PRE-PACKHOUSE PRECAUTIONS

1 INTRODUCTION

For the successful control of post-harvest diseases, control measures should have been applied before the fruit reaches the packhouse. Packhouse treatments as such are not sufficient to minimise post-harvest losses.

Integrated fruit production in the southern African citrus industry includes the optimal integration of all production practices, starting with the correct choice of cultivar prior to establishment of the orchard through to the control of post-harvest decay. Numerous post-harvest diseases result from pre-harvest infections. A drastic change in the incidence of post-harvest diseases can therefore be affected pre-harvest by means of practices such as spraying of trees with fungicides or plant hormones, the removal of dead wood, pruning of trees to prevent fruit contact with the soil, the removal of fallen fruit, control of fruit flies, False Codling moth, mealybug and other insects which may damage fruit. The level of post-harvest decay is also influenced by picking and transport practices, fruit maturity, pruning of trees, fertilisation and irrigation practices and the presence of ground covers. Correct management of numerous pre-harvest practices which could influence post-harvest decay is therefore of primary importance with a view to cost effectiveness, viability and minimisation of adverse effects of the environment, which is the objective of Integrated Fruit Production.

2 PREVENTION OF PRE-HARVEST INFECTION BY DECAY-CAUSING ORGANISMS (PATHOGENS)

2.1 Insect control

Fresh insect stings are one of the main causes of major post-harvest diseases. Such fresh stings are not readily detectable on a grading table and difficult to grade out.

Fungicide treatments are ineffective because stings are difficult to penetrate and the infection is often too far developed for successful fungicide treatment. The result is that diseases such as blue and green mould, sour rot, *Trichoderma* brown rot, etc. develop in packed fruit, notwithstanding the application of a fungicide in the packhouse. The pathogens causing these diseases can only penetrate the fruit through wounds. Populations of insects such as fruit flies, false codling moth, carob moth, fruit sucking moths, etc. should therefore be kept as low as possible by means of appropriate control measures.

2.2 *Phytophthora* brown rot

2.2.1 General information

This disease can be devastating, especially during seasons of high or frequent rainfall during harvesting or where fruit is in contact with the wet ground. *Phytophthora* brown rot is not controlled by the registered post-harvest fungicides and prevention of infection is therefore essential.

When raindrops splash from the ground onto the fruit or when fruit is in contact with the wet soil, the *Phytophthora* fungus can penetrate the rind of the fruit within 3 hours at temperatures between 12°C and 20°C.

A warm water treatment (4 minutes at 46°C to 49°C) within 24 hours of infection will prevent brown rot development, but this is mostly impractical since fruit normally cannot be harvested within 24 hours after rain has fallen.

2.2.2 Orchard practices

Brown rot is best controlled by means of preventative measures in the orchard, i.e. before the fruit is harvested.

The same fungi which cause *Phytophthora* root or collar rot in citrus trees also cause brown rot of fruit. Control of root and collar rot will therefore also help to prevent infection of the fruit.

Trees in orchards with *Phytophthora* should be skirted to prevent fruit from touching the ground.

Do not pack fruit which has been under floodwater for export since a high proportion of this fruit will develop brown rot.

The incubation period of the fungus, i.e. the time that elapses between infection and symptom expression, varies from 9 to 16 days at ± 10°C and 4 to 6 days at 15 to 30°C.

Infected fruit could therefore be packed and develop decay in the carton although there was no sign in the orchard that infection had taken place. Infected fallen fruit under the trees is a sure indication that other fruit might also be infected.

Growers in areas where brown rot occurs, should protect their fruit by spraying with a fungicide in early autumn (approximately three weeks before commencement of picking), especially if continuous rains start falling and wet, humid conditions result which are favourable for the infection of fruit with *Phytophthora* zoospores.

All fruit up to one metre above ground level should be completely covered with a fungicide, as well as the trunk of the tree and the soil surface underneath the canopy of the tree.

To prevent infected fruit from reaching the packhouse, fungicide sprays should be applied three to four weeks before harvest. The spray should be repeated if heavy rains should fall after application.

2.2.3 Crop protection fungicides

According to reports, the following spray mixtures will protect fruit effectively:

Aliette - use 250 g product per 100 litres water.

Phytex - use litre 1 product per 100 litres water.

Dithane M45 - at 200 g product/100 litres water.

Mikal M - at 450 g product/100 litres water.

Copper containing fungicides - use at 93 g metal copper per 100 litres water.

Bordeaux mixture - the following mixture is recommended from California: 3 - 4,5 - 100, i.e. 3 pound copper sulphate pentahydrate and 4,5 slaked lime per 100 US gallons. In metric terms this is 363 g copper sulphate ($CuSo_4$, $5H_2O$) plus 545 g slaked lime per 100 litres water. The metal copper content (Cu) of the spray is 93 g Cu per 100 litres water.

2.3 Pre-harvest application of fungicides for diseases other than *Phytophthora*

Some post-harvest diseases are caused by fungi which infect the fruit long before it is harvested. These infections usually only develop once the fruit has been harvested and packed. These rots include *Alternaria* core or navel end rot, anthracnose rot, *Botrytis* grey rot, *Diplodia* stem end rot and *Phomopsis* stem end rot. These diseases are well controlled by the registered post-harvest fungicide treatments and further suppressed by pre-harvest sprays for the control of blackspot and *Alternaria* brown spot.
Where *Alternaria* navel end rot is a serious problem, the following spray programme can be used, as recommended by Dr Tian Schutte:

Horizon EW (250 g/litre). Use 80 ml product per 100 litres of water. Apply at 50% and again at 100% petal fall.

2.4 Removal of dead wood

The fungi *Colletotrichum gloeosporioides*, which causes anthracnose, *Botryodilodia theobromae*, which causes brown stem end rot, and *Phomopsis citri*, which causes Phomopsis stem end rot, all produce their spores on dead wood in the tree. These spores are washed onto the fruit, where infection takes place during rainy weather. Infection of fruit can therefore be prevented by the annual removal of all dead wood on the tree prior to fruit set.

3 ORCHARD HYGIENE (SANITATION)

For a lesion in the rind of fruit to develop decay, it must be infected with enzyme producing Penicillium mould spores, which destroys the skin's resistance to infection. With only a small number of spores in the wound, the fruit is usually consumed before the appearance of visible signs. With more than 100 spores in the wound, the visible lesion will appear after three days if the temperature of the fruit is 20°C or higher. One decayed fruit contains in excess of a billion mould spores. Unless the rotten fruit is removed from the orchard, there will be more than enough mould spores in the orchard to infect every wound caused during the picking process.

With an excessive spore load in the orchard, it is highly probable that fungal strains resistant to the post-harvest fungicides in use will find their way to wounds in the rinds of fruit. Although resistant strains form a very small proportion of

the total spore load and therefore do not cause decay, the presence of a large number of fungicide sensitive spores in the same wound may enable the resistant strains to cause decay, thus producing spores and increasing the percentage of resistant strains in the total spore population. This could lead to poorer decay control achieved with existing post-harvest fungicides.

Where the spore load in the orchard is high, fine splits in the rind or injuries may become infected only days before harvesting, in which case post-harvest chemical treatment will not prevent decay.
The objective should therefore be to prevent the formation of blue and green mould spores in the orchard. Attempts should be made to remove any fruit showing signs of developing blue and green mould still on the trees, for example after hail storms, after heavy fruit fly or false codling moth infestations or in the event of high incidence of creasing and stylar end split.

It is therefore essential that fallen fruit be picked up regularly, preferably before any spores can form. While the fruit is small and very green, sanitation once a week is sufficient. As the fruit approaches maturity, sanitation twice weekly is required since spores develop within as little as three days. The fruit thus collected, must be buried (at least 30 cm deep) or chopped in a hammer mill and spread out to dry. The pieces of chopped rind should be small enough to ensure quick drying.

The *Alternaria* fungus, which causes stem end, navel end and core rot in citrus fruit survives from one season to the next and sporulates on dead and hardened fruit still hanging on the tree or lying on the orchard floor. Such hardened fruit therefore serves as a source of infection and should be removed.

Sour rot spores are spread from fallen, infected fruit to fruit on the tree by fruit flies, and vinegar flies. The sour rot fungus (*Geotrichum citri aurantii*) is virtually absent in soil which has never been planted to citrus. An increase in pathogen levels in new citrus soils can therefore be prevented by removing fallen fruit from the orchard to an isolated spot.

Sanitation cannot be effective unless the trees are skirted and grass and weed cover between rows kept short. Skirting of trees will facilitate the removal of fallen fruit and prevent the development of a hot, humid microclimate under the tree, which is ideal for the rapid formation of mould spores on fallen fruit.

4 IMPORTANCE OF OPTIMUM HARVEST DATE

Citrus fruit cannot be stored indefinitely and the longer the fruit hangs on the tree after reaching acceptable internal quality, the shorter its subsequent storage and shelf life. It is therefore vital that fruit be harvested as soon as possible after acceptable internal quality has been reached.

4.1 Poor rind colour

Poor rind colour at a stage when the fruit has reached acceptable internal quality is probably the main reason for delayed picking. Although climatic conditions play an important role in determining the colour of the fruit by the time it is ready for picking, the grower must try to avoid any cultural practices which may result in poor colour, i.e. late nitrogen applications (within four months of harvest), applications of guano or kraal manure, late oil sprays (within four months of harvest), etc. (See chapter on crop manipulation in Volume II of the Integrated Production Guidelines).

Post-harvest applications of Ethrel, as well as shipping of fruit at higher than optimum temperatures for decay control, undoubtedly will result in higher decay levels in overseas markets.

4.2 Creasing

Creasing increases with delayed harvesting. These fruit are also very decay prone. Growers are urged to apply preventative GA_3 sprays in orchards where this normally is a problem. (See the chapter on physiological disorders in Volume II of the Production Guidelines).

Alternatively, pre-harvest spraying with calcium acetate and Ethrel may be applied to improve fruit colour so that the fruit can be harvested at an earlier date.

4.3 Endoxerosis in lemons

Lemons with endoxerosis are more waste prone and should not be packed for export.

Endoxerosis is a physiological disorder of lemon fruit. The first signs of endoxerosis can be detected by cutting off the nipple of the fruit. The albedo will have a pinkish or rust brown colour. This is caused by gum formation in the vascular bundles. As the condition progresses, gum formation spreads through the core of the fruit to the stem end and into the pulp. Drying out of the vesicles then occurs, spreading from the nipple to the stem end. At this stage the fruit is extremely susceptible to *Alternaria* core rot.

Endoxerosis has been linked with fruit age and the growth rate of the fruit. Fast growing fruit is less susceptible to endoxerosis. Fruit of which the growth rate has been impeded by moisture or temperature stress have more endoxerosis. Long periods of water stress and high ambient temperatures seem to be the main conditions leading to endoxerosis, which has a greater tendency to develop when, under these conditions, there are ripe or almost ripe fruit on the tree.

No control measures have been developed at this stage, but in an attempt to prevent the development of endoxerosis in lemons, water conditions should be as favourable as possible during heat waves. Leaf potassium levels should be maintained within the recommended range.

However, under certain climatic conditions lemon trees may wilt despite sufficient water. This is caused by excessive transpiration, when the roots are unable to keep up with the foliar demand for water. It is important to take note of such conditions and of the possible development of endoxerosis. Endoxerosis may even develop in lemons of 5 cm in diameter, irrespective of colour, and usually gets worse the longer the fruit hangs on the tree. Consult "Handling of lemons - Endoxerosis" with regard to harvest strategy.

5 EXTENSION OF THE HARVESTING SEASON

In cases where picking can be delayed, growers are urged to spray GA_3 plus 2,4-D.

Lemons sprayed with gibberillic acid (GA) to extend the harvest period, may develop more decay than fruit picked within the normal packing period. This particularly happens when lemons sprayed with GA are left on the trees for a period of more than four weeks after the date on which they would normally have been picked.

6 SAFE HARVESTING PRACTICES

6.1 Careful handling

It is very important to realise that decay usually starts in the orchard during the picking and transport of fruit to the packhouse. Any injury to the fruit serves as a point of entry to spores. In fact, this is the only way in which blue and green mould and the sour rot fungus can penetrate the citrus fruit prior to packing. Every precaution must therefore be taken to avoid injuries. **The more injuries present on the fruit, the more difficult it is to prevent decay by means of post-harvest applications of fungicides in the packhouse**.

Avoid fruit injury by rough usage of ladders, squeezing fruit in picking bags between body and ladder, bumping full picking bags against trailers or lug boxes, rough dumping of fruit into lug boxes or trailers, overfilling and stacking lug boxes, etc.

Ensure that no cuts, scratches, punctures and abrasions are caused by pickers with long fingernails, careless handling of clippers, dust particles or sharp objects in picking bags, lug boxes or trailers. Fruit which is transported for long distances over dusty roads, should be covered with canvas.

Dry twigs on trees should be removed regularly. These twigs injure fruit during picking and end up in picking bags, lug boxes and trailers, causing further injury.

Ensure that clippers are in good working order and that it is possible to make a square cut across the stem as close to the button as possible. Even new clippers may be defective in this respect. Any stem that protrudes beyond the shoulder of the fruit injures other fruit in the picking bag, lug boxes, trailers, bulk dumping tank, on the washing line and even in the packed carton. Short, sharp stems caused by angle cuts are especially dangerous.

Snap-picking should be done correctly and only

in orchards where snap-picking is possible. Incorrect snap-picking may cause numerous injuries and devastating waste losses. The instructions contained in the chapter on "Harvesting of Citrus" and the bulletin available from CRI, Nelspruit, should therefore be carefully studied before embarking on any snap-picking.

Avoid oleocellosis, i.e. a burn caused by oil escaping from ruptured oil cells in the rind. Do not pick fruit too soon after rain, too early in the morning when there is still dew on the fruit or during very cold, humid conditions, i.e. conditions resulting in a turgid, tender rind.

Fruit may be severely injured during rough transport over bad roads or when transported in trailers or lorries with over-inflated tyres and travelling too fast.

Avoid long drops when fruit is emptied from picking bags or when the fruit is unloaded at the packhouse into bulk dumping tanks or onto moving belts. Fruit should be rolled gently into lug boxes or trailers and rolled out gently at the packhouse.

6.2 Monitoring of injuries

The following methods can be used to determine the amount of injuries on the fruit:

Indigo carmine stain : The fruit is submerged for 5 minutes in a solution containing 0,1% indigo carmine plus a few drops of wetting agent (Teepol, Agral, etc.) plus a few drops of 0,5% hydrochloric acid. Injuries will show up as bluish-green marks.

TTC stain - TTC (2,3,5-triphenyl-2H-tetrazoliumchloride) is a colourless dye which stains fresh fruit injuries red. Prepare a solution containing 1 g TTC/litre water. Keep the fruit submerged for 30 minutes if the temperature of the fruit and of the solution is above 20°C. If the temperature of the solution is below 20°C, soak the fruit for at least 1 to 2 hours. Store the solution in a plastic container for re-use.

Ferric chloride stain - With ferric chloride injuries on fruit are stained blue-black. The fruit is dipped in 5% ferric chloride solution containing a few drops of wetting agent for 5 minutes. The fruit is then rinsed, dried and dipped in a 5% tannic acid solution for a few minutes. The tannic acid solution is unstable and can only be used for 1 day.

6.3 Handling of lemons

Injuries and oleocellosis - Since lemons are mostly harvested when still green and hard, with an immature skin, they are extremely susceptible to injury. If roughly handled, numerous injuries may occur, giving access to decay organisms and resulting in oleocellosis. *Penicillium digitatum* may enter the fruit through ruptured oil cells, causing green mould rot. The stylar end of the lemon (nipple) is particularly prone to damage, and although leaving an unobtrusive oleo mark, it is a major point of entry for green mould organisms. Not only is the nipple often not properly covered with fungicide solution during packhouse applications, it is also frequently injured after fungicide application, e.g. during sizing, thus giving rise to points of entry for decay causing organisms.

Endoxerosis - Development of endoxerosis takes place independently of external fruit colour. It is found in green, silver and fully coloured fruit. However, the major proportion of fruit affected by endoxerosis are better coloured tree ripe fruit. It affects trees of all ages and in all production areas. Fruit on the northern side and in the top of the tree is more often affected. Samples of this fruit should be cut and checked for endoxerosis and if the incidence of endoxerosis is high, these fruit should be picked separately and withheld from export.

Fruit should be picked regularly and internally ripe fruit removed. This will reduce the number of over-mature fruit, which are more susceptible to endoxerosis.

Endoxerosis mostly occurs in fruit picked from February to April, which usually arise from flowering during May/June/July of the previous year. If the early flowering fruit (which later develops endoxerosis) is removed in September/October, when it can still be distinguished from the in-season fruit, very little endoxerosis is found later. This involves removing all the mature and large immature fruit still on the trees in September/October, after export packing has been completed. The small, immature fruit arising from the in-season flowering, should, of course, be left to develop.

Snap-picking – Snap-picking is allowed for all citrus varieties other than soft citrus, but is not recommended for lemons. Exporters who snap-pick their fruit are doing so at their own risk.