th>&gt; 500 = +++</th>
<th>0 = No sample</th>
</tr>
</thead>
</table>

REMOVE AND COPY TO RECORD YOUR OWN INFORMATION
# Fertiliser Record Sheet

(One block per sheet)

## Block Details

<table>
<thead>
<tr>
<th>Block Name:</th>
<th>Tree Age:</th>
<th>Trees/Ha:</th>
<th>Irrigation System:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year:</th>
<th>Planting Distance:</th>
<th>Trees/Acre:</th>
<th>Fertilisation: Yes or No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Crop Production

<table>
<thead>
<tr>
<th>Bins</th>
<th>Half-Bins</th>
<th>No. of Trees</th>
<th>Tree Spacing</th>
<th>Yield (t/ha)</th>
<th>(t/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Estimated Tree Vigour

(water-shoot growth in the top third of the tree)

- **High**: growth longer than 1 metre
- **Moderate**: growth from 0.5 to 1 metres
- **Low**: growth less than 0.5 metres

## Fertiliser Records

<table>
<thead>
<tr>
<th>Date</th>
<th>Fertiliser</th>
<th>Amount of Fertiliser</th>
<th>Units of Nutrient</th>
<th>How Applied</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>kg/ha</td>
<td>kg/tree</td>
<td>Units of N</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Date

<table>
<thead>
<tr>
<th>Gypsum or Lime</th>
<th>Amount</th>
<th>How Applied</th>
</tr>
</thead>
<tbody>
<tr>
<td>kg/ha</td>
<td>kg/tree</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

REMOVE AND COPY TO RECORD YOUR OWN INFORMATION
6. Soil management

Best Practice
Ensure adequate surface drainage (eg hilling and/or laser grading inter-rows)

Refer to Chapter 8 of this guide for more information on drainage.

Best Practice
Incorporate a surface mulch where appropriate

Refer to Chapter 8 of this guide for more information on benefits of mulch.

Best Practice
Check crusting of soil and water infiltration

Refer to Chapter 8 of this guide for more information on soil properties

Best Practice
Record the amount of and timing of any gypsum or lime applied (gypsum for soil structure problems and lime for pH problems)

Record your own data of when and how much gypsum and lime were applied on the ‘fertiliser record sheet’ at the end of Section 5.
Installation and Monitoring of Testwells

Installation and Siting of Testwells

Water tables in any area can be highly variable because they are affected by soil type, rainfall, topography, land use and irrigation. Testwells can be located:

a) In problem drainage areas
b) On different soil types over the farm
c) Where salinity or waterlogging is becoming evident
d) In between or above tile drainage lines
e) Lowest parts of the orchard
f) In areas where channel seepage may be evident

From Punnett (1996)

In an orchard, testwells have a number of roles. These include testing irrigation efficiency, assisting with irrigation scheduling and identifying problem drainage areas. In these cases, testwells should be situated within the tree row. They should be positioned to ensure no damage from orchard traffic.

Testwells can also be used to manage tile drains and help determine when to turn off tile drainage pumps. In addition, a sample of water can be taken from the test well and the amount of salts measured. As the water table depth fluctuates salts can be left in the rootzone. These salts have the potential to cause harm to horticultural crops. The measurement of water table depth and salinity can help determine areas where there may be a potential salinity problem.

Testwells can be easily made as described in the diagram above and installed at appropriate sites in the orchard. It is important to note that a bore construction licence is required if you are putting down a deep bore to extract groundwater. However, it is not required when constructing a shallow (less than 3 m deep) testwell.

Monitoring Testwells

Water table depths in irrigation areas normally fall over summer and rise during wet autumn, winter and spring periods. To appreciate changes in water table depths over a year, it is important to take monthly measurements. Measurements should be taken just before an irrigation cycle commences to reduce the risk of irrigation water seeping into the testwell and distorting the reading. The following steps are recommended:

(a) Set a regular time of the month to monitor the testwells (being aware of irrigation events). If the testwell is dry, then the watertable is obviously deeper than 2.8 m.

(b) If water samples are being collected to measure salinity, the testwells should be bailed beforehand. Irrigation water and rainfall, along with groundwater that has concentrated in the testwell, can significantly alter the salinity level of the groundwater.

To gather a fresh sample, remove all groundwater from the testwell using a bailer. Allow 4 days for the water in the testwell to return to its static level, before measuring the depth of the water table and taking a water sample.

(c) Note the water table level reading and the groundwater salinity on a data sheet (or in your Watertable Watch record book) for later reference. These record books are available free of charge from Agriculture Victoria, Tatura.
Soil and Water Salinity Monitoring

**Salinity Units**

Salinity is measured as the ability of soil or water to transfer an electric current and often referred to as Electrical Conductivity or EC. EC readings increase as salinity levels increase.

- **Units For Water Salinity**: MicroSiemens per centimetre (μS/cm). This is most commonly used for water. It is commonly referred to as EC or EC units.
- **Units For Soil Salinity**: DeciSiemens per metre (dS/m). This is the standard unit of electrical conductivity, used mainly for soil salinity measurements.

These can be converted easily by remembering that 1,000 μS/cm = 1 dS/m.
The old units for EC were ppm and the conversion is 1 dS/m = 640 ppm.

**Testing For Water Salinity**

Testing the salinity of groundwater in testwells can indicate how saline the surface soil may become if the watertable rises to within 1 m of the soil surface. Testing surface water will indicate how suitable it is for irrigation. Testing the salinity of groundwater (pumped from an aquifer) and drainage water will also show whether these sources may be suitable for irrigation after dilution (shandying). The amount of dilution required depends on factors such as soil type and crop grown.

When testing a water sample, fully immerse the end of the meter in the sample. If the salinity is out of the range of the meter, samples can be diluted by a specified amount of rain water. For example, mixing a sample with an equal volume of rainwater will halve the salinity, so the measurement will have to be doubled to determine the true salinity of the sample. Record your readings.

**Testing For Soil Salinity**

**Collecting Soil Samples**

Ideally, soil samples should be taken during the period of highest soil salinity (i.e. at the end of the irrigation season). This will give an indication of the worst salt conditions that an orchard experiences. A sample at the beginning of the irrigation season will indicate the amount of leaching from winter rains.

Use an auger to take samples from “zones” within your orchard. A zone is an area with similar texture (sand, silt, clay) and likelihood of being affected by salinity. Samples should be collected from 5-10 different sites in each zone. Always take samples from the same depths and at the same time of year so that readings can be compared with future tests. Common depth intervals used are:

- 0.10 - 0.30 m
- 0.30 - 0.60 m
- 0.60 - 0.90 m
- 0.90 - 1.20 m

The depth of sampling can be partly decided upon by the depth of the active root zone. Once you have selected your zones, auger a hole down to the desired depth. Place soil from each depth interval into a separate numbered bag (for example, Site 1 0.10-0.30 m, etc.). Mark the location of all samples taken on a rough map, identified by the site number on the bag.

**Doing Your Own Soil Salinity Tests**

You can now either send your samples to a laboratory, or do the simple field measurement described below, using a salinity meter. To do a field salinity test using the standard EC15 (1 part soil : 5 parts water) method, you will need a 140 ml (or larger) screw top container.
(a) Break up any clods in your sample into small particles. If possible, dry and crush the soil first, but this is not essential.

(b) Fill the lid of your container with soil from your sample. Once this is level with the rim of the lid, tip it into your container.

(c) Take 5 lides full of rainwater and add this to the container. It is important to test the rainwater with your salinity meter first to make sure it is "fresh" (less than 100 μS/cm or EC).

(d) Place the lid on your container and shake for at least 2 minutes to make sure the salts from the soil dissolve in the water. If you have more time, leave the container for 1 hour before shaking again. This may bring more salt into solution.

(e) Let it stand for 5 minutes.

(f) Take a reading with a salinity meter. Place the electrodes of the meter in the muddy water (not the soil resting on the bottom).

(g) Wash the electrodes (bottom) of the salinity meter and the container out between tests with rainwater.

(h) Record your salinity results. Turn the meter off when you have finished testing.

**INTERPRETING SOIL SALINITY RESULTS**

The most common and simplest test carried out on soil is the Electrical Conductivity of a soil:water mix, consisting of one part soil to five parts water. This is referred to as EC<sub>15</sub>. However, EC<sub>15</sub> readings are not a true representation of the salinity around a plant's roots. The salinity measurement used for this is referred to as the Electrical Conductivity of a soil saturation extract (EC<sub>e</sub>) and is used to relate soil salinity directly to plant growth.

To interpret what the soil salinity readings mean, it is necessary to convert the EC<sub>15</sub> reading you have just done to an EC<sub>e</sub> reading, by taking into account soil texture. The following table gives the multiplication factor that needs to be used to convert your EC<sub>15</sub> reading into EC<sub>e</sub>. This method of predicting EC<sub>e</sub> is not as accurate as a laboratory analysis. To find out the texture of the soil you are testing, take a handful of the soil left in your bag and moisten it with water until you have a ball of soil in your hand that is moist all the way through, but just fails to stick to your fingers. It should not be saturated. Try rolling the ball into a thin thread and then flatten it into a ribbon by pushing it out between your thumb and forefinger.

<table>
<thead>
<tr>
<th>Soil Texture Group</th>
<th>Multiplication Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandy loams</td>
<td>14</td>
</tr>
<tr>
<td>Loamy loams</td>
<td>10</td>
</tr>
<tr>
<td>Light clays</td>
<td>8</td>
</tr>
<tr>
<td>Heavy clays</td>
<td>6</td>
</tr>
</tbody>
</table>

*Sandy loams have some coherence and can be rolled into a stable ball, but not to a thread. Sand grains can be felt between your fingers.

Loamy loams can be rolled into a thick thread, but this will break or crack before it is 3-4 mm thick. The soil ball is easy to roll and has a smooth spongy feel with no obvious sandiness.

Light clays can be rolled into a thread 3-4 mm thick without cracking. It bends easily (i.e. is flexible), feels smooth with some resistance to rolling out. Ribbons to about 70 mm between your thumb and forefinger.

Heavy clays can be rolled to a thread 3-4 mm thick and formed into a ring in the palm of the hand without cracking. These soils are smooth and very flexible with a moderate to strong resistance to rolling out.*

Above: Soil texture groups and associated multiplication factors for converting EC<sub>15</sub> readings to EC<sub>e</sub> readings. For example, if the soil you are working with is a light clay with an EC<sub>15</sub> reading of 0.5 dS/m, multiply the 0.5 by 8. The resulting figure of 4 dS/m is the EC<sub>e</sub> reading for the soil sample.
Soil Water samplers, also known as “suction tubes” and “ceramic samplers” have been used to monitor nutrient leaching in recent years in the Swan Hill, Sunraysia and Shepparton areas, but also offer a simple method to measure soil salinity. Water is collected from the soil and the electrical conductivity (EC) can then be measured. The EC of this water relates to the soil salinity level.

Soil water samples can be extracted directly, enabling on-site measurement of their salt or nitrate concentration without delay. Also, samples can be extracted at a fixed position within the soil and with minimal interference to it. This enables repeated sampling at one spot and provides confidence that trends of soil salinity and nitrate are not due to variation of sampling at different spots.

**Soil Water Samplers**

Soil water samplers consist of:
- a porous ceramic tip buried in the soil
- a microtube glued into the tip
- a needle inserted into the top end of the microtube
- a syringe to apply suction and collect the sample
- Quad section blocks to maintain suction.

**Soil Water Sampler**

The ceramic tip’s permeability to water and the contact between the tip and the soil are critical; the contact influences the rate at which the samples can be extracted. Surrounding the tip with a slurry of silica improves this contact and the sampler reliability. Many types of ceramic tips are available, but the most common types used are the “filter tube” and the “tensiometer tip”. Tensiometer tips are a little more expensive, but are preferred because they are simpler, more robust and collect soil water more effectively. Syringes and microtubes are very cheap and apply suction to the inside of the ceramic tip very effectively.
Installing Water Samplers
The most important things to ensure when installing a soil water sampler are:
• placement of the tip at a representative position
• minimal interference with the soil
• no preferential flow down the auger hole
• good contact between the soil and the tip
• prevention of “sealing” of the tip surface.

Where should Water Samplers be installed?
At each monitoring site, it is critical to ensure that sampler tips are placed at representative positions in the rootzone. Initially, we recommend the installation of samplers at two depths at each monitoring site. Both tips should be installed in the part of the soil which is regularly wetted by the irrigation system. One should be at a depth midway down the rootzone and the other should be close to the bottom.

When should samples be taken?
Soil water salinity increases as the soil dries. If we want to collect samples that have the same salinity as the water we would extract from a saturated paste, we should apply suction while the orchard soil is saturated (that is while the tensiometer reads zero – no suction). An ideal time to sample is from approximately four hours after the end of the irrigation until a sufficient sample to measure has been collected (before the tensiometer needle has reached 3 kPa). Sampling earlier can result in an underestimation of soil salinity, because it takes time for salts to dissolve evenly through the increased volume of water in the soil. Sampling later may make it difficult to get an adequate sample in some soils. Nitrate sampling can be undertaken at the same time.

How can the salinity of the sample be measured?
The salinity of the soil water samples can be measured with a portable EC meter, while Nitrate test strips are used to measure the nitrate levels of the water.

How can the information be used?
Soil samplers can be used to detect trends in the salinity and nutrient status of the orchard soil. Detection of nitrate leaching is also extremely valuable. Further work still needs to be done to relate absolute values from the soil water samplers to effects on production.
Leaf Analysis – Sampling Procedure

The following is the recommended procedure for collecting a representative sample of leaves for analysis.

1. Sample anytime from mid January to the end of February.
2. Collect one leaf from the mid-shoot position on this season's new lateral growth. Do not collect any spur leaves or leaves without water shoots.
3. Collect 4 mid-shoot leaves from around the outside of 25 trees at approximately shoulder height. This means 100 leaves are collected per block. Samples should be taken from trees evenly spaced within the block, from trees on the same soil type, the same irrigation and management inputs, the same age and variety.
4. Collect healthy leaves. Do not collect any leaves that are damaged, covered in dust or have mite burn.
5. Wear a plastic glove when collecting samples to prevent contamination of the leaves by sweaty hands (salt).
6. Collect leaves in a paper bag and label with name, address, and block sampled.
7. Keep samples cool and send immediately to laboratory. Leaves deteriorate after picking and tests are usually lower for nitrogen if leaves are not kept cool and dried within 24 to 48 hours.
8. Record previous fertiliser applications, tree vigour, crop load and fruit size to help interpret analysis results.

NOTE:
- For high density trellis blocks take one leaf per tree and sample 100 trees, samples should be taken from alternate sides in the tree row. Samples should be taken from trees evenly spread within the block.
- Some companies will provide a self-contained kit with instructions.
Recommended Soil Sampling Procedures

pH
1. Sample every 3–5 years or before replanting
2. Remove leaf litter and topsoil to 2 cm
3. Sample to a depth of 15 cm on 20 sites in the orchard
4. Mix soil samples together from the 20 sites and collect a subsample of 500 gms
5. Send to laboratory for testing
6. Record results – check against recommended pH
7. Decide on action – more lime?

Salinity
1. Soil sample if you suspect a problem
2. Take a soil sample at the end of the irrigation season (this will be when highest salt levels)
3. Take samples from particular zones – obvious problem areas
4. Take from 10 different sites to a variety of depths in the shed
5. Mix same depth samples together and send subsample of 100 gms to the lab
6. Record results and compare with EC standards
7. Decide on management – leaching, better drainage, less corrugation.

Soil pH and Soil Tests
Soil analyses are mainly used to measure soil acidity or alkalinity (pH), salinity (Na and Cl) and gypsum requirement. A soil analysis is also useful to determine how much P and if needed, how much K is available in the topsoil. Soil pH is expressed as either pH (CaCl₂) or pH (water):
• pH (water) means that the soil pH was measured in 1 part soil to 5 parts water.
• pH (CaCl₂) means that the soil pH was measured in a standard calcium chloride (CaCl₂) solution.
This measure has reduced variability due to salinity compared to soil pH (water) measurements.
Soil pH has a large influence on soil nutrient availability to the tree. For pears the soil pH should be between 5 and 6 (CaCl₂) and should be checked every 3 to 5 years.

If you want to check the soil pH in your orchard, only take soil samples where the N and irrigation has been applied. Always remove the top 2 cm of leaf litter and soil (especially if lime has been applied in the past 5 years) and sample to a depth of 15 cm on 20 sites in the orchard. Mix the soil samples from the 20 sites and send a sub-sample of 500 g to the laboratory for analysis. When replanting, this is best done just before tree removal after harvest.

Before Replanting
Before replanting, check the soil pH in the topsoil. If it is low or if no lime has been applied for several years, a subsoil pH check at 15 to 30 cm, and at 30 to 45 cm should be included.

Other Soil Tests for Replant Sites
– Gypsum requirement in subsoil only
– Nutrients in topsoil (P)
– pH in topsoil and subsoil.
NITROGEN APPLICATION GUIDE

Developed for Pome and Stone Fruit Orchards in the Goulburn-Murray Valley

To use this chart work through each of the following steps:

1. Choose an appropriate form of nitrogen for your soil pH. There are four main forms of nitrogen: (i) Ammonium i.e. ammonium sulphate, (ii) Urea (iii) Mixed i.e. ammonium nitrate and (iv) Organic i.e. animal manure

Your Soil pH Range

<table>
<thead>
<tr>
<th>Suitable Forms of Nitrogen for the pH Ranges shown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkaline Soil pH (&gt;6.5 in CaCO₃)</td>
</tr>
<tr>
<td>- Ammonium, urea, mixed, nitrate, organic sources.</td>
</tr>
<tr>
<td>Good Soil pH (5.0-6.5 in CaCO₃)</td>
</tr>
<tr>
<td>- Urea, ammonium, nitrate, mixed, organic sources. (Avoid fertilizers containing nitrogen as ammonium only*)</td>
</tr>
<tr>
<td>Acid Soil pH (4.0-5.0 in CaCO₃)</td>
</tr>
<tr>
<td>- Nitrate based fertilizers only. (Avoid fertilizers containing nitrogen as ammonium only*)</td>
</tr>
<tr>
<td>Strongly Acid Soil pH (&lt;4.2 in CaCO₃)</td>
</tr>
<tr>
<td>- Fertilizers that contain ammonium only will not be used if soil pH is less than 5.0 unit. See Table 2 below</td>
</tr>
</tbody>
</table>

2. Select a fertiliser that contains an appropriate form of nitrogen for your soil pH and that suits your application technique, i.e. broadcast or fertigation. Take into account the effect of the fertiliser on soil pH. Be aware of the % nitrogen content when comparing fertiliser costs and when determining application rates.

<table>
<thead>
<tr>
<th>Fertiliser</th>
<th>Nitrogen Content</th>
<th>%</th>
<th>Effect on soil pH</th>
<th>Solubility in water</th>
<th>Suitability for fertigation</th>
<th>Suitability for broadcast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium Sulphate</td>
<td>21</td>
<td>Lowers</td>
<td>Strongly lowers</td>
<td>High</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>NPK (containing ammonium sulphate)</td>
<td>20</td>
<td>Lowers</td>
<td>Strongly lowers</td>
<td>Partial</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>MAP (monosodium phosphate)</td>
<td>18</td>
<td>Lowers</td>
<td>Strongly lowers</td>
<td>Partial</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Urea</td>
<td>46</td>
<td>No effect</td>
<td>Lowers</td>
<td>High</td>
<td>✗</td>
<td>✗ (water in)</td>
</tr>
<tr>
<td>Ammonium Nitrate</td>
<td>34</td>
<td>No effect</td>
<td>Lowers</td>
<td>High</td>
<td>✗</td>
<td>✗ (water in)</td>
</tr>
<tr>
<td>NPK (containing urea)</td>
<td>27</td>
<td>No effect</td>
<td>Lowers</td>
<td>Partial</td>
<td>✗</td>
<td>✗ (water in)</td>
</tr>
<tr>
<td>Calcium Ammonium Nitrate (CAN)</td>
<td>16</td>
<td>No effect</td>
<td>Lowers</td>
<td>Partial</td>
<td>✗</td>
<td>✗ (water in)</td>
</tr>
<tr>
<td>Nitrate</td>
<td>16</td>
<td>Increases</td>
<td>Slight increase</td>
<td>High</td>
<td>✗</td>
<td>✗ (costly)</td>
</tr>
<tr>
<td>Potassium Nitrate</td>
<td>16</td>
<td>Increases</td>
<td>Slight increase</td>
<td>High</td>
<td>✗</td>
<td>✗ (costly)</td>
</tr>
<tr>
<td>Organic</td>
<td>4</td>
<td>No effect*</td>
<td>Lowers</td>
<td>Low</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Manures (dried/poached)</td>
<td>4</td>
<td>No effect*</td>
<td>Lowers</td>
<td>Low</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Composted manures</td>
<td>4</td>
<td>No effect*</td>
<td>Lowers</td>
<td>Low</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Blood and Bone</td>
<td>4</td>
<td>No effect</td>
<td>Lowers</td>
<td>Low</td>
<td>✗</td>
<td>✗</td>
</tr>
</tbody>
</table>

* Efficient use if all applied nitrogen is taken up by roots. Urea is a poor choice for fertigation. See Table 3 below. May induce stress on plants. ✗ Factor: strongly indicates

3. Apply fertiliser as efficiently as possible by careful application, determining the correct rate and by careful irrigation with the correct runtime for your soil and irrigation system.

What is Efficient Fertiliser Usage?

The proportion of applied fertiliser taken up by fruit trees is typically low (i.e. 30%), which is not very efficient. Nitrogen fertiliser can be lost by leaching due to heavy rainfall or poor irrigation management. Losses can also occur as gas and this is increased by waterlogging or failure to water fertiliser into the soil. Fertiliser uptake can be improved (i.e. made more efficient) by careful timing to meet tree demand. Careful fertiliser application techniques, splitting larger fertiliser applications and good irrigation management are all important to maximise root uptake of fertiliser. The “Efficient” and “Inefficient” headings in Table 2 above give the best and worst possible effects of each fertiliser on soil pH. The best case is 100% efficient where all fertiliser is taken up by the tree. The worst case is 0% efficiency where there is no tree uptake and all fertiliser is leached.

Hints on Efficient Nitrogen Application Techniques

- Microjet or drip: - Fertigation: - apply in the last hour of a normal irrigation or in a short special run (1-2 hours) a day after an irrigation. Timing: Spread fertiliser a day or two after an irrigation and irrigate it for 2 hours.
- Sprinkler: - Timing: spread and irrigate for 2 hours. Fertigation: - apply in the last 2 hours of an irrigation or in a short special run 2 days after an irrigation.
- Flood or furrow: - Timing: spread and irrigate or spread and cultivate.
- Rainfall: - Choose the form of fertiliser carefully (avoid urea) and apply just before rainfall is forecast and at the correct time of year. * (days sufficient for fertilizer to take from roots before ending the irrigation)

Avoiding Fertiliser and Nutrient Leaching

Urea and nitrate are mobile in the soil and are easily lost by leaching down past the roots with excessive irrigation or rainfall. Ammonium, potassium and phosphorus are less mobile and are not as easily leached.

Check Your Irrigation Management

Your normal irrigation runtimes should suit the rootzone only. Excessive runtimes will leach fertiliser and nutrients past the rootzone and cause soil acidity (low soil pH). Nutrients such as nitrate are continually released in the soil and are prone to leaching by long irrigation runtimes. Determine your maximum irrigation runtime and then vary the interval between irrigations to maintain optimal soil moisture. However, if saline irrigation water is applied, some controlled leaching could be required to prevent salt accumulation in the rootzone.

4. Check the time required for fertiliser to become fully available to the tree. The majority of nitrogen is taken up by tree roots as nitrate. Most fertilisers require a period of breakdown before all of the nitrogen is released as nitrate.

- Ammonium
- Urea
- Nitrate
- Organic nitrogen

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## Best Management Practices

### Shoot Growth

<table>
<thead>
<tr>
<th>MONTH</th>
<th>JUL</th>
<th>AUG</th>
<th>SEP</th>
<th>OCT</th>
<th>NOV</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHOOT GROWTH</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bud burst</td>
<td>Lateral shoot growth</td>
<td>Spring root growth</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Fruit Growth Cycle (WBC & Packhams)

<table>
<thead>
<tr>
<th>MONTH</th>
<th>JUL</th>
<th>AUG</th>
<th>SEP</th>
<th>OCT</th>
<th>NOV</th>
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<tbody>
<tr>
<td>FRUIT GROWTH CYCLE</td>
<td></td>
<td></td>
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<tr>
<td>Cell division this is the period when cells are formed to become fruit cells</td>
<td></td>
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</table>

### Nitrogen Story in Trees and Soil

<table>
<thead>
<tr>
<th>MONTH</th>
<th>JUL</th>
<th>AUG</th>
<th>SEP</th>
<th>OCT</th>
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<tbody>
<tr>
<td>WEEK No.</td>
<td>1 2 3 4</td>
<td>1 2 3 4</td>
<td>1 2 3 4</td>
<td>1 2 3 4</td>
<td>1 2 3 4</td>
</tr>
<tr>
<td>NITROGEN STORY IN TREES AND SOIL</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Heavy winter/spring rain is likely to leach nitrogen</td>
<td>Trap nitrogen in grass</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Root growth starts from stored nitrogen</td>
<td>Flowering and shoot growth from stored nitrogen</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil nitrogen at its highest</td>
<td></td>
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</tbody>
</table>

### Orchard Management

<table>
<thead>
<tr>
<th>MONTH</th>
<th>JUL</th>
<th>AUG</th>
<th>SEP</th>
<th>OCT</th>
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<tbody>
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<td>WEEK No.</td>
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<td>1 2 3 4</td>
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<td>1 2 3 4</td>
<td>1 2 3 4</td>
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<tr>
<td>ORCHARD MANAGEMENT</td>
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<tr>
<td>Pruning</td>
<td>Frost control (e.g., close mowing and spray tree lines)</td>
<td></td>
<td></td>
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<tr>
<td>Integrated Pest Management</td>
<td></td>
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</tbody>
</table>

### Nitrogen Fertiliser Application

<table>
<thead>
<tr>
<th>MONTH</th>
<th>JUL</th>
<th>AUG</th>
<th>SEP</th>
<th>OCT</th>
<th>NOV</th>
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<tbody>
<tr>
<td>WEEK No.</td>
<td>1 2 3 4</td>
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<tr>
<td>NITROGEN FERTILISER APPLICATION</td>
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<tr>
<td>Apply nitrogen - up to 50 kg/ha if necessary. Depends on vigour last season</td>
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### Irrigation Management

<table>
<thead>
<tr>
<th>MONTH</th>
<th>JUL</th>
<th>AUG</th>
<th>SEP</th>
<th>OCT</th>
<th>NOV</th>
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<tbody>
<tr>
<td>WEEK No.</td>
<td>1 2 3 4</td>
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<tr>
<td>IRRIGATION MANAGEMENT</td>
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<tr>
<td>Usually sufficient soil moisture from winter rainfall</td>
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**Natural Resources and Environment**

**Agriculture • Resources • Conservation • Land Management**
## PRACTICES - PEARS

<table>
<thead>
<tr>
<th>DEC</th>
<th>JAN</th>
<th>FEB</th>
<th>MAR</th>
<th>APR</th>
<th>MAY</th>
<th>JUN</th>
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<tr>
<td>Full leaf cover</td>
<td>No new leaf growth</td>
<td>Leaf fall</td>
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**Carotenogenesis** (this is the period when the cells fill up with water and sugar)
- **WEC - Harvest**
- **Packham - Harvest**

### Days after full bloom
- 0-60: Growth and development
- 60-120: Flowering

### DEC - JUN

#### Roots
- Roots can take up soil-applied nitrogen throughout this time.

#### Soil Nitrogen
- Soil applied nitrogen will move into leaves and buds.
- Soil nitrogen stored in roots.

#### Nitrogen Transfer
- Trap nitrogen in grass.
- Nitrogen moves from leaves to be stored in buds, bark, and roots.

#### Summer Pruning
- If more light needed into tree.

#### Management (IPM) Monitoring
- Leaf sampling
- Interpret leaf test results and plan fertiliser program.

#### Organic Matter Breakdown
- Organic matter breaks down into tree - usable nitrogen.

#### Supplement Nitrogen
- Supplement nitrogen (low biuret) foliar urea @ 4% if vigour is low or if leaf test N is very low.
- Apply nitrogen (50-100 kg/ha) rate depends on vigour, crop, and soil fertility.

#### Irrigation
- Maintain full irrigation - **Critical** for fruit setting.
- Reduced water demand after harvest.

#### Period
- Maintain full irrigation - **Critical** for fruit setting.
- Reduced water demand after harvest.
## Toolbox

### Conversions

#### AREA:
- 1 hectare (ha) = 10,000 square metres (m²)
- 1 hectare = 2.5 acres

#### VOLUME:
- 1 acre foot = 1.23 ML
- 1 cubic metre (m³) = 1,000 litres
- 1 Megalitre (ml) = 1,000,000 litres

#### SOIL MOISTURE CONTENT:
- 1% = 10 litres per cubic metre
- 1% = 10 millimetres per metre soil depth

#### SOIL MOISTURE TENSION:
- 100 kPa = 1 bar = 100 centibars

#### EVAPORATION:
- 1 millimetre (mm) = 1 litre per square metre (L/m²)
- 100 millimetres = 1 Megalitre per hectare (ML/ha)
- 1 inch = 25.4 mm
Glossary

Available soil moisture (%)  
The total amount of soil water available to trees between field capacity and permanent wilting point.

Clay  
A soil in which clay particles (ie. particles less than 0.002 mm in diameter) constitute more than 30% of the mass. Clay soils feel very sticky when wet.

Crop Coefficient (Kc)  
The proportion of water used by a orchard in relation to evapotranspiration from a reference grass crop.

Crop Factor (CF)  
The proportion of water used by an orchard in relation to a US Class A pan evaporimeter.

Distribution uniformity (DU)  
A measure of how water is distributed from a pattern of sprinklers. It is written as a percentage and the higher the percentage the more uniform the water distribution is.

Drippers  
A common name for emitters used in trickle irrigation.

Electrical conductivity (EC)  
A measure of salinity based on the capacity of a solution to conduct an electric current.

Emitters  
Microjet, dripper or knocker sprinkler heads that control the distribution and application rate of irrigation.

Evaporation pan (Epan)  
An instrument for measuring evaporation from an open surface of water. Dimensions should be equivalent to the standard US Class A pan evaporimeter.

Field capacity  
In soils, field capacity is the point when drainage stops and the soil is holding all the water it can. This is approximately – 8 kPa in most soils in the Goulburn Valley.

Flow Rate  
The amount of water that an irrigation system puts out over time, for example 35 L/hr.

Leaching  
The downward movement in soil of soluble minerals and chemicals with water.

Loam  
A soil that contains about 60% sand, 20% silt (ie. particles between 0.002 and 0.02 mm diameter) and 20% clay. Loam soils feel smooth and spongy when rolled into a ball.

Microjets  
Generally, spray outlets with no moving parts where the shape of the microjet (or a secondary series of holes) is used to spread water from a central orifice.

Minisprinklers  
Miniature sprinklers with small orifices that allow for discharge rates less than normal sprinklers.

Permanent wilting point  
Soil water content when plants cannot extract any more water and will be severely damaged. Occurs at a soil moisture tension of 1500 kPa.
**pH**
Decreasing values of pH correspond to increasing acidity.

**Planting area**
A term used to define the area of land a tree is planted on, and is obtained by multiplying the row spacing by the tree spacing along the tree-line (for example, the allotted area for a tree planted at 6 m x 6 m = 36 m$^2$). The term is used for converting millimetres to litres (for example, 1 mm of evaporation over 36 m$^2$ = 36 L of evaporation).

**Planting square**
The allotted area of one tree; calculated as the tree spacing (m) multiplied by the row spacing (m).

**Readily Available Water (RAW)**
The amount of water available in soils between field capacity and a minimal or no stress situation.

**Reference crop evapotranspiration ($ET_o$)**
Calculated water use for a reference grass crop from solar radiation, wind speed, humidity and temperature.

**Regulated Deficit Irrigation (RDI)**
An irrigation strategy to manipulate yield, quality and vegetative growth with water stress. In stone and pome fruit the aim is to reduce vegetative vigour and increasing yield.

**Saline water**
Water with harmful levels of dissolved salts (sodium chloride).

**Sand**
A soil in which sand particles (i.e. particles greater than 0.02 mm in diameter) constitute more than 75% of the mass. Sandy soils never feel sticky when wet and cannot be rolled into a stable ball.

**Saturation**
Water content of a soil when all the pores are filled with water.

**Soil horizons**
A term used to describe the different layers of soil across a vertical soil profile.

**Soil pit**
A pit excavated with a backhoe, approximately 1.5 metres (4'11") deep, 2 metres (6'6") long and 80 – 90 cm (3') wide. Used to assess amount of water held in the rootzone.

**Soil texture**
Refers to the amount of clay, silt and sand in a soil. A light-textured soil is high in sand, whereas a heavy textured soil is high in clay.

**Soil water content**
A volumetric measure of how much water is in the soil. Usually expressed as a percentage of the soil volume. For example, 8% is equivalent to 80 L of water per cubic metre of soil.

**Soil moisture (water) tension**
The tension at which water is held to the soil particles. The drier the soil, the greater the soil water tension. Tension is equivalent to the pressure needed to force water from the soil. Plants roots must exert suction on the soil, equivalent to this pressure, to extract water from the soil, so the term is commonly used to describe the dryness or wetness of soil.

**Water holding capacity**
The total amount of water that a soil can hold from saturation to complete dryness.

**Water stress**
Physiological response of plants to a limitation in the supply of water.
3. References and further reading

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