ABC

Agrobiotechnology (P) Ltd.

# Lemon

# Citrus Scientific Agronomy

The lemon (Citrus × limon) is a small evergreen tree native to Asia. The tree's ellipsoidal yellow fruit is used for culinary and non-culinary purposes throughout the world, primarily for its juice, though the pulp and rind are also used in cooking and baking. The juice of the lemon is about 5% - 6% citric acid, which gives lemons a sour taste. The distinctive sour taste of lemon juice makes it a key ingredient in drinks and foods such as lemonade.

## Land Preparation :

Where practicable, site preparation for growing citrus should be cleared completely and levelled before any planting operation begins. Any debris and unwanted materials should be removed from site, so as not to affect future field preparations.

Land preparation should be guided by topography, drainage requirements possible soil erosion and anticipated field layout. The site should be ploughed to a depth of at least 60 cm and beds cambered to at least 6.7 m wide. The top of the camber should be 1 m above the furrow, allowing sufficient depth of soil for tap root and lateral root growth, thereby ensuring proper anchorage for the plant.

Rotavating the land at this stage will help in reducing the size of the clods in the soil, forming a finer tilth whilst at the same time grading the beds. At this stage organic matter in the form of manure as well as lime stone ( if recommended) can be applied.

## Tree Spacing :

The tree spacing and filed layout adopted should allow for maximum interception of sunlight to obtain the highest yield per hectare while maintaining adequate space for mechanical operations. Recommended spacing for citrus can be approximate:
Sweet Lime : 6.5m x 6.5 m
Lemon : 4.5 m x 4.5 m

## Planting Distance :

Several planting patterns are in use, the most important being the square, the rectangular and triangular patterns. The number of plants per hectare will vary with layout desired. The rectangular and square layouts are neat systems easy to layout and allow for easier mechanization. The Triangular layout makes more efficient use of space by allowing a narrow inter row and about 15% more trees can be planted.
Where the land is undulating the trees may be planted in lines following the contour of the land. The trees will not be equidistant and the number of plants will be generally less than the other layouts. However, there is the advantage of preventing excessive soil erosion which outweighs the reduction in the tree population.

## Planting season :

The best time to plant tree is early in the wet season during June – July. Trees planted at this time can become well established before dry period begins. If however rainfall is uncertain or irrigation is not available at planting then the plants should be properly watered and mulched with dry vegetation to conserve water. Keep mulch at least 30 cm from the stem of the plant to prevent stem rot/foot rot and possible death of the plant. Do not plant more trees than can be cared for in one season.

## Planting :

The citrus plant must be removed from the polyethylene bag. Trees should be planted at the same depth as it was in the polyethylene bag. Ideally the bud union should be at least 30 cm above soil level. Do not establish the plant too deeply since the scion can come in contact with soil and foot rot can occur even at this early stage. Too shallow planting depth will expose the roots and cause poor growth.
For citrus trees to be healthy and productive, they require a range of mineral nutrients or elements which they extract from the soil. The level or concentration of these mineral nutrients in the leaves closely reflects the nutrient level in the plant and affects its vigor, health and fruitfulness. Rootstocks also can influence the trees ability to accumulate or exclude mineral elements. A successful nutrition program must include consideration of the important nutrients: nitrogen, phosphorus, potassium, calcium, magnesium, manganese, zinc, copper, iron, sodium and boron; and the chloride ion. Plant nutrition is a

complex process involving many elements and interactions. A successful fertilizer program is evolved over a number of years through careful monitoring of nutrient levels in the soil, plant tissue and assessment of yields and fruit quality.

## Functions of the main nutrients :

### Nitrogen (N) :

Important for the development of healthy shoots and fruits. It promotes fruit set and subsequent fruit sizing. Nitrogen levels affect yields.

### Phosphorus (P) :

Maintains good fruit quality. Ensures sugar development and high juice content and is needed in balance with nitrogen to produce smooth rinds. Phosphorus has a role in sugar transport within the tree and in the development of roots, flowers and shoots. Phosphorus levels affect yields.

### Potassium (K):

Important for the maintenance of tree vigour and the development of fruit quality and size. It has a vital role in the development of Vitamin C. Increased potassium results in thinner peels, increased juice content, total acidity and ascorbic acid. Potassium is also important for successful post-harvest storage of fruit.

### Magnesium (Mg) :

Necessary for chlorophyll development and seed development which in turn plays a vital role in the production of key growth regulators.

### Zinc (Zn) :

Aids in the formation and the function of chlorophyll and certain enzymes. Low levels of zinc result in small fruit with thick peels. Adequate levels of zinc are needed for successful development and set of flowers.

### Manganese (Mn) :

Has a key role in fruit production.

### Iron (Fe) :

Plays a vital role in the development of leaves.

### Calcium (Ca) :

Has a vital role in cell structure and strength and shelf life of fruit. Leaf tissue results may not be a good indicator of calcium levels in fruit. In some regions irrigation water often has relatively high levels of sodium, boron and chloride. The level of these elements is important because they can have negative effects on growth when they occur in higher than optimal levels. They can invalidate subsequent interpretation of other elements if they are in the “too high” or “excess”.

Soil analysis can provide information on soil texture, pH, the level of nutrients in the soil and nutrient ratios. Soil analysis results tell you what nutrients are in the soil. They do not tell you what is able to be taken up by the plant, leaf analysis provides this information. Soil analysis is of little value in highly alkaline soils as the extraction methods used in the laboratory do not simulate what the plant can extract. In neutral and acid soils the results of analysis is valuable and is used to help determine fertilizer requirements. The best time for sampling is before your main ground fertilizer application which normally occurs mid to late winter. It can often be done at the same time as your plant analysis. However, to avoid errors, sampling should not be done within two months of any fertilizer application to the soil. A sample size of about 400 g is required for analysis. The depth at which the sample is taken is also important and is specified by the analysis company. Soil tests at two depths, 0-15 cm and 15-30 cm are normally used in tree crops. A representative soil sample of a block or paddock is a composite sample made up of 20-30 individual samples which are mixed together into the one sample.
Different soil types should not be mixed together. Soil samples are normally taken in the plant row and within the effective root zone of the tree (ie halfway between the tree line and the trunk).

### pH testing :

Soil pH measures the acidity or alkalinity of the soil solution on a scale from 0 to 14,with 7 as neutral. pH can be measured in calcium chloride ($CaCl_2$) or water. pH measured in water is 0.5-0.8 higher than pH measured in $CaCl_2$.Remember that the pH scale is logarithmic; that is, each number going down the scale is10 times more acid than the number above. For example, soil with pH 5 is 10 times more acid than the number above For example, soil with pH 5 is 10 times more acid than one with pH 6.pH can be measured using a simple field kit Soil pits are useful for looking at soil conditions in the orchard. The pH level can be raised by the addition of lime or dolomite (which also provides magnesium). The quantities needed are determined by the soil type(more lime is needed on heavy clays than on sand) and the degree of acidity.

## Organic carbon :

Organic carbon is an estimate of the soil organic matter (humus) content. The percentage of organic carbon in organic matter is relatively constant and can be assessed as:
Percentage of organic matter = percentage of organic carbon x 1.6.
The benefits of organic matter include improves soil structure, provides nutrients, improves cation exchange capacity, provides mulch. If the soil shows an organic carbon percentage under three, then organic matter levels are low. A reading of less than one is very low.
Organic matter levels are increased by :
• Reduced cultivation;
• Addition of plant materials either as manure, cover crops, permanent swards or mulches.

## Nitrogen (N) :

Nitrogen is one of the key elements in plant growth. Most soil testing laboratories measure the nitrate (NO3)content of soil and express the results as mg/kg or parts per million (ppm) present as nitrate. Horticultural crops require high levels of nitrogen. A few points to note includes:
• Nitrate forms of nitrogen leach very easily.
• Soil type and organic matter levels affect soil levels, with heavier soils and higher organic matter levels having a greater capacity to retain nitrogen.
Nitrate levels of less than 40 mg/kg are considered low for horticulture in most situations.

Severe nitrogen deficiencysymptom

## Phosphorus (P) :

Phosphorus is another key element for plant growth. It stimulates root development, early growth and hastens maturity. Most laboratories analyse phosphorus using either the Bray or Colwell method. In each instance results are measured in ppm or mg/kg. A reading below 50 mg/kg is considered low for horticulture and a reading less than 20 mg/kg is very low. At a pH less than 5, phosphorous is fixed to the soil, iron and aluminium particles and is much less available to the plant. Phosphorous is not very mobile. In permanent crops it is best applied at planting. Dry conditions hinder the uptake of phosphorous.

## Potassium (K) :

Potassium increases plant vigour and disease resistance as well as improving fruit quality. Soil test readings are in milli equivalents per 100 grams of soil(m.e./l00 g). Requirements vary between crops, but as a rule of thumb, are adding of less than 0.5 m.e./l00 g indicates a shortage. Below pH 5.5,immobilization of potassium increases rapidly. Dry soils have lower potassium availability.

## Electrical conductivity (EC) :

This is a measure of salinity or the excess salt content of soils. At high levels of salt in the soil, plants are not able to absorb sufficient water. The EC figure reported should be multiplied by a factor depending on the texture of the soil.

Conventionally, saline soils are defined as those having an Ece value of greater than 4ds/m. However, it is important to realize that the sensitivity of plants to salinity varies greatly with different species. The Ece value for lemons is 1.7 ds/m. This is the maximum Ece value for no yield reduction. However, it is emphasized this figure is intended as a guide only; factors such as stage of growth (seedlings are usually more sensitive than mature plants), crop management, fertilizer application rates and placement, irrigation type, water quality and soil drainage all affect the occurrence and severity of salt toxicity.

## Cation exchange-capacity (CEC) :

CEC is a measure of the ability of soil to attract and hold cations by electrical attraction. The surfaces of clays and soil organic matter generally have net negative electric charges. This is, neutralised by positively charged ions(cations). Because they are held by electrical charges, they can be replaced by other cations. This process is known as cation exchange. The concentrations of these cations are expressed as milli equivalents per 100 grams soil (m.e./100g).

This takes account of their different valencies and atomic weights. Multiplication factors for converting EC (1 : 5) to an approximate quantity of cations that a soil can hold is called the cation exchange capacity(CEC).

The five most abundant cations in soil are calcium (Ca2+), magnesium (Mg2+),potassium (K+), sodium (Na+), and aluminium ($Al_3^+$). The cations manganese(Mn2+), iron (Fe2+), copper (Cu2+) and zinc (Zn2+) are usually present in only trace amounts and so do not contribute significantly to the exchangeable soluble cation complement. It is therefore common practice to measure the concentrations of only the five most abundant cations. Their concentrations may be summed to give an approximate value of CEC (sometimes called the effective CEC). The individual cations may then be expressed as a percentage of the CEC. Sandy soils and acid soils that have been strongly leached often have very low levels of exchangeable calcium and magnesium, and plant growth may be limited as a result. Also, exchangeable potassium levels below 0.2m.e./100g suggest that a response to the application of potassium fertiliser is possible, particularly where heavy removal of potassium by harvesting of the crop occurs. There is considerable evidence, however, that the proportions of the various cations of the CEC (expressed as a percentage) are more relevant to plant performance than the actual levels. A guide to desirable ranges for many plants are:

- Calcium ---------------- 65-80%
- Magnesium ----------- 10-15%
- Potassium ------------- 1-5%
- Sodium ---------------- 0-1%
- Aluminium ------------ less than 5%

Values of exchangeable magnesium greater than 20% may induce potassium deficiency. Conversely, values of exchangeable potassium above 10% may result in magnesium deficiency. Soils having values of exchangeable sodium exceeding 6% are described as sodic. The clay particles in such soils are liable to disperse on wetting, causing structure to deteriorate, with resultant problems for agricultural production. A ratio of exchangeable calcium to exchangeable magnesium less than 2 is also thought to favour clay dispersion. Exchangeable aluminium is usually present in the soil at pH ($CaCl_2$) levels of less than 5.0, and is always associated with low levels of exchangeable calcium and magnesium. When aluminium levels reach 20-30%, most agricultural plant species perform poorly and the response to super phosphate application is reduced. However, some plants are sensitive to much lower levels than 20-30%.

### MICRO NUTRIENT DEFICIENCIES

Micronutrients commonly low in citrus are zinc, manganese and magnesium. These deficiencies can be a result of too low or too high soil pH, nutrient imbalances, or naturally low nutrient levels in the soil. Nutrient deficiencies can be more easily diagnosed using plant analysis. Visual symptoms can be used but take care as sometimes they can be confusing, particularly when deficiencies of several nutrients occur at the same time. Deficiency problem can be alleviated either by improving soil pH, or by application of the required nutrient (soil, fertigation or foliar) or a combination of both.

### Foliar Application

Foliar application is commonly used to correct micro nutrient deficiencies especially if they are a consequence of soil pH. Foliar application of nutrients is most effective when applied to young flush growth, 1/3rd to 2/3rds full leaf size. Mature foliage has a thick waxy cuticle which may reduce uptake of these nutrients. Traditionally foliar applications of zinc, manganese and magnesium were applied once a year in spring. However, more recently citrus growers have been making two applications annually, in spring and summer, with good results.

## Magnesium deficiency :

Magnesium deficiency symptoms

Magnesium deficiency is chiefly a problem of acid leached soils. Symptoms develop on mature leaves at any time of the year, but most usually as the fruit is maturing, especially in limbs bearing a heavy crop. Yellow blotches start near the edges of the leaves, and eventually coalesce to form yellow bands on each side of the midrib. These areas enlarge until only a triangular-shaped area at the base of the leaf remain green.

## Manganese deficiency :

Manganese deficiency symptoms

Manganese deficiency occurs in acid soils where the manganese content is low or in alkaline soils, where manganese may be present but unavailable to the plant. Manganese deficiency is indicated when leaves become mottled with lighter green or yellowish green areas between the major veins. The veins themselves and bands of tissue on each side remain green. Leaf size is usually normal. Both young and mature leaves may show symptoms. Where the deficiency is Magnesium.

## Zinc deficiency :

Zinc deficiency affects citrus growing on both acid and alkaline soils but is usually more severe on alkaline soils. Excessive use of phosphate fertilisers can accentuate zinc deficiency Leaves are small and abnormally narrow and rather crowded on short stems; this produces a bunched appearance. Areas between the main lateral veins are whitish yellow. This mottling, which first appears between the main veins, is shown in the young growth and persists as the leaf ages. There is considerable dieback of the smaller twigs with production of multiple buds and numerous small, weak shoots, so that the trees become bushy and stunted. Mild early stages of zinc deficiency resemble those of manganese deficiency. Zinc and manganese deficiencies can occur in combination and may be treated with a combination spray.

## Iron deficiency :

Trees suffer from iron deficiency mostly in calcareous soils with high pH (alkaline) values. High levels of phosphorous can also induce iron deficiency. The younger leaves are light green to pale yellow with a network of darker green veins. In general, leaf size is normal and the shoots are not shortened. In severe cases the leaves become very pale, even whitish, and the colour of the smaller veins fades until only a little green remains in the midrib. Dieback occurs, little or no fruit is carried and new growth is poor.

Iron deficiency symptoms

**Fertlizer Recommendation (Grams/Tree)**

| Fertilizer | Age of Tree | | | |
|---|---|---|---|---|
| | 1st Year | 2nd Year | 3rd Year | 4th Year |
| Nitrogen | 150 | 300 | 150 | 600 |
| Phosphorus | 50 | 100 | 150 | 200 |
| Potassium | 25 | 50 | 75 | 100 |

Nitrogen containing fertilizers should be applied in three equal splits in January, July and November months, Phosphorus containing fertilizers in two splits in January and July months and Potassium containing fertilizers may be applied as singly dose in January.

## Irrigation

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 inter row 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.

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.

**Water Requirement : (Litres/Day/Tree)**

| Month | Age of Tree ( Years) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | >10 |
| January | 7 | 15 | 22 | 30 | 44 | 62 | 72 | 82 | 92 | 102 |
| February | 9 | 20 | 30 | 40 | 60 | 82 | 96 | 101 | 121 | 137 |
| March | 12 | 26 | 40 | 53 | 78 | 109 | 127 | 145 | 163 | 181 |
| April | 14 | 29 | 43 | 63 | 87 | 123 | 143 | 163 | 183 | 204 |
| May | 17 | 34 | 52 | 74 | 102 | 143 | 166 | 188 | 211 | 235 |
| June | 11 | 22 | 34 | 48 | 67 | 95 | 110 | 126 | 142 | 157 |
| July | 8 | 18 | 26 | 41 | 56 | 79 | 92 | 105 | 118 | 131 |
| August | 7 | 14 | 23 | 34 | 42 | 60 | 70 | 80 | 90 | 100 |
| September | 8 | 15 | 25 | 36 | 45 | 65 | 76 | 87 | 98 | 108 |
| October | 9 | 17 | 27 | 40 | 52 | 79 | 92 | 105 | 118 | 131 |
| November | 8 | 15 | 25 | 36 | 45 | 63 | 74 | 85 | 96 | 150 |
| December | 6 | 11 | 19 | 24 | 35 | 49 | 57 | 65 | 73 | 82 |

## Pruning and Canopy Management

Lemon trees tend to have a more willowy or weeping tree structure than that of most orange and mandarin varieties. The branches and limbs tend to be more easily broken in strong winds and when the crop load is heavy. Overall lemon tree branches tend to be longer, thinner and more flexible than those of orange trees. Pruning should aim to shorten these branches. In some varieties, such as Eureka and Meyer, the fruit tend to be borne in clusters at the ends of branches, which then bend downwards under the weight of the fruit. When the fruit are removed the branch normally springs back in to position. Sometimes the crop load is so heavy that these long willowy branches can break. Fruit produced on the outside of trees and in clusters on the ends of branches are more prone to wind damage. Pruning should aim to encourage fruit on the insides of trees where it is more protected from wind. Lemons also have a tendency to produce strong, vigorous upright water shoots that are usually thorny. These are normally unproductive and should be removed as early as possible. Sometimes these water shoots can be used quite effectively to replace old unproductive structural limbs when rejuvenating trees. In some areas lemons grow almost continuously throughout the year producing multiple leaf flushes and crops. The new leaf flush in lemons tends to be a reddish purple colour which changes to green as the leaves mature.

## PRUNING STAGES

Young tree formation Pruning normally starts when the trees are 18 months to 2 years old. At this stage pruning is used to develop the trees structural framework. The aim is to have 3-5 main limbs, with the lowest branch starting at least 65cm above the ground. Maintenance pruning of bearing trees. A more regular program of pruning starts when the trees start to regularly crop. The aims of pruning now are more diverse.

**Pruning is undertaken to :**

- Remove diseased, dead, weak or old growth;
- Remove crossed over branches or branches in the wrong place;
- Thin out and open up the tree canopy to improve light and air penetration; reduce or manipulate flowering or crop load.
- Reduce tree height or width;
- Improve spray coverage.

Rejuvenation pruning of old trees:

This type of pruning is normally undertaken on old trees which are still healthy with the aim of reinvigorating the tree to improve cropping potential. With this type of pruning major limbs are normally removed (skeletonizing) to encourage replacement with new young branches. This type of pruning should be undertaken over a number of years. Typically trees are pruned initially on one side so that some crop yield is retained, the other side is then pruned 1-2 years later

**PRUNING TIPS**

Pruning should be a regular part of tree management.

When hand pruning sterilise your pruning equipment after each tree to reduce the spread of disease. When using mechanical pruning machinery, the blades should be sterilised after each block or variety. (A sterilizing solution of 3% sodium hypochloride can be used.)

Heavy pruning should not be carried out in hot weather as sunburn of branches or fruit may occur.

In areas where there is the potential for frost, pruning should not be done at a time when the resulting young flush growth will be susceptible to frost damage.

Heavy pruning at the wrong time can result in excessive vegetative growth.

Pruning during bud break or flowering will impact on crop load.

The heavier you prune the longer it takes for the tree to recover and therefore crop

## Diseases :

### Lemon Scab

Lemon scab is a serious disease of all lemon varieties grown in coastal areas. The disease also affects even rough lemon root stocks. Lemon scab is caused by the fungus Sphacelomafawcettii var. scabiosa.

### Symptoms :

Citrus scab attacks the fruit, leaves and twigs, producing slightly raised, irregular scabby or wart-like outgrowths. At first these outgrowths are grey or pinkish, becoming darker with age. They are more common on fruits than leaves. The raised lumps associated with scab can be confused with symptoms caused by the disease botrytis (which is uncommon) or wind rub abrasions on young fruit.

### Disease source :

Spores of the fungus are readily produced on the surface of scab lesions on young fruits throughout the year. Spores of the fungus are spread by wind and rain. The fungus over-winters on the tree canopy, mostly in scab lesions on fruit. Rough lemon rootstock is also very susceptible to scab and can act as a source of the fungal inoculums. Moist conditions favour disease development. Most spores come from small infected lemon fruits.

**Infection period :**

Lemon foliage is susceptible to infection when the new growth flush is less than 25% expanded. Immature lemon fruits are susceptible to infection from quarter petal-fall to about 12 weeks later (or 3-4 cm in diameter). Leaf wetness is the most important factor determining infection. For germination and infection to occur the scab spores need a wetting period from rain, overhead irrigation or spraying of at least 4 hours continuously or 1-2 hours followed by 3-4 hours within the next 24 hours. Brief wetting of foliage by non-fungicidalspray treatments has also been found to promote infection.

Temperature does not appear to have a major impact on the disease. The severity of infection depends on the amount and frequency of wetting periods whilst the growth flush and fruit rind are susceptible to attack. The extended bloom period in lemons makes accurate timing of sprays difficult.

**Control :**

Protective copper sprays are the only products registered to control scab in citrus. Since copper is a protectant fungicide the entire fruit surface needs to have a continuous coating of copper in order to be protected from infection by the fungal spores. This protective copper coating does not expand as the fruit grow so unprotected gaps on the fruit surface will occur and these areas will be susceptible to infection (if conditions are conducive). Therefore the protective copper layer may need to be reapplied to the growing fruit during the susceptible stage. Another problem with controlling scab in lemons is the extended flowering and multiple cropping habit of these trees in warmer areas and the decision of when to apply the protective sprays. In areas where there is only one main crop a year a control strategy is simpler to implement. Overall control is a combination of both management practices and protective copper sprays.

Trees need to be regularly pruned to keep them open and free of deadwood. This will help to reduce the source of disease spores, allowing for better air movement within the tree and better spray coverage inside the tree. In coastal areas if trees are not regularly pruned then they should be replaced after 10–12 years because of the amount of dead wood and subsequent disease load in the trees. The fruit surface needs to be protected until fruit is 3–4 cm in diameter (9–12 weeks). The recommendation for timing of copper sprays has traditionally been at the main flowering in spring at quarter to half petal fall and then to apply a second copper spray 6–8 weeks later. However, due to the habit of lemon trees producing multiple crops, copper sprays may need to be applied at other times of the year to protect the spring and summer crops. Obviously it is highly unlikely that the first spray would protect the fruit continuously for 6 weeks in wet conditions. The best control strategy is to get the first spray on at the right time (quarter to half petal fall). The timing of your next spray will be variable depending on weather conditions. For example, if the weather conditions are generally dry after the first spray and rainfall events are unlikely to cause a spore release then a second spray at 6 weeks may be all that is required. However if the weather is rainy and it is likely to trigger an infection then the second spray may need to be applied earlier. In the end there is no hard and fast rule, it is a choice of which crop needs protecting and putting the sprays on at the right time and then finetuning the program according to local weather conditions.

**Phytophthora Root Rot :**

Phytophthora root rot causes a slow decline of the tree. The leaves turn light green or yellow and may drop, depending on the amount of infection. The disease destroys the feeder roots of susceptible rootstocks. The pathogen infects the root cortex, which turns soft and separates from the stele. If the destruction of feeder roots occurs faster than their regeneration, the uptake of water and nutrients will be severely limited. The tree will grow poorly, stored energy reserves will be depleted, and production will decline. Phytophthora species are present in most citrus groves. They can survive adverse conditions as persistent spores in the soil. During moist conditions, large numbers of motile zoospores, which can swim in water for short distances, are produced. Zoospores are the infective agents that are carried in irrigation or rainwater to the roots. Phytophthora citrophthora is a winter root rot that also causes brown fruit rot and gummosis. Phytophthora citrophthora is active during cool seasons when citrus roots are inactive and their resistance to infection is low. Phytophthora parasitica is active during warm weather when roots are growing.

## Control Measures :

### Sanitation

It may be possible to slow the spread of Phytophthora within an orchard by avoiding movement of infested soil, water, and plant parts from an area where Phytophthora rot has developed. Surface and subsurface drainage water and anything that can move moist soil can carry the pathogen to a new area, including boots, car tires, and tools. If the physical setting allows drainage water to flow from infested to uninfected areas within the garden during wet weather, consider putting in drains to channel the water away from healthy plants.

### Selection of planting stock :

Plant only certified nursery stock from a reputable source, and choose the most resistant rootstocks or varieties available for your area. Carefully select individual plants that are free of symptoms and/or that come from healthy lots of material.

### Rotation :

If tomatoes have been affected by Phytophthora root rot, avoid planting tomatoes or other susceptible plants such as eggplant or peppers in the same soil for at least one or two seasons. Plant a resistant crop such as corn instead, or leave the soil unplanted and do not irrigate, but keep it well worked to allow the soil to dry as deeply as possible. Different species of Phytophthora attack beans and cole crops, so these plants can be substituted as well.

### Chemical control :

The most effective way of preventing Phytophthora rot diseases is to provide good drainage and to practice good water management. Along with the appropriate cultural controls, the fungicide“Aliette” will help prevent Phytophthora infections. When applied as a foliar spray it is absorbed by foliage and moves into roots. However, do not rely on fungicide applications alone to control root and crown rot diseases. Disease symptoms are often difficult to distinguish from nematode, salt, or flooding damage; only a laboratory analysis can provide positive identification.

## Phytophthota gummosis :

### Symptoms

An early symptom of Phytophthora gummosis is sap oozing from small cracks in the infected bark, giving the tree a bleeding appearance. The gumming may be washed off during heavy rain. The bark stays firm, dries, and eventually cracks and sloughs off. Lesions spread around the circumference of the trunk, slowly girdling the tree. Decline may occur rapidly within a year, especially under conditions favorable for disease development, or may occur over several years.

Phytophthora fungi are present in almost all citrus orchards. Under moist conditions, the fungi produce large numbers of motile zoospores, which are splashed onto the tree trunks. The Phytophthora species causing gummosis develop rapidly under moist, cool conditions. Hot summer weather slows disease spread and helps drying and healing of the lesions.
Secondary infections often occur through lesions created by Phytophthora. These infections kill and discolor the wood, in contrast to Phytophthora infections, which do not discolor wood.

- Avoids contact of the susceptible scion bark with infested soil.
- Adequate soil drainage is essential because poor drainage and over watering combine to promote build-up of pathogen populations in the soil, which increases the risk of bark infection.
- The soil surface under the tree must be kept free of weeds.
- Injuries to the trunk bark must be avoided, since they provide entry points for pathogens

In addition to improving the growing conditions, the spread of the disease can be halt by removing the diseased bark and a buffer strip of healthy, light brown to greenish bark around the margins of the infection. Allow the exposed area to dry out. You can also scrape the diseased bark lightly to find the perimeter of the lesion and then use a propane torch to burn the lesion and a margin of 2.5 cm around it. Recheck frequently for a few months and repeat if necessary.

Chemical control may be warranted if cultural controls are inadequate. Systemic fungicides fosetyl-aluminum can control Phytophthora gummosis and copper sprays can be used to protect against infection. Fungicides may be applied to young trees on a preventive basis to control gummosis. On tolerant rootstocks, fungicide treatments are used only if bark lesions develop. Fungicides should be applied during periods of susceptible root flushes, and soil applications should be targeted to areas of highest fibrous root density under the canopy. If 50% or more of a trunk or crown region on a mature tree is girdled, it is more economical to replace the tree than to try to control the infection.

## Citrus Canker

### Symptoms and Signs :

Citrus canker can be a serious disease where rainfall and warm temperatures are frequent during periods of shoot emergence and early fruit development. Citrus canker is mostly a leaf-spotting and fruit rind-blemishing disease, but when conditions are highly favorable for infection, infections cause defoliation shoot dieback, and fruit drop. Xanthomonas axonopodispv. citriand Xanthomonas axonopodispv. Aurantifolii are the pathogen responsible for this disease.

Canker infected fruit, foliage, and stems

**Leaf Lesions :** Citrus canker lesions start as pinpoint spots and attain a maximum size of 2 to 10 mm diameter. The eventual size of the lesions depends mainly on the age of the host tissue at the time of infection and on the citrus cultivar. Lesions become visible about 7 to 10 days after infection on the underside of leaves and soon thereafter on the upper surface. The young lesions are raised on both surfaces of the leaf, but particularly on the lower leaf surface. The pustules eventually become corky and crateriform with a raised margin and sunken center. A characteristic symptom of the disease on leaves is the yellow halo that surrounds lesions. A more reliable diagnostic symptom of citrus canker is the water-soaked margin that develops around the necrotic tissue, which is easily detected with transmitted light.

### Fruit and Stem Lesions :

Citrus canker lesions on fruit and stems extend to 1 mm in depth, and are superficially similar to those on leaves. On fruit, the lesions can vary in size because the rind is susceptible for a longer time than for leaves and more than one infection cycle can occur. Infection of fruit may cause premature fruit drop but if the fruit remain on the tree until maturity such fruit have reduced fresh fruit marketability. Usually the internal quality of fruit is not affected, but occasionally individual lesions penetrate the rind deeply enough to expose the interior of the fruit to secondary infection by decay organisms. On stems, lesions can remain viable for several seasons. Thus, stem lesions can support long-term survival of the bacteria.

Figure 7

### Disease Cycle :

Bacteria propagate in lesions in leaves, stems, and fruit. When there is free moisture on the lesions, the bacteria ooze out and can be dispersed to infect new growth. Wind-driven rain is the main dispersal agent and wind  at the speed of 18 mph aids in the penetration of bacteria through the stomatal pores or wounds made by thorns, insects (leafminer), and blowing sand. Pruning causes severe wounding and can lead to infection. Multiplication of bacteria occurs mostly while the lesions are still expanding and numbers of bacteria produced per lesion is related to general host susceptibility.

### Disease Management :

Exclusion: The first line of defense against citrus canker is exclusion. Citrus canker still does not exist in some countries or regions of countries where climatic conditions are favorable for pathogen establishment, which is probably because of rigid restrictions on the importation of propagating material and fruit from areas with canker. Unfortunately, with increased international travel and trade, the likelihood of X. axonopodispv. citri introduction is on the rise as it is with many exotic pests and pathogens.

**Sanitation :** Numerous cases of new infections of citrus canker are linked to human and mechanical transmission. Humans can carry bacteria on their skin, clothing, gloves, hand tools, picking sacks, ladders, etc. Vehicles can become contaminated by brushing wet foliage or coming in contact with plant material. Machinery such as tractors, implements, sprayers, hedgers, etc. can similarly become contaminated and even inadvertently transport plant parts. In areas where citrus canker is resident, it is necessary to construct decontamination stations for personnel, vehicles and machinery which are sprayed with bactericidal compounds.

**Eradication :**

Once introduced into an area, elimination of inoculum by removal and destruction of infected and exposed trees is the most accepted form of eradication. To accomplish this, trees may be uprooted and burned or in urban areas, cut down and chipped and the refuse disposed of in a landfill.

**Disease Management :**

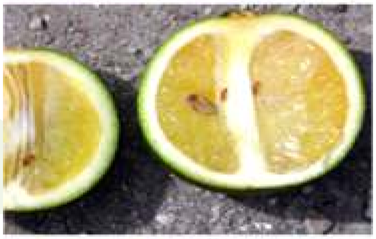
In regions where canker is endemic, certain cultural practices are used to reduce the severity of the disease. It is imperative to avoid working in infected orchards when the trees are wet from dew or rain. The reduction of wind is another primary concern. Wind speeds are reduced by deployment of windbreaks on the perimeter of the orchard or between the rows. Reduction of wind speed lowers the probability of direct penetration of stomata's by bacteria as well as entry of wind-induced injuries on foliage and fruit.

Where canker is a major problem, control requires integration of appropriate cultural practices including sanitation, windbreaks and leafminer control with frequent applications of copper sprays. Copper sprays have been shown to reduce infection somewhat. Because the fruit is susceptible to canker during the first 90 days after petal fall, it is important to maintain a protective coating of a copper material on the fruit surface during this period. Two or three treatments may be needed for this purpose, depending on rainfall and cultivar susceptibility. Windbreaks can greatly reduce spread and severity of disease and increase the efficacy of copper sprays. Leafminer control is particularly important on young trees and certain cultivars that have a high proportion and greater frequency of vegetative growth flushes.

**Huanglongbing Disease ( Citrus Greening)**

Huanglongbing (HLB), also known as citrus greening disease, is a bacterial plant disease that – while not harmful to humans or animals and is fatal for citrus trees. The disease destroys the production, appearance and economic value of citrus trees. Diseased trees produce bitter, hard, misshapen fruit and die within a few years of being infected. HLB is considered to be one of the most serious plant diseases in the world and currently there is no cure.

HLB is spread by the Asian citrus psyllid, a tiny insect that feeds on the leaves and stems of citrus trees. When an Asian citrus psyllid feeds on an HLB infected tree, it can pick up the bacteria that cause the disease. Once infected, a psyllid carries the disease causing bacteria for life and can transfer the disease when feeding on other citrus trees. An important way to control the spread of HLB is to stop the Asian citrus psyllid.



The disease can also be spread by grafting infected plant tissue onto another plant. For this reason, it is important to only use registered budwood with documentation that demonstrates it came from a disease-free tree.

Detection of HLB can be difficult, as symptoms may not show up for more than a year after the tree has become infected. The first symptoms are yellowed leaves. However, citrus trees often have yellow leaves because of nutritional deficiencies. HLB leaf symptoms are somewhat unique in that the yellow mottling caused by HLB is not the same on both sides of the leaf.

Later symptoms of HLB-infected trees include lopsided, small fruit, and premature and excessive fruit drop. Additionally, the disease can cause entire shoots or branches of the tree to become yellow.
The best way to protect your citrus tree from HLB is prevention. Inspect your tree monthly for the Asian citrus psyllid.
HLB and the Asian citrus psyllid threaten not only local farms and farmers we count on for fresh, healthy, locally produced citrus, but also residents' ability to grow citrus fruits in their backyards.
Once a tree is infected with HLB, it will die and must be removed to protect other nearby citrus trees. Diseased trees can become a reservoir and breeding ground for Asian citrus psyllids carrying HLB, allowing the insects to spread the disease. Infected trees must be removed to protect other citrus trees.

## Citrus Blight :

Citrus blight is one of the most important decline diseases of citrus in the world. This disease occurs widely in many countries in Central and South America as well as in South Africa, Australia, and other areas. Blight is rare in arid, winter-rainfall areas such as the Mediterranean, California, and inland areas of Australia.
A disease referred to as blight has been studied in Florida for over 100 years. This disease was commonly observed on trees on sour orange rootstock in the coastal citrus areas of Florida. Since it was not characterized at the time, it is not known whether this disease is the same as the one now known as blight. Citrus blight in the early days in Florida was known variously as young tree decline (even though it only affected bearing trees), sandhill decline, and rough lemon decline. All of these names refer to the same disease. Only in the 1970s and 1980s were studies conducted that led to clear differentiation of blight from other decline diseases.

## Harvest and Post-Harvest :

The most commonly used non-destructive indices of harvest maturity are peel color and size. Lemons may be picked either at the dark green color stage or when the peel has started to turn yellow. Fruit picked at the dark-green stage have the longest post harvest life, but generally have not reached their maximum juice content. Fruit left on the tree to turn slightly yellow will have higher juice content, but a shorter market life.


Fruit size may also be used to determine harvest maturity. Lemon fruit with a diameter less than 5 cm are generally not sufficiently developed and have less than the desired juice content. Juice volume is the most commonly used internal index for determining harvest maturity. Random samples of fruit of similar size are harvested and the % juice content is measured. The generally accepted standard for proper harvest maturity is a minimum juice content of 28% by volume.

## Preparation for Market

The lemons should be brought to the packing area soon after harvest to begin the steps of preparing the fruit for market. These steps involve cleaning, grading, and packing, apart from that it may be need to be treated with ethylene in order to improve the external peel color. The ethylene treatment should be done prior to cleaning, grading, and waxing.

## De-Greening :

Lemon fruit may have sufficient juice content for harvest when the peel is still green. In order to change the external color and de-green the peel, lemons can be exposed to either ethylene gas or liquid ethylene. These treatments break down the green chlorophyll pigment in the peel surface and allow the yellow carotenoid pigments to be expressed. Ethylene treatment is solely cosmetic in effect and does not alter the flavor of the fruit or the juice content. The de-greening protocol involves exposing green-skinned lemons to low concentrations of ethylene (usually between 1 to 10 ppm) at 20-25°C, 90% relative humidity for several days. The optimal ethylene concentration and treatment duration varies by the cultivar and growing conditions. Excessive ethylene (above 10 ppm) can cause stem end rot and increase decay. In order to achieve good de-greening results, adequate internal air movement is necessary. Also, regular ventilation with fresh outside air is needed to keep the $CO_2$ levels inside the treatment chamber low enough (below 2000 ppm) to avoid the inhibition that high $CO_2$ levels have on the effectiveness of ethylene. A liquid ethylene-releasing compound, called ethephon [(2-chloroethyl) phosphonic acid], is another effective de-greening agent. It is applied by dipping the lemons for 1minute in a tank of clean water with 500 ppm ethephon. It is important that the water be properly sanitized with chlorine (150 ppm hypochlorous acid at a pH of 6.5). A fungicide should also be added to prevent post harvest decay. Recommended fungicides are benomyl (500 ppm active ingredient) or thiabendazole or imazalil (1000 ppm active ingredient).

A negative consequence of de-greening lemons is the increase in senescence of the stem end and abscission of the button. De-greening should always be done prior to waxing. The wax coating will partially restrict gas exchange through the peel and inhibit the action of ethylene.

## Cleaning :

Washing of the lemons after harvest is necessary to improve the appearance of the fruit by removing dirt, sooty mould, scale insects, and spray residues. Lemons can be cleaned manually by hand rubbing or brushing individual fruit dumped in a tank of sanitized water with detergent. Either sodium hypochlorite or sodium o-phenylphenate (SOPP) can be used as sanitizing agents for the wash water. Sodium hypochlorite is readily available in the form of household bleach. It is typically sold in a 5.25% solution. The wash water should be sanitized with a 150 ppm sodium hypochlorite concentration and maintained at a pH of 6.5.Lemons can also be cleaned mechanically by passing the fruit over a series of soft bristled roller brushes. The lemons are thoroughly wetted as they pass under a series of spray nozzles. Rotating brushes will remove most of the debris. Soap or detergent may be added to the fruit to improve the effectiveness of the cleaning operation as the fruit continues across the brushes. Adequate cleaning usually requires about 30 seconds on the brushes, rotating at about 100 rpm. The fruit is then thoroughly rinsed as it passes over the last of the brushes. Excess water on the fruit can be eliminated with sponge rollers. The lemons may then continue down a slow moving conveyor belt for sorting and grading or be put on a mesh or screen table for drying and eventual grading.
Thiabendazole (TBZ), imazalil, and benomyl are the most effective post harvest fungicides for lemons and can be applied as high pressure sprays after washing. They are typically applied at a dose of 500 to 1000 ppm active ingredient in water. These fungicides can also be applied in water-emulsion waxes.

## Sorting :

Immediately after washing the lemons should be sorted into different grades based on external appearance. The main characteristics used in categorizing the fruit are intensity and uniformity of yellow colour, size, shape, smoothness, and freedom from damage and decay. The fruit within each grade should be uniform in appearance and void of noticeable blemishes. Lemons with discolored peels and bruised or wrinkled skins should not be packed for the fresh market.

## Waxing :

Lemon fruit benefit from a post harvest wax application. Much of the surface wax on the peel of the fruit is removed during cleaning. Waxing retards moisture loss and the rate of shrivel, thereby extending market life. Water-emulsion waxes do not require completely dry fruit, so the wax can be applied right after washing and grading. In small volume operations, the wax can be applied manually by rubbing individual lemons with a water emulsion wax soaked cloth. Larger volume operations will find it more efficient to apply the wax automatically from overhead spray jets as the fruit is moving underneath on a series of slowly rotating (not more than 100 rpm) horsehair-type roller brushes. Care must be taken to avoid over-application of the wax. Too thick a coat may restrict gas exchange through the peel and create an internal oxygen deficiency. This may result in the development of off-flavors. A carnauba water-emulsion wax is preferred over ashellac - based wax because of better gas exchange and less likelihood of juice fermentation. A fungicide can be incorporated in the wax to prevent post harvest decay.

Recommended fungicides are thiabendazole or imazalil (2000 ppm) or benomyl (1000ppm). The fungicide concentration incorporated in the wax is double the amount recommended in wash or spray water.

## Packing :

Lemons should be packed in strong, well-ventilated containers. Wooden crates are adequate for domestic marketing. However, large sacks holding more than 30 kg of fruit should not be used. Fruit inside the sacks are not adequately protected and considerable compression bruising will occur.

## Temperature Management :

The optimal post harvest storage temperature for lemons depends on skin color. Green lemons should be stored at 12°C and at this temperature have an estimated storage life of up to 4 months. Yellow coloured lemons should be stored at a slightly cooler temperature, with 10°C being ideal. Potential storage life at this temperature will be several months.

## Relative Humidity :

In order to minimize moisture loss and maintain post harvest fruit quality, lemons should be stored at their optimum relative humidity (RH) of 90% to 95%. At a low RH the peel will lose water and become shriveled within several weeks. This will negatively impact the appearance and market potential of the fruit.

## Post harvest Disease :

Lemons are susceptible to a number of post harvest fungal diseases. Some of the pathogens attack the fruit prior to harvest, but exist in a resting state until the conditions are right for infection. Others infect the fruit only after harvest. Lemons should be harvested and handled gently to avoid bruising and skin injury, which greatly accelerates post harvest microbial decay. Reduction of post harvest decay is also achieved by the use of appropriate pre-harvest and post harvest fungicides, proper sanitation of the wash water, and prompts cooling to 12°C. In addition, adequate ventilation during storage is necessary to remove ethylene, which increases the severity of many post harvest diseases. Small pads treated with the fungistat diphenyl are beneficial in retarding decay development when placed inside cartons.

## Green Mould :

Green mould, caused by the fungus Penicillium digitatum, is typically the worst post harvest disease of lemons. It attacks injured areas of the peel and first appears as a soft, watery, slightly discoloured spot on the rind. The spot enlarges to several centimetres in diameter within a day at ambient temperature, and the rot soon penetrates the juice vesicles. White fungal growth appears on the fruit surface and soon after olive-green spores are produced. The sporulating area is surrounded by a broad zone of white fungal growth and an outer zone of softened rind.

The spores are easily dispersed if the fruit is moved. If the storage RH is low, the whole fruit shrinks to a wrinkled, dry mummy. If the RH is high, the fruit collapses into a soft, decomposing mass. The decay spreads very little in packed cartons, but masses of spores produced on one infected fruit can soil surfaces of healthy fruit with green-coloured spores. This disease develops most rapidly at about 24°C. It can be minimized by using good pre-harvest sanitation practices, careful harvesting and handling to avoid injuries to the peel, a post harvest dip or spray with a benzimidazole fungicide (i.e. 500 ppm benomyl, or 1000 ppm thiabendazole or imazalil); and holding the fruit at 12°C.

## Blue Mould :

Blue mould, caused by the fungus Penicillium italicum, is another common post harvest disease of lemons, but is usually less prevalent than green mould. Early symptoms are similar to green mould. Diseased tissue becomes soft, watery, and slightly discoloured and is easily punctured. The lesions enlarge more slowly than those of green mould. A white, powdery fungal growth develops on the lesion surface, and soon blue spore mass forms, leaving only a narrow white fringe of fungal growth surrounding the lesion. A pronounced halo of water-soaked, faded tissue surrounds the lesion between the fringe of fungal growth and the sound tissue. The blue spores covering the fruit may become brownish-olive with age. Healthy fruit in packed containers become soiled by spores shed from the diseased fruit. Unlike green mould, blue mould spreads in packed containers and results in nests or pockets of diseased fruit.

Like green mould, blue mould develops most rapidly at about 24°C. However, blue mould grows better than green mould at cool temperatures and may predominate over green mould in yellow coloured lemons stored at 10°C. Immediate cooling after packing significantly delays development of blue mould, especially if the fruit storage temperature can be maintained at 12°C. Additional disease control recommendations are identical to those listed for green mould.

**Black Mould :**

Black mould, caused by the soil-borne fungus Aspergillus niger, infects lemons only at fairly high temperatures and only after they have been weakened in some way. External symptoms begin as a very soft sunken water soaked spot on the peel. The spot enlarges and black spores resembling soot appear in the center (see photo). The decay is accompanied by a fermented odour. Internal symptoms of black mould include the development of masses of black powdery spores which become obvious when the fruit is cut open. Harvesting and handling wounds predispose lemon fruit to infection. The fungus may also invade the peel through cuts in the skin or a stem-end injury. Black mould develops rapidly at ambient temperature and spreads to adjacent fruits. In mixed infections, it tends to outgrow other fungi. Control of black mould is obtained by avoiding damage to the peel tissue and storing the fruit at 10°C to 12°C. Decay is insignificant at temperatures below 15°C.

**Gray Mould :**

Gray mould, caused by the fungus Botrytis cinerea, is a common post harvest disease of lemons during cool temperature storage under high humidity. Symptoms appear as a brown leathery decay of the peel, with gray brown to olive spore masses forming around the affected areas of the fruit surface. The disease spreads readily by contact with adjacent fruit, giving rise to large nests of diseased fruit in packed containers. Optimal temperatures for growth of the fungus are between 18°C to 23°C. However, some growth will also occur at the recommended cool storage temperature. Proper field sanitation, pre-harvest fungicide sprays, and prevention of wounds on the fruit help reduce the incidence of gray mould.

**Black Rot :**

Black rot, caused by the fungus Alternaria citri, is a serious disease in lemons that have been stored for more than one month. The fungus typically enters the fruit through the button and stem-end decay occurs. Lesions developing from infections of the button become light brown to black in colour, and gradually progress over the fruit surface from the blackened button towards the stylar-end. As the button deteriorates during storage, the fungus grows from the surface into the fruit. The pathogen will seldom invade a green button, so it is important to prevent button desiccation. Entrance of the fungus into the fruit is also aided by mechanical injury or cracks in the peel. Fruit harvested over-mature are more susceptible to black rot. Advanced symptoms of black rot include a blackish green fungal growth on the fruit surface. Internally, the tissue turns black in the centre of the fruit. The decay does not spread from infected to healthy fruit in packed containers.

Control of black rot is obtained by pre-harvest fungicide sprays to lower the inoculum level, careful harvesting to avoid wounding of the tissue, applying 2,4-D as a 500 ppm dip to delay button senescence, and storage of the fruit at 12°C. Black rot development in lemons can be reduced by a pre-harvest foliar spray of gibberellic acid.

**Brown Rot :**

Brown rot, caused by the fungus Phytophthora, is a common post harvest decay of lemons during high amounts of rainfall. Lemons hanging low on the tree are often infected by rain-splashed soil. Winds can then spread the actively growing fungus to fruit in the upper tree. The disease generally occurs during the later stages of fruit development. Symptoms of brown rot appear as a light brown discolouration of the peel. The affected area is firm and leathery a white fungal growth develops on the peel during humid conditions. Infected fruit have a pungent, rancid odour, which distinguishes this disease from other rots. Control of brown rot is obtained by a combination of field sanitation, pre-harvest sprays of copper or fosetyl-Al (Aliette) fungicides, disinfection of the harvest containers, and wash water sanitation. Holding green lemons at 12°C and yellow lemons at 10°C will significantly retard the development of brown rot. Immersion of the fruit in a hot-waterbath at 46°C to 48°C (115°F to120°F) for 2 to 4minutes kills the fungus provided it is confined to external layers of the rind. Fungus that has penetrated well below the rind will survive the heat treatment. Turgid lemons may be injured by the heat treatment and should be allowed to wilt for 1 or 2 days before treatment.

### Anthracnose :

Anthracnose, caused by the fungus Collectotrichum gloeosporioides, usually appears on lemons previously injured or held too long in storage. Also, fruit which need a higher concentration of ethylene to de-green the peel will have a higher incidence of anthracnose. Ethylene triggers the growth of the dormant fungus and it also increases the susceptibility of the rind to further invasion. Anthracnose lesions associated with uninjured rind of de-greened fruit are initially silvery gray and leathery, and retain the same degree of firmness and elevation as the adjacent healthy rind. As the decay advances, the rind becomes brown to grayish black, and eventually a soft rot occurs. Lesions may develop on any area of the fruit surface. Lesions may also form immediately around the button where the fungus colonizes the senescent button before spreading into the adjacent healthy rind. Anthracnose lesions associated with injured rind appear as brown to reddish brown or black spots that may be firm and dry, or if sufficiently advanced, the rind becomes softened. Under humid conditions, the masses of spores on the lesion surface appear pink or salmon-coloured. The disease does not spread from infected to healthy fruit in packed containers.

Control of anthracnose is obtained by pre-harvest sprays of benomyl and post harvest dips in thiabendazole or imazalil (1000 ppm active ingredient) before de-greening, and holding the fruit at 10°C to 12°C.

### Stem-end Rot :

Stem-end rot, caused by the fungi Lasiodiplodia theobromae and Phomopsis citri, is widely prevalent and results in serious losses in humid growing areas such as Guyana. Fungal spores enter calyx tissues or lodge beneath the calyx at the time of flowering and remain dormant until the fruits are harvested. Symptoms appear as water-soaked spots near the stem end of the fruit, which generally turn light to dark brown. The brownish decay proceeds down the rind of the fruit. In the case of Lasiodiplodia, the advancing margin of the rot progresses in lobes or a finger-like pattern. The advancing margin of Phomopsis stem-end rot progresses evenly. Decayed tissue is initially firm, but later becomes wet and mushy and gives off a sour, fermented odour. The decay does not spread from infected to healthy fruit in packed containers.

Control of stem-end rot is obtained by pre-harvest fungicide sprays, post harvest application of imazalil (1000 ppm), and storage at 10°C. Also, a post harvest application of 2,4-D (500 ppm) helps control stem-end rot by delaying button abscission. Susceptibility to stem-end rot increases with increasing age of the fruit at harvest.

### Sour Rot :

Sour rot, caused by the fungus Geotrichum citri-aurantii, is the most objectionable and unpleasant of all the lemon decays. The organism invades the rind through injuries made by insects, mechanical injury, or other pathogens. Ripe or over-mature fruit are more susceptible to sour rot than green or immature fruit. The disease is also more severe during and after prolonged wet seasons. It is especially problematic on lemons that have been stored for long periods. Sour rot is frequently associated with green and blue mould infections. The initial symptoms of sour rot are similar to those of the Penicillium moulds. Highly active extra-cellular enzymes produced by the sour rot fungus degrade the rind, segment walls, and juice vesicles, causing the fruit to disintegrate into a slimy, watery mass (see photo). Under high RH, the lesion may be covered with a yeasty, sometimes wrinkled layer of white or cream-coloured fungal growth. The fungus requires a high water content of the peel and storage at a high RH. The sour odour associated with advanced stages of disease development attracts fruit flies, which can spread the fungus to infect other injured fruit.

Post harvest treatment with sodium o-phenyl phenate provides some control of sour rot. Immediate storage of lemon fruit at 10°C also will delay disease development. The benzimidazole fungicides are not effective against sour rot.

## Cottony Rot :

Cottony rot, caused by the fungi Sclerotinia, is not a common post harvest citrus disease, but it can occasionally cause heavy losses of lemons. The infected area of the fruit is at first firm and brown, but subsequently the peel tissue softens and fluid is released. As the fungus grows it results in a white cottony look to the surface of the fruit. Decay spreads by contact of an infected fruit to all surrounding healthy fruit in the container.

## Post harvest Disorders :

### Chilling Injury

Lemon fruit are susceptible to low temperature injury, commonly known as chilling injury (CI), if held at temperatures below 10°C (50°F). CI is a physiological disorder which adversely affects the appearance and quality of the fruit. Fruit symptoms include pitting and sunken lesions on the peel surface, skin discolouration, staining of the membranes separating the segments, decay, and off-flavour of the pulp. Damage is a function of temperature and time, with more CI incurred at lower temperatures and longer exposure durations. The use of pre-harvest applications of the growth regulator gibberellic acid reduces susceptibility to CI, as does maintenance of a very high RH(>95%) storage environment. Preconditioning lemons by holding the fruit at ambient temperature for several days before storing at chilling temperatures will also reduce injury. Waxing the fruit and a post harvest fungicide application will lower the amount of damage and decay from CI.

### Oleocellosis :

Oleocellosis, or oil spotting, is a result of mechanical damage to the peel. The outer portion of the lemon fruit contains oil glands which are rich in oil and terpenes. When the oil glands are ruptured, the oil and terpenes leak out and are toxic to the surrounding cells. This results in death of the adjacent epidermis and the formation of irregularly shaped yellow, green, or brown spots in which the oil glands of the skin stand out prominently because of slight sinking of the tissues between them. Turgid fruits are most likely to have oleocellosis because their oil glands are more easily ruptured. Fruit turgidity is greatest in the early morning and under very humid, wet conditions. Harvesting under such conditions or while dew is on the fruit should be avoided. Fruit should be picked when the fruit surface is dry and should be handled carefully so that oilglands are not punctured or ruptured. Oleocellosis can be minimized by picking fruit in the afternoon of sunny days, waiting to harvest 2 or 3 days after a rain or an irrigation, using padded harvest containers, and having pickers wear cotton gloves. Lemons may also be left in the field overnight in their harvest container to allow the turgor pressure to decline. The lower fruit turgor pressure permits safer transport to the packing area.

### Peteca :

Lemons may develop large sunken areas of the rind or pits soon after packing. Peteca is a type of rind pitting in which the edges of the depressions are gently rounded. The outer layer of the rind sinks, at first without losing its normal colour, but eventually the oil glands begin to darken. Heavy brushing of the peel increases the incidence of peteca. Also, storage of lemon sat 100% RH will significantly increase the amount of peteca. Although the cause of peteca is not known with certainty, it is thought that heavy oil sprays prior to harvest can increase the severity of this disorder. Lemons should not be subject to excessive brushing and should be waxed with a carnauba based wax.