# Minimising Frost Damage to Citrus

In July last year there were some severe frosts throughout the citrus growing regions with temperatures in certain parts of the Riverland getting as low as -6° Celcius.

These severe frosts had citrus growers madly trying to find information on determining the level of frost damage to fruit and what to do with the fruit if it was damaged.

Some frost damaged fruit did get through to the USA market causing some repacking to occur.

This article has been written in order to help reduce the incidence of frost damaged fruit reaching our export markets and affecting prices.

## Why Does A Frost Occur?

Two types of frost situations can occur. One is called an 'advection frost', which occurs when freezing air blowing into an area displaces warmer air that was present before the frost occurred. This is the main type of frost that occurs in Florida, USA.

The other type of situation, a 'radiation frost', is characterised by light or no winds, temperature inversions and clear skies. Frost occurs on cloudless nights when the clear skies allow heat to be lost rapidly from soil and plant surfaces.

Windless nights increase the chance of frost because there is no mixing of the cold air near ground level with warmer air higher up.

*Frost on citrus trees, Ramco 1982*

Whether the soil surface and surrounding air reaches the frost temperature of 0°C or not depends on:-

1. The amount of heat stored in the top 300-380 mm of soil during the day.
2. The amount of heat lost by radiation at night. This depends on the rate of heat loss and length of night. The rate of heat lost is greatest on a clear still night. Fog, clouds and wind tend to protect crops from radiation frost.
3. The flow of heat from the deeper soil to the radiating soil soil or plant surface.
4. The moisture content of the air. The higher the amount of water or humidity in the air, then the lesser the chance of frost.

## Factors Affecting Frost Damage In Citrus

1. **Generally, 4 hours or more of temperatures of -2°C or below will cause some mature fruit damage.**
2. **Immature autumn flush leaves are much more vulnerable to frost damage than spring and summer flush leaves.**
   Loss of autumn flush growth, however, is of little consequence because it is not mature enough to form flower buds and hence does not have the potential to produce fruit in the following season.
3. **Immature fruit is more vulnerable to damage than mature fruit.**
   As fruit ripens, its sugar content increases producing a more concentrated solution that has a lower freezing point.
4. **Mandarin fruit should be protected on the same levels as oranges.**
   However, the foliage of most mandarin cultivars is more frost hardy.
5. **Trees in poor condition or suffering from water-stress at the time of frosting are more likely to have damaged fruit.**

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# Minimising Frost Damage to Citrus cont.

6. **Trees planted in the low-lying areas will almost always be worst affected.**
7. **Trees which lack foliage will usually have more severely damaged fruit.**
   This is because in a radiation frost they lose stored heat to the sky more rapidly.
8. **Fruit on the tops of trees may be worse affected due to radiation effects.**
9. **Fruit on the inside of the canopy is less affected by frost.**
   This is due to the fruit being protected by the canopy.
10. **In areas of high ground cover, fruit low on the tree may suffer more freezing injury than from the sides of the trees.**
11. **Fruit subject to rapid thawing after frost are more likely to be damaged than slowly thawing fruit.**
    Eg. The northern and eastern sides of the tree may carry more severe frost damage than fruit on the southern side of the tree.

| Fruit Temperatures At Which Freezing Begins | |
|---|---|
| **Variety** | **Temperature at which damage occurs** |
| **Oranges, Grapefruit, Mandarins** | |
| Green Oranges | -1.9° C to -1.4° C |
| Half-ripe oranges, grapefruit and mandarins | -2.8° C to -1.7° C |
| Ripe oranges, grapefruit and mandarins | -3.9° C to -1.7° C |
| **Lemons** | |
| Buds and Blossoms | -2.8° C |
| Button Lemons ( up to 12mm diameter) | -1.4° C to -0.8° C |
| Green Lemons (greater than 12mm diameter) | -2.8° C to -1.4° C |
| Tree-ripe Lemons | -3.3° C to -0.8° C |

(Opitz,K.W., Brewer,R.F., and Platt, R.G., 1979)

## Preventing Frost Damage

### 1. Cold air drainage

Cold air moves like water and fills hollows and low-lying ground. Windbreaks and other vegetation, including weeds and cover crops, often hold back air movement creating localised areas where frosts can occur. Sometimes it is necessary to open gaps in windbreaks to improve air movement.

### 2. Weeds and soil

Weeds reduce the amount of heat absorbed by the soil during the day and also slow down the radiation of heat from the soil at night.

A bare, damp, compact soil is the best protection against frost.

But because of the benefits of reduced dust levels and higher levels of beneficial insects by having interrow sod culture, it is recommended in areas of high frost risk that the sod culture be kept closely mowed and adequately watered.

Orchards should not be cultivated during frost-risk periods unless they can be watered and compacted before the next frost, as cultivated soil with lots of air pockets reduces the level of heat which can be absorbed and released by the soil.

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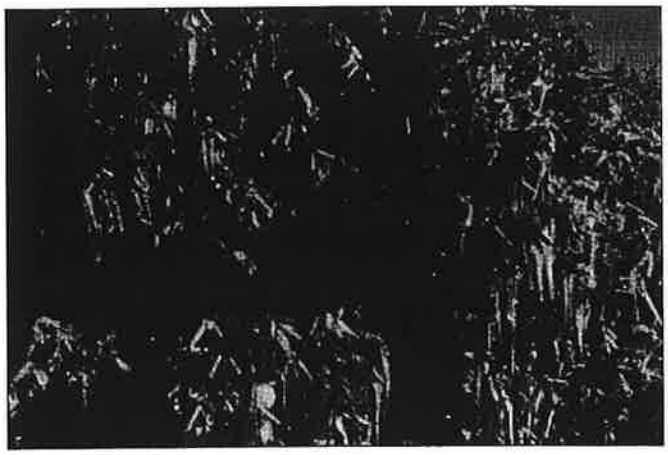
## 3. Applying Water

A relatively cheap way of supplying heat to an orchard is to apply water, but it is a procedure that must be managed carefully.

As the water cools, it releases heat to the orchard, and as it freezes it releases large amounts of heat. Oranges encrusted in ice may appear to be a disaster, but almost certainly they are undamaged. Because water freezes at 00C and fruit at about -20C, the fruit and leaves are protected as long as water continues to be added to the ice to prevent the temperature dropping to the point at which plant tissue freezes.



*Frost on citrus trees, Romco 1982*

To keep the fruit above freezing point it is important to keep sprinklers running until ice on the trees has almost thawed. If sprinklers are turned off too early on frosty mornings the cooling effect of evaporation can quickly freeze and damage the fruit.

Although overhead sprinklers are an effective means of frost control, they can have two major disadvantages.

1. **Breaking of Limbs**
   During severe or prolonged frosts, ice builds up on tree limbs to the extent that limbs break.
2. **Development Of Root Rots**
   During a long series of frosts, and when frosts begin early in the night, sprinklers must be run for many hours and soils become waterlogged. This encourages the development of phytophora root rots.

## 4. Heaters And Wind Machines

Heaters or frost pots, although effective in raising orchard temperature, are expensive to buy and to run and are therefore generally not a viable option for the Riverland.

Wind machine effectiveness needs to be assessed for individual properties. Wind machines draw warm air from near the inversion layer and distribute it near the ground. The inversion layer is the point at which air temperatures cease to rise and begin to fall. This usually occurs 10 to 50 metres above ground level.

Before investing in a wind machine, a grower should research several factors, including orchard topography, height of the inversion layer and temperature gradient to the inversion layer.

# After a Frost

## 1. Assessing Frost Damage and Crop Management

The first step in managing frost damaged trees is to assess the extent of damage. As every frost is different it is very difficult to make an immediate assessment of damage.

### FRUIT

- Fruit damage is estimated by making cuts through the fruit at hourly intervals in the morning following a frost. Some ice formation in the top 6 mm of the juice vesicles indicates mild damage, while solid ice formation in the centre signifies severe damage and loss of a portion of the crop.
- Damaged citrus fruit can be identified a day or two after a frost by their water-soaked appearance inside.
- Rind burn can occur, but often there is damage within the fruit without visible symptoms on the outside.
- If extensive fruit damage has occurred, some fruit abscission occurs within 1-2 weeks following a freeze.
- High daytime temperatures following a freeze will, in particular, accelerate fruit drop and segment drying.

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- Fruit damaged by frost should be harvested as soon as possible and sent to the juice factory quickly to minimise decreases in juice content and yield losses due to fruit abscission.
- After drying out and fruit drop occurs, processors are unlikely to accept fruit even at a discount.
- At harvest, any remaining severely frost-damaged fruit should be picked and dropped to leave a clean tree for the next crop and to ensure the resources of the tree are invested in the next crop and not in the frost-damaged crop.
- After ice in the fruit has melted, water is transpired through the peel rather than dehydrating the juice sacs, thus decreasing juice content.
- Some alternaria decay is likely to occur in frost damaged fruit about 3-4 weeks after the freeze.

## LEAVES

Leaf damage is difficult to assess during a frost night.

- Watersoaked (dark green areas occur in part or all of the leaf) or curled leaves may or may not be significantly damaged.
- The morning following a frost leaves may be rolled up and appear dry and dull green. These leaves will probably, but not always, abscise over the next week, again depending on temperature.
- Frost damaged leaves abscise between the petiole and the lamina (leaf blade) with the petiole dropping later. Leaf abscission is usually more extensive at the top of a tree than at the base following a radiative frost because temperatures are lower in this area due to direct exposure to the sky.
- It is not uncommon for temperatures of exposed leaves to be 1-20C lower than sheltered air temperatures reported 1.5 metres above ground level. Therefore caution should be exercised in interpreting minimum air temperature data relative to extent of frost damage.
- Within one week of a frost the extent of leaf damage should be quite apparent.
- Trees can recover even from total defoliation and in some cases flowers and fruit will be produced in the next season, depending on when a frost occurs, whether flower buds have already been initiated and the extent of wood damaged.

## STEMS

The consequences of frost damage to twigs, stems and trunks is more difficult to assess than that to fruit or leaves.

- In general, small twigs will be damaged before larger limbs and trunks.
- Twigs or limb dieback may not become visible for weeks after a frost.
- It is common for large limbs to bud out in spring following frost damage, only to die back in the summer or fall due to latent frost damage to cambial tissues.
- Another indication of wood damage is when leaves turn brown but do not abscise following a frost. This indicates more severe frost damage than defoliation alone, and usually indicates severe limb damage.
- Because frost damage to the wood is so difficult to assess, frost damaged trees should not be pruned until late spring or summer following a frost.
- After the extent of frost damage has been assessed by evaluating the extent of cambial discolouration, pruning should be done to minimise problems resulting from melanose (a fungus which is harboured in dead wood).
- If the trees are pruned too early the extend of dieback is likely to be increased, and some healthy wood that appears to be dead could be removed.

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- Pruning can be done by machine hedging and topping for minor damage or using chain or pneumatic saws when more selective, extensive hand-pruning is needed.
- If only the tree's trunk is alive and major branches do not re-shoot, the tree is severely damaged. Allow such trees to grow until regrowth is about one metre long and then begin to thin the new shoots to form a new framework of branches. Pinch the tops out of shoots to remain until the root-to-top growth balance is almost restored.
- Damage is very severe when all the wood above the bud union is dead. Where this has happened, leave the trunk as a support to train up a shoot from the rootstock. When the shoot reaches pencil thickness it should be budded and trained to develop into a new tree. Again, only pinch out the tips of other watershoots so that they do not become dominant over the selected shoot.

## 2. Cultural Practices For Frost Damaged Trees

- Where frost damage is moderate or severe, the amount of irrigation should be reduced. Less water is needed because the areas of leaves is smaller. If the same volume of water is applied, soils are likely to become waterlogged and the risk of root-rotting fungi increased.
- Similarly, application of nitrogen fertiliser should be reduced if the tree size has been significantly reduced. For example, if the tree size has been halved, the nitrogen fertiliser applied should also be halved.
- Two or three foliar sprays of zinc and manganese are likely to be needed as the trees rapidly recover because roots do not absorb these nutrients very well in alkaline soils. In acid soils, these sprays are less likely to be needed.
- Weed control becomes a problem in frost damaged orchards because the orchard floor receives more sunlight than a fully canopied orchard, so weed growth needs to be more rigorously maintained.

# SQF 2000 - A Quality System for Growers

Everywhere the markets are asking for quality systems and food safety back to the farm. Whether it is Woolworths and Coles on the domestic market, or the large chain stores in our export markets.

To assist growers and packers to adapt to this market driven demand, a proposal has been submitted to the Citrus Market Development Group by Citrus Growers of South Australia for the Australian citrus industry to take a national approach to food safety and quality.

The aim of the project is threefold:

1. To develop a SQF 2000 facilitators' course based on the citrus industry so that those people training the growers and packers in SQF 2000 are fully qualified for the task.
2. To develop an SQF 2000 generic growing and packing manual for the citrus industry.

   This will have two effects:

   - It will save growers and packers time rewriting manuals.
   - It will develop into a real life best practice manual which can be upgraded on an ongoing basis by industry technical experts.
3. Finally, to develop a SQF2000 network to facilitate and coordinate training throughout Australia so that the whole industry will have a single focus.

   If you would like to know further details about this project call Nigel Duddy, Industry Development Officer with CGSA on 85 822 055.