NSW DEPARTMENT OF
PRIMARY INDUSTRIES

Growing lemons in Australia- a production manual - Readers' Note

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

http://www.dpi.nsw.gov.au/agriculture/horticulture/citrus/lemon-manual

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8. Irrigation

INTRODUCTION

Citrus trees are evergreen and require water throughout the year. Mature citrus trees can use between 800-1500 mm of water per year depending on rainfall and irrigation management. In general citrus trees have some ability to withstand water shortages and their thick leaves (especially older leaves), low number of stomata on leaves, and waxy fruit help conserve water.

Various cultural practices also impact on plant water use and irrigation. Although cover crops or interrow sods compete for water they also reduce evaporation and runoff, improve water infiltration, soil structure and soil health. The use of mulch improves water infiltration, soil structure and water holding capacity and reduces evaporation and runoff. Controlling weeds reduces competition for water and skirting trees helps improve sprinkler irrigation distribution and allows for easier maintenance of irrigation systems.

Photo by Greg Moulds

Young trees with a single dripper line

There is very little information specific to the irrigation of lemons so the following is general information for citrus. It is recommended that your irrigation system be designed and installed by a qualified irrigation specialist. To learn more about irrigation you could also attend one of the accredited irrigation courses available, such as Waterwise on the Farm.

IRRIGATION MANAGEMENT

Good irrigation management requires information about:

- Crop water requirements
- Rootzone depth
- Soil characteristics
- Water quality

The benefits of good irrigation practices and an efficient irrigation system include:

- ☑ long term productivity;
- ☑ increased production per megalitre;
- ☑ improved water use efficiency;
- ☑ reduced production costs;
- ☑ reduced runoff and subsurface drainage losses;
- ☑ applies water evenly, at a rate that is less than the infiltration rate of the soil;
- ☑ matches the climate and crop requirements;
- ☑ is compatible with the physical and topographic conditions of the area;
- ☑ is compatible with the management operations of the orchard.

CROP WATER REQUIREMENTS

Water is transported throughout the tree almost continuously from the soil to the roots, then into the various plant parts and finally into the leaves where it is released into the atmosphere as water vapour (transpiration) during daily cycles of photosynthesis. Water is needed for photosynthesis, nutrient acquisition and uptake. It is crucial for successful bud initiation, flowering, fruit set and fruit growth. Water use is highest in the warmer months between October and March and lowest in the winter during June and July. Leaf stomata open in the early morning and peak water demand is usually in the early afternoon.

Crop water use is affected by many factors. These include:

- ***crop conditions***- variety, rootstock, root depth, tree age, tree size, growth stage and crop load;
- ***soil conditions***- texture, rootzone depth, water content and availability, infiltration rate and water holding capacity;
- ***climatic conditons***- temperature, rainfall, solar radiation, evaporation, humidity and wind.

A knowledge of the various stages of growth in citrus is important for irrigation management.Trees go through a number of growth stages throughout the year. The timing and length of each stage depends largely on the climatic conditions of the growing region.

The key stages include:

- bud formation and flower initiation (mid-late winter)
- flowering and fruit set (early spring)
- fruit growth - cell division (late spring-early summer)
- fruit growth - cell expansion (mid summer- autumn)
- fruit maturation (late autumn-winter)

The most critical times to avoid water stress are at flowering and fruit set and during the early cell expansion stage of fruit growth (September to February). Avoiding water stress during these critical growth stages maximises fruit set and fruit size. At less critical times the amount and frequency of irrigation can be reduced without significantly impacting on yield or tree health.

ROOTZONE DEPTH

Seventy-five percent of citrus tree roots are concentrated in the top 45-60cms of the soil, but there can be roots down to 1.5m depending on soil type. When irrigating you need to apply water to the majority of the rootzone for optimum production. Rootzone depth is used to calculate the volume of water that needs to be applied. Volume (ML) = rootzone depth (mm) x area (ha).

In dry arid regions where rainfall is limited, the tree roots tend to be concentrated in the area where the irrigation water is applied. In the more humid subtropical regions with higher rainfall the tree roots are more widespread.

Depth of the rootzone can also be influenced by rootstock choice. Rough lemon is generally more deep rooted and subsequently more drought tolerant then *P. trifoliata* and the citrange rootocks.

Soil temperature, oxygen levels, and the presence of pest and disease pathogens also have an important effect on root function. Low ($<7^{0}$C) and high ($>30^{0}$C) soil temperatures and low oxygen levels can slow or stop the roots functioning, preventing them from taking up water and nutrients from the soil. Pest and disease pathogens reduce root performance by damaging or killing feeder roots.

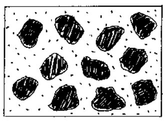
SOIL CHARACTERISTICS

Lemons grow best in soils with good drainage, such as sandy loams and clay loams. The soil type and its condition determines:

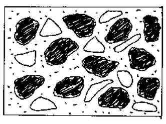
- how water moves through the soil (permeability, infiltration rate and drainage);
- water-holding capacity (how much water it will hold and for how long);
- rooting depth (how deep to water).

The soil is made up of particles of sand, silt, clay and organic matter and the pore spaces between them. The type and amount of these particles determine the soil type. Information on soil type and structure is critical to irrigation management.

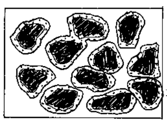
Soil Water: Soil water is held in the pore spaces and is attached to the soil particles. When all the pore spaces in the soil are filled with water, the soil is said to be saturated. As the plant takes up water and the soil dries, the water in the large pore spaces is the first to be used, followed by the water in the smaller pore spaces. The water closely attached to the soil particles is held with such force that the plant roots cannot extract it.



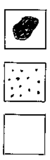
Saturated soil - all the pore spaces are filled with water.



Soil at Field capacity - there is a good balance of air and water in pore spaces.



Soil at Wilting Point - the only water in the soil is held tightly around soil particles and is not able to be taken up by plant roots.



Soil particles

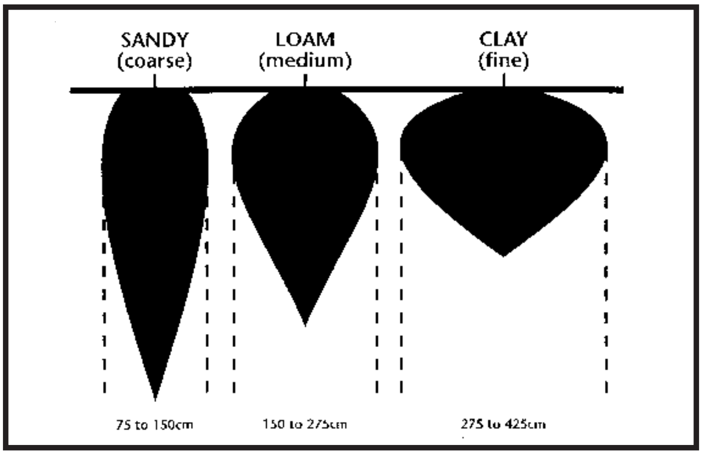
Water

Air

Infiltration: The downward movement of water into the soil is referred to as infiltration. Soil type and structure strongly influence infiltration rate. Light sandy soils have a faster infiltration rate than soils with a lot of clay. As a guide, an application rate of up to 8 mm/h is satisfactory for sandy soil, and 4 to 5 mm/h in clay soils.

When using drip irrigation water in sandy soils tends to move more vertically than horizontally, whereas in heavier textured soils water moves more horizontally giving a better lateral spread. A general guide to typical soil wetting patterns is shown in Figure 1. The infiltration rate of soils is important when designing the application rate of sprinklers and drippers.

Figure 1. Wetting patterns in different soil types



Permeability: The movement of water through the soil is referred to as permability. Soils with a good structure are more permeable than compacted or heavy clay soils. Some soils can also have impermeable layers which can impede drainage and cause waterlogging. The permeability of a soil is important when designing irrigation application rates.

Waterholding Capacity: The soils ability to hold and retain water is referred to as the water holding capacity (WHC). The amount of soil organic matter and clay particles influence the WHC of soils. Sandy soils have a low WHC while clay soils have a high WHC.

DESCRIBING SOIL WATER STATUS

There are several terms used to describe the moisture content of soils. These are used in deciding when to irrigate.

Saturation point: When it rains, or when you irrigate, all the soil pores fill up and the soil is then said to be saturated. At this point there are no air spaces in the soil and therefore no oxygen. Once the soil is saturated, any more water added causes run-off. Depending upon the soil type, soils may remain saturated for hours or days.

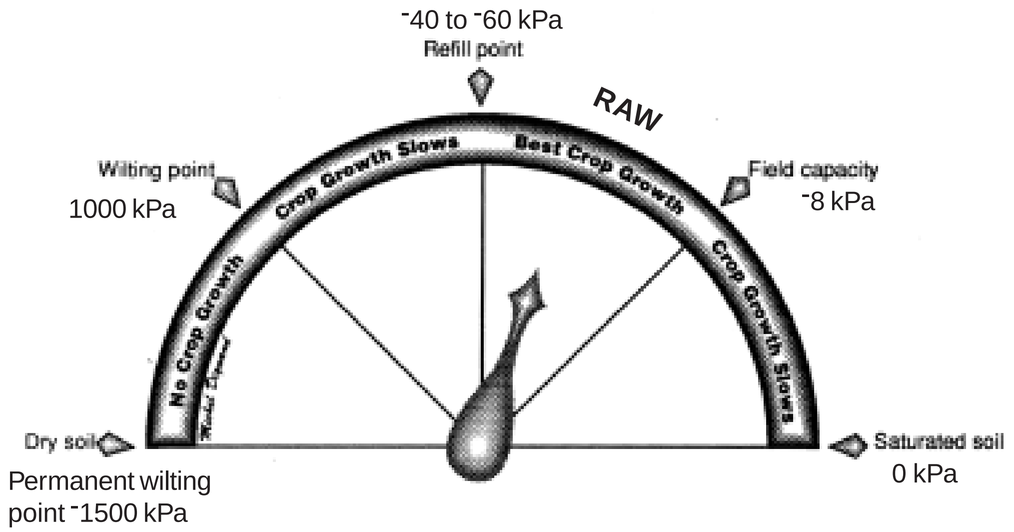
Field capacity: When the larger soil pores have drained (1- 4 days), the soil is said to be at field capacity. At this point the soil is still wet, but not saturated. The water is primarily held in the small capillary pores of the soil, which is the main source of plant moisture. At this point, the water is readily available for plant use. As water is progressively removed from the soil (surface evaporation, plant extraction and deep drainage) the soil dries. The drier the soil, the higher the suction, and the harder the plants have to work in order to extract water. If a plant has to work too hard at extracting water, it will begin to show symptoms of water stress. Field capacity in most soils is at a tensiometer reading of $^-8$ kPa.

Readily available water (RAW): Water that can be easily removed from the soil by plants is called the readily available water. To achieve high yields, irrigation management should aim to ensure that the plants are always using readily available water. RAW is expressed in millimetres per centimetre (mm/cm) or metre (mm/m) and indicates the volume of water (mm) held in every centimetre (cm) or metre (m) of soil throughout the plant root zone. The RAW capacity of a soil forms the basis for scheduling irrigations. Table 1 gives RAW values for a range of soil textures.

Table 1. Readily available water for tree and vine crops for a suction level of -40 to -60 kPa for different soil textures. (Extracted from the ***Waterwise on the Farm Course Manual)***

soil texture	sand	loamy sand	clayey sand	sandy loam	light sandy clay loam	loam	sandy clay loam	clay loam	light medium clay	medium clay	heavy clay
readily available water (mm/cm)	0.38	0.55	0.60	0.65	0.74	0.84	0.71	0.65	0.57	0.57	0.41

Refill point: When all the readily available water has been used the plant roots cannot easily extract water. This stage is referred to as the refill point and this is the time to irrigate. For most tree crops the refill point is between -40 and -60 kPa. Water is still present in the smaller pores, but plants have to exert a great deal of energy to extract it. Plant growth and fruit development is halted while soil moisture remains at this point.



(Extracted from ***Irrigation Scheduling for Fruitgrowers)***

Permanent wilting point: It is easy for plants to extract water when the negative pressure is anywhere between -8 kPa (the tension after a full irrigation) to -60 kPa. These figures vary with soil type, crop variety and age. As the soil gets drier, it still contains water but the plants have to exert a tension greater than -60 kPa to use the water. This extra effort may stress plants and reduce yields. Eventually the soil reaches a point at which the plant can no longer extract any water and this is known as the permanent wilting point. Once the soil has passed this point, water is held by the soil so tightly that the plant will wilt and die from lack of water. Permanent wilting point is reached in most soils at -1500 kPa.

WATER QUALITY

There are a number of factors that affect water quality and these can be detrimental to tree growth and development. Any water you plan to use for irrigation should be tested by an accredited laboratory. The quality of irrigation water should be regularly monitored because it can change over time and fluctuate with seasonal conditions (especially during a drought).

Salinity: One of the greatest water quality concerns is salinity. Salt in irrigation water affects crop performance in several ways:

- dissolved salts in the root zone can affect water availability (salt outcompetes roots for moisture);
- reduces shoot growth and yield (normally reduces fruit number);
- depending on rootstock can decrease % juice, acidity and TSS;
- the presence of certain elements such as chloride, sodium, or boron can cause toxic effects.

During a drought the salinity of the water usually increases. In conditions of low humidity the effects of salinity can also be intensified . Testing the salinity of the water will indicate if the water is suitable for irrigation.

Salinity measurements of water are referred to as the electrical conductivity (EC) of the water. EC measures the extent to which water conducts an electrical current and the higher the salt load the higher the conductivity. EC can be easily measured using a handheld EC meter or by sending a sample to a laboratory for analysis. EC is generally expressed in microsiemens per centimetre (*u*S/cm) but sometimes as decisiemens per metre (dS/m) or millisiemens per centimetre (mS/cm). [1dS/m = 1mS/cm = 100*u*S/cm].

The salinity threshold for lemons is 1.3 dS/m (sand), 0.7dS/m (loam) and 0.4dS/m (clay). Lemons are more sensitive to salinity than oranges and grapefruit.

It is estimated that water at an EC of 1.6dS/m would result in a 10% reduction in yield. Other factors, such as the soil's ability to drain, the method of irrigation, the level of rainfall, the variety and rootstock also affect the ability of plants to cope with salinity when wetting of the foliage is avoided. Rootstocks vary in their ability to restrict the uptake of sodium and chloride ions. *P. trifoliata* accumulates chloride ions and is salt sensitive, whereas Cleopatra mandarin, Troyer and Carrizo citranges have good salt tolerance. (For more information refer to the Rootstocks section).

pH: Water with a pH reading between 6.0 and 8.5 is generally suitable for irrigation. Highly alkaline water with high carbonate and bicarbonate levels can affect plant uptake of calcium, magnesium and some trace elements. It also tends to precipitate calcium carbonate which can cause blockages in pipes. Carbonate and bicarbonate levels of up to 150 mg/L are acceptable, while 350 mg/L would be cause for concern.

Sodicity: The concentration of sodium ions (Na+) or sodicity of the water is also important.The sodium adsorption ratio (SAR) is a measure of the imbalance of sodium ions relative to calcium and magnesium ions in the water. High SAR levels cause poor water penetration through the soil, poor drainage, low aeration levels and poor soil structure. Soils affected often have a hard, blocky structure and surface crusting. High sodium levels in soils can be treated with gypsum.

A general guide to SAR values:

- < 6.0 $(mmole/L)^{1/2}$ – waterlogging unlikely;
- 6.0-9.0 $(mmole/L)^{1/2}$ – a problem exists but can usually be managed with gypsum;
- > 9.0 $(mmole/L)^{1/2}$ – severe problems.

Chloride: High chloride levels in water may cause poor growth and death of plant tissue and sensitive plants (especially if the water is sprayed directly onto the plant). If the water is applied by drip irrigation, and not on the plant, levels below 140 mg/L (ppm) are generally acceptable. Readings between 140 to 350 mg/L should be treated with caution, and any above 350 mg/L should not be used.

Calcuim Carbonate Saturation Index: The calcuim carbonate saturation index gives the relationship between pH, salinity, alkalinity and water hardness. It indicates whether the water is likely to cause corrosion of pumps and pipes and blockages of drippers and pipes. Figures between ⁻0.5 and 0.5 are usually okay.

Iron: Soluble iron and bacterial iron can cause blockages to pipes, drippers, and sprinklers and damage to pressure gauges. If water with high soluble iron is applied by overhead sprinklers, it can discolour leaves and reduce transpiration and photosynthesis. Iron levels as low as 0.1 mg/L (0.1 ppm) can cause problems with blockages in micro-irrigation systems. The simplest treatment to remove iron from water is to use aeration, followed by settling and then filtration.

Turbidity: Turbidity measures the amount of solids in water. Turbidity can be high in some rivers and streams. Erosion of soil is a major cause of turbidity. The dispersed clay particles stay suspended in water for long periods and can cause a build-up of sludge causing blockages in drippers and laterals.

Nutrients: Excessive nutrients in water can be due to organic or inorganic fertilisers or other sources of organic matter. Excessive nutrient loads in water can result in:

- prolific growth of aquatic weeds and algae which restrict water flow;
- reduced water quality from the production of algae and bacterial toxins;
- clogged filters.

SCHEDULING IRRIGATION

Efficient irrigation systems match plant water use with water application. Irrigation scheduling allows you to apply the right amount of water at the right time. It helps you make decisions on the amount of water to apply, when to start and stop the irrigation, and the interval between irrigations.

The benefits of irrigation scheduling include:

- ☑ provides optimum soil water conditions for plant health and growth;
- ☑ uses water efficiently and effectively;
- ☑ maximises productivity;
- ☑ minimises leaching, runoff and wasteage.

Not scheduling irrigations correctly frequently leads to periods of over-watering (waterlogging) or under-watering which both affect tree health and yield.

Under-irrigating trees causes water stress. Water stress occurs when the tree cannot replace the losses from transpiration. It can occur when soil water is low, on hot windy days or when root function and performance is affected by unfavourable soil temperatures (too low or high), low oxygen levels, or the presence of pests (eg. nematodes) or disease pathogens (eg. *Phytophthora* root rot). Trees can suffer water stress before there are any obvious visual symptoms. Symptoms of water stress can be more severe on shallow rooted rootstocks.

Some of the symptoms and effects of water stress include:

- wilting and thickening of leaves;
- fruit and vegetative growth slows or stops;
- leaf and fruit drop;
- reduced fruit set;
- nutrient defeciencies;
- salt damage;
- shoot and tree death;
- increases TSS and % acidity;
- decreases fruit size and % juice;
- can improve skin quality;
- can initiate flowering.

Over-irrigating trees can lead to waterlogged soils.

Some of the symptoms and effects of waterlogging include:

- sparse foliage and stunted trees, which reduces yield;
- reduced oxygen levels in the soil (reducing root function);
- root death;
- increased root diseases such as *Phytophthora* root rot;
- nutrient leaching;
- wastes water (through surface runoff and subsurface drainage);
- TSS and acidity decrease (especially in oranges);
- % juice increases.

Irrigation scheduling involves using information about a range of factors. These factors are divided into three categories and include:

1. **Plant based scheduling -** includes using knowledge of plant growth stages and visual assessment of the plant.
2. **Soil based scheduling -** includes using soil water monitoring devices and visual assessment of soil moisture by the appearance and feel of the soil.

Monitoring soil water: Monitoring soil moisture status using tensiometers, test wells and other devices provides a sound basis upon which to develop and improve your irrigation practices. Monitoring soil moisture before an irrigation is important in scheduling the quantity of water to be applied and to predict the timing of the next irrigation event. Monitoring soil moisture after an irrigation provides information on the fate of water down the soil profile and can identify problems with the depth of the irrigation water applied. Soil water can be determined by measuring either the soil water tension or the total water content. Various instruments are available which vary in cost and complexity.

Tensiometers are useful for monitoring soil moisture status

Tensiometers are the most widely used device for measuring soil water tension. They act like artificial plant roots measuring the force in kilopascals (kPa) required to extract moisture from the soil. In order to get accurate measurements tensiometers must be maintained in good condition and have good contact between the ceramic tip and the soil. They work best in coarser textured soils and are unsuitable in cracking clays. They measure tensions up to ⁻85kPa. Tensiometers should be placed at several depths in the soil (for example 30,45 and 60cm depending on plant rootzone depth) to gauge water content throughout the entire root zone. The drier the soil the higher the reading. Table 2 provides a general guide to tensiometer readings.

Table 2 General guide to tensiometer readings. *(*Extracted from the ***Waterwise on the Farm Course Manual)***

Readings (-kPa)	Interpretation
0-10	Soil is very wet. continual readings in this range indicate excessive irrigation and waterlogging. Plant root damage highly probable.
10-25	Best balance of soil moisture and air. Ideal for plant growth.
25-40	Soil moisture sufficient for plant growth. May need to irrigate on light soils.
40-60	Soil is getting dry. Crops are probably stressed. Crops should be irrigated in this range.
over 60	Irrigate now

Gypsum blocks also measure water tension and can be used in finer textured soils such as loams and clays where tensiometers are unsuitable.There are two types of gypsum blocks the GBH and the GBL and they measure different soil moisture ranges. The GBL measures between ⁻10 and ⁻200kPa and the GBH measures between ⁻60 and ⁻600kPa. The GBL is the most suitable as soil moisture needs to be kept between ⁻10 to ⁻60kPa for citrus.

Instruments that measure the soil water include the neutron and C probes and the Gopher, Diviner and EnviroSCAN sensors. These instruments are more expensive but provide very accurate readings. They use loggers to automatically record measurements which can then be downloaded to a computer and used to automate irrigations.

3. **Weather based scheduling -** includes assessing local climatic conditions and evapotranspiration (ET).

Water is lost from soil surfaces through evaporation and from plants through transpiration. The combined losses from evaporation and transpiration is called evapotranspiration (ET). ET is equivalent to plant water use and is used to work out the irrigation requirements of crops. ET varies between regions and is influenced by local climatic and soil conditions and the crop type.

Computer technology using weather bureau information can be used to predict estimated evapotranspiration using a known reference crop. This figure is referred to as Reference Crop Evapotranspiration (ETo) and can be related to the water used by a specific crop type. The ETo figure needs to be converted to equal the water use by a typical citrus tree and this is done using a value known as a crop factor (Kc). For more information on crop factors talk to your local horticultural or irrigation advisor.

IRRIGATION SYSTEMS

Lemons can be watered using any of the main irrigation systems. In Australia most orchards use either mini or microsprinklers or drip irrigation. The use of drip irrigation has become more common since the 1990's.

Drip

Drip irrigation can be used in a range of soil types including sandy soils and those with a low water holding capacity. Drip irrigation applies water directly to the rootzone of the tree and soil water is maintained by frequent irrigations. It is potentially the most water efficient system. Young trees are often set up with one dripper line and as trees grow a second line can be added to the other side of the row. The benefits and limitations of drip irrigation include:

- ☑ Ability to automate irrigation events.
- ☑ Allows fertigation.
- ☑ Reduced labour.
- ☑ Even distribution of water across whole block.
- ☑ Ability to apply exact amounts of water.
- ☑ Access into blocks whilst irrigating.
- ☒ Initial setup costs high.
- ☒ Limited leaching ability.
- ☒ Not able to irrigate inter-row sods

Mini or Micro Sprinklers

These sprinkler systems are suitable in a wide range of soil types including those with low infiltration rates and water holding capacity. The benefits and limitations of microsprinkler systems include:

- ☑ Ability to irrigate sod culture .
- ☑ Ability to deliver exact amounts of water.
- ☑ Water distribution across the block better than flood but not as good as drip.

- ☑ Ability to automate irrigation events.
- ☑ Offer some protection against frost
- ☑ Allows fertigation.
- ☑ Easy to apply leaching irrigations.
- ☒ Need to keep trees well skirted.
- ☒ Need to have good weed control.
- ☒ Regular field check for blocked and broken sprinklers.
- ☒ Wind can affect the uniformity of water distribution
- ☒ Can increase humidity in the lower tree canopy

Overhead sprinklers

The use of overhead irrigation has become less common in the last 20 years. The benefits and limitations of overhead sprinkler sytems include:

- ☑ Ability to irrigate sod culture.
- ☑ Ability to deliver exact amounts of water.
- ☑ Water distribution across the block better than flood but not as good as drip.
- ☑ Allows for frost protection (if water is available in channel).
- ☑ Ability to automate irrigation events.
- ☑ Removes dust from trees.
- ☑ Easy to apply leaching irrigations.
- ☒ Regular field check for blocked and broken sprinklers.
- ☒ High maintenance costs (parts wearing, higher pumping costs).
- ☒ Poor distribution of water in windy conditions.
- ☒ Requires quality water, cannot use slightly saline water due to risk of scorching leaves.
- ☒ High evaporation losses in hot windy weather.
- ☒ Can contribute to pest/disease problems.
- ☒ Increased humidity in the trees canopy.
- ☒ Higher cost

Furrow

Furrow irrigation is best suited to deep permeable soils (such as loams and clay loams) with gentle slopes and high water holding capacity. The benefits and limitations of furrow irrigation include:

- ☑ Low set-up and running costs.
- ☑ Larger wetted area of the root zone.
- ☑ Easy to apply leaching irrigations for salinity control.

- ☑ Can fill profile quickly.
- ☒ Uses valuable space for open head ditch and supply system.
- ☒ Difficult to deliver an exact amount of water.
- ☒ Access to block not possible for a number of days after irrigation.
- ☒ Uneven distribution of water along the furrow.
- ☒ Locked into a set application time.
- ☒ Hard to prevent water from going beyond root-zone.
- ☒ High labour input.

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