Cultivation Of Citrus In Guyana And Post Harvest Handling

CITRUS

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INTRODUCTION

The Citrus is a member of a very large group of shrubs or trees of the Family Rutaceae, with the most important being the Citrus spp., but also includes some of the Poncirus *(Trifoliate Orange)* and Fortunella *(Round Kumquat)* spp.

Hybridisation, polyembryony and mutations that readily occur in this group further complicate the taxonomy.

VARIETIES

Several varieties of citrus are grown in Guyana, but most growers have lost the original names. These are oranges, grapefruits, limes, tangerines or mandarins and citrus hybrids.

Oranges *(citrus sinensis)* are a popular citrus fruit grown along the entire Atlantic Coast of Guyana. The vast majority of oranges produced in the country are seeded Valencia, Pineapple, Parson Brown and Hamlin types, used for both fresh market and juice. Only a limited amount of seedless navel oranges are grown.

Tangerines *(citrus reticulate)* or mandarins are the second most important type of citrus grown in Guyana. Most of the tangerines produced in the country have seeded fruit with Dancy being a leading cultivar. Nearly all the tangerines produced in Guyana are sold as fresh fruit in the domestic fresh market, although small volumes are exported.

Limes *(Citrus aurantifolia and Citrus latifolia)* are the third most important type of citrus in Guyana in terms of production volume, and are the leading citrus export. The seeded West Indian lime (also known as Mexican lime or Key lime) is the kind most widely grown. Small quantities of the seedless Tahiti lime (also known as Persian lime) and the Bears lime are also produced. Nearly all the limes are sold as fresh fruit in the domestic market, although small volumes are exported to Barbados.

Grapefruit *(Citrus paradise)* is a minor citrus in Guyana and essentially all the fruit is consumed in the domestic market. Almost all grapefruit produced in the country have seeded fruit and consist of the cultivars White Marsh, Duncan, and Ruby. Market demands in many countries have shifted in preference to red-fleshed cultivars. There is also the cultivation of small acreages of some citrus hybrids. These hybrids include Ortanique and King.

CULTIVATION

Citrus can be propagated by seed or vegetatively by cuttings, layers, budding or grafting. However, in the commercial planting of Citrus, budding is by far the most common method of propagation.

There are two sections to the budded plant viz.:

- The rootstock, which consists of the rooting system and the bottom part of the main stem or trunk, and
- The scion or bud of the selected variety to be grown on the rootstock and developing as the entire top portion of the tree.

In the main, Rootstocks are chosen for resistance to diseases, adaptability to soil type, quality and yield of fruit. Nowadays, the primary selection of rootstocks is made for resistance to Tristeza, which is considered the most destructive virus disease of citrus.

The Tristeza-resistant rootstocks which are suitable for conditions in Guyana are Carizzo Citrange, Cleopatra Mandarin, Rangpur Lime, Rough Lemon, Swingle Citrumelo and Volkameriana Lemon.

However, as each of the rootstocks varies regarding resistance to additional virus diseases as well as to the other factors mentioned, it is recommended that every estate should have plants on more than one type of rootstock.

A limited amount of budded Citrus plants primarily on Rough Lemon rootstock, are usually available from the NARI

Nurseries, Also, plans are in place to produce Tristeza-free plants in the not to distant future. However, growers of large areas are encouraged to produce their own plants.

Seeds are extracted from the fruit of the selected rootstock (e.g. Rough Lemon washed to remove slime, dried at room temperature, soak for 10 minutes at 49-52^{O}C then treated with a fungicide (e.g.) Captan) and stored moist in polythene bag at 4^{O}C, 40^{O}F for not too excessive a time until needed. The seeds are planted in prepared seedbeds or boxes and are transplanted when 4-6 inches (10- 15 cm) high into individual plastic plant bags or field beds. Alternatively, the seed could be planted directly into the plastic plant bags, putting 2-3 seeds per bag, thinning out and transplanting into other bags depending on the germination and growth.
Depending on the rootstock being used, the seedlings should be ready for budding in 4 to 8 months from sowing.

Budwood is selected from healthy, high yielding trees free from viruses. At this stage, it is recommended that the grower solicit the assistance of an experienced budder or NARI horticultural personnel.
Budding is usually conducted at a height of 12 to 15 inches (30 to 37.5 cm) from ground level using the inverted “T” method. After successful budding, the plants should be ready for transplanting in 3 to 6 months time.

Site Selection
Citrus can be grown in a variety of soils but irrespective of the soil type, it I essential that adequate drainage be provided. For under waterlogged conditions, growth is stunted and the plants are more prone to disease infestation.

In areas exposed to constant high winds, Windbreaks should be planted. Wind adversely affects the growth of Citrus, causing excessive twig dieback and premature flower drop on the windward side. Fruit trees such as Malacca Apple (Eugenia sp.) and Jamoon (Eugenia sp.) have successfully been used as windbreaks.

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Spacing
As a general rule, space citrus trees using the diameter of the canopy of a fully grown tree as a guide. In other words, if correctly spaced, the edges of the branches of the fully-grown trees should just touch.

The spacing therefore would vary with the soil type, terrain and other factors that affect tree growth. **As a general guide however, the following distances between plants are suggested:**
Grapefruit - 6 m (20 ft.) to 7.5 m (25 ft.)

• Oranges - 4.5 m (15 ft.) to 6 m (20 ft.)

• Limes/Tangerines - 3.6 m (12 ft.) to 4.5 m (15 ft.)

Planting
Planting should be conducted early in the wet season when moist soil conditions exist.

Planting holes are dug to a size that would accommodate the plant in the bag. The size of the hole is therefore around 30cm (1 ft) in length, width and depth.

The roots of bare root plants are more spread out and a - larger hole will have to be made to accommodate these plants.

The topsoil removed in digging the hole could be mixed with rotted manure and//or some phosphate fertiliser. Some of the soil is then returned to the hole filling about half way up.

The plastic bags are carefully removed keeping the rootball intact and the plants are placed in the holes. The balance off the topsoil is the returned to fill the hole an thoroughly compressed. The plants should then be watered.

After planting it is recommended to stake the plant to prevent movement by wind.

AFTER CARE

Intercropping
As the area between the citrus plants is no fully occupied until about 4 years after planting, other crops could be grown in this area. However, these crops should be grown in such a way so as not to compete with the young citrus plants for light, water and nutrients. As such a distance of about 1.2 m (4 ft.) should be kept clear around the young plant.

Vegetables and small quick growing fruit such as Bananas and Papaw are the common crops used in this fashion.

Pruning

As the young citrus plant begins to grow, shoots originating from the rootstock (below the bud union) could develop. These rootstock shoots are usually very vigorous and could hamper the growth of the scion or bud.

Consequently, it is necessary to examine the young citrus plant at least once per month and remove all shoots developing from the rootstock.

Little other pruning is necessary except for the shaping of the framework to produce a structurally balanced tree.

As the trees grow older, the rootstock shoots become less, and little or no pruning may be necessary except for the removal of dead wood.

However, sometimes the lower branches grow towards the ground, restricting air movement around the rootstock area. This tends to increase the humidity around this area encouraging the development of fungal diseases. Pruning of those lower branches may therefore be necessary.

Fertilising

Fertiliser needs of the Citrus plants are directly related to the type and nutrient status of the soil. It is essential' therefore that a soil analysis be conducted to determine these factors for the particular location. However, in the absence of a precise soil analysis, the following might suffice:

Riverain Soil - Compound Fertiliser 12:12:17:2 at the rate of 225g (1/2 lb.) to 0.9 kg (2 lbs.) depending on the age and size of the plant, applied twice per year usually at the beginning of each wet period.

Sandy Soil - The above could be used a the higher rate as well as 3:9:30 + FTE at the rate of 225g (1/2 lb) per plant once per year.

WEED CONTROL

General Weeds compete with the Citrus plants for moisture and nutrients as well as providing conditions for the development of unwanted pests and diseases. Therefore, the control of weeds is highly desirous.

Weeding around the plants is usually done manually, while general weed control could be accomplished by the following, singly or in combination.

- Manually
- Chemically
- Mechanically, by the use of brush cutters and/or mowers.

For chemical control, Glyphosate (RoundUp) or Paraquat (Gramoxone, Millquat) at a rate of around 2-3 pints/acre (2.5-3.75 litres/hectare) or 1/2-3/4 pint (250-375 mls.) in a 5 gallon (20L) sprayer, could be used. For a more lasting effect, use can be made of a mixture of Paraquat at the same rate as above, together with Diuron (Karmex) at a rate of around 2-3 lbs./acre (2.2-3.3 kg/hectare) or 1/2 -3/4 lbs. (. 2.3 kg) in a 5 gallon (20L) sprayer.

This mixture however, is antagonistic to other crops and must not be used if intercropping is being pursued.

Also, in applying these herbicides, care should be taken to avoid "spray drift" onto the crop plants or severe damage might occur. To minimise the risk of drift, it is recommended that a "spray shield" be used and the spraying of very tall weeds be avoided.
However, where only grass weeds are present, the herbicide Fusilade (Flauzifopbutyl) or Nabu (Sethoxydim) can be used at half the rate of Paraquat, without a shield as only grass is affected.

MAJOR PEST AND DISEASE OF CITRUS IN GUYANA AND THEIR MANAGEMENT STRATIGIES

PEST OF CITRUS

Citrus trees are host to a wide variety of insects and mites, many of which are potentially injurious to the tree's fruit. However, many of these species are kept at acceptable population levels by naturally occurring predators and parasitoids.
Active management is recommended for the following pests.

1. Leaf Cutting Ants Acoushi Ants *(***Atta sp.)***

The Acoushi Leaf Cutting Ants (*Acromyrmex octospinosus* and *Atta cephalotes*), cause considerable damage by cutting leaves and flowers (**Figure 1**). Repeated defoliation can result in the death of the citrus tree.

In certain areas, the establishment of orchards is not possible without control of these ants.

Fig 1. Leaf Cutting Ants

Control is normally affected by the use of one or a combination of:

• Baiting (Production done scientifically by specialist at the crop protection - NARI)

• Fogging

• Spraying

Baiting
This method capitalises on the insect's habit of taking material into the nests to culture a fungal food, and the nests need not necessarily be located. Control is affected by the use of poison bait such as the one developed by the NARI and sold at the Head Office or at Plant Nurseries.

The bait is scattered along the working trail and feeding holes of the ants, but not poured into the holes. Another method is to place the bait into open ended cylindrical tubes (PVC, Cans, Bamboo) which in turn are placed in the trails or near feeding holes.

Putting the bait into the tubes offers some protection against adverse weather.

Contact by hands with the bait should be avoided as this might neutralise the effect of the attractant in the bait.

Fogging
Fogging is recommended for the control of very large nests, which must be located. It is done with a Swing Fog machine and the fogging agent could be any soil or contact insecticide such as Basudin (Diazinon) or Malathion.

It should be noted that all the holes in the nest except the fogging hole will have to be plugged to effect the fogging exercise.

Spraying
Small nests with no mounds and little underground chambers can be sprayed with an appropriate soil insecticide such as Basudin (Diazinon) at a rate of about 10 mls in 4 Litres of water (2 teaspoons in a gallon of water).

It should be noted that the occurrence of any unusual pest or disease should be reported to the Crop Protection Section at NARI for investigation.

2. Citrus Leaf Miner - *Phyllocnistis citrella*

Fig 2. Symptoms of the presence of citrus leaf miner

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This is a serious pest of the Plant Nurseries where it attacks Rough Lemon seedlings and budded citrus plants.

The larvae of this insect burrow in the leaves of the citrus plants producing the characteristic tracings on the leaf often referred to as “Chinese Writing” (**Figure 2**). Without control, the leaves display curling and eventually abcise, finally leaving a defoliated seedling that soon dies.

In the Plant Nurseries, control is currently achieved by the use of the insecticide Admire (Imidacloprid) applied to the foliage or soil at the rate of 1-2 teaspoon (5 - 10 ml) in 1 gallon (4 L) of water.

In the field, it would be uneconomical for prolonged use of this insecticide and control is normally left to the natural enemies of this pest.

3. Citrus Aphid *(Toxoptera citricida)*

Toxoptera citricida only feeds on newly developed terminals including unexpanded and young expanded leaves and flower buds of citrus and citrus relatives (**Figure 3**). Once the tissue becomes unfavourable for feeding, the colonies produce alate adults for dispersal, and the remaining nymphs either die or leave the trees searching for other branches or trees. The dispersal of nymphs from one tree to another by crawling a distance of up to 8-12 m is often observed. *T. citricida* is a colonizer species and is not a strong flyer; long distance disperal is mostly aided by wind current. Alate adults could, therefore, play an important role in the epidemiology of Citrus tristeza virus.

Fig 3. Citrus Aphid

The major impact of *T. citricida* is due to its efficient transmission of Citrus tristeza virus (CTV), a phloem-limited closterovirus. Two types of CTV strains are economically important: those that cause decline of citrus budded onto sour orange *(Citrus aurantium)* rootstock; and those that cause stem pitting of grapefruit and sweet orange regardless of rootstock. Both are readily transmissible by *T. citricida*.

CTV is semi-persistently transmitted by citrus aphids. Aphids acquire virus from an infected trees with feeding times as short as 5-10 min; transmission efficiency increases with feeding times up to 24 h. There is no latent period and the virus does not multiply or circulate in the aphid. The time required to inoculate a plant is the same as for acquisition. The aphid is capable of spreading the virus for 24-48 hours without reacquisition.

Control

Cultural Control

Management of virus inoculum is the most important control strategy because spread of severe strains of Citrus tristeza virus (CTV) is the major problem associated with *T. citricida*. The first factor to consider is the prevalence of CTV and its strains in a particular area.

If virulent stem pitting strains and *T. citricida* are endemic, citrus scion varieties tolerant to CTV should be planted. These include mandarins, and tangarine. Only CTV-tolerant or resistant rootstock should be used. Avoid planting grapefruit or sweet orange unless they have been pre-infected with a cross-protecting CTV strain. If CTV strains are less virulent than the previous scenario, sweet oranges and grapefruit, preferably pre-inoculated with a mild CTV isolate, can be grown with consideration for the market targeted (e.g. fresh fruit, domestic, export, juice, etc.). When CTV problems are anticipated, closer plant spacing should be considered to maximize land use during the grove's early years. Trees that decline or become stunted can either be replaced or simply removed and neighbouring trees allowed to fill in.

Tree size is managed by trimming the sides and tops of trees. This practice produces conditions excellent for CTV spread and allows tree canopies to touch in the direction of the row. Pruning induces new shoot growth in which CTV multiplication is optimal as long as temperature and moisture are favourable. Hence the uniform growth that results from pruning maximizes opportunities for CTV acquisition and inoculation.

If CTV incidence is undetectable or mild and *T. citricida* is not established in a particular region, citrus trees grafted on sour orange rootstock may still be acceptable. This decision depends on the risk of losses due to CTV versus the advantages gained by the use of sour orange (e.g. salinity, cold hardiness, Phytophthora, high soil pH, poor drainage). Several areas have managed CTV by eradication of infected trees. This programme is cost effective if virus incidence is low and spread is slow.

Regardless of the present CTV/aphid vector situation, a citrus budwood certification programme is essential for a good citrus industry. CTV and all other citrus virus and virus-like agents are readily graft transmissible. Diagnostic methods are available for testing and detection of citrus pathogens in budwood sources. Serological and molecular biology allow some rapid evaluation of pathogen virulence. Thermotherapy and shoot tip grafting are now standard methods to eliminate pathogens from budwood. If a cross-protective CTV isolates are available, they can be incorporated into the budwood certification programme.

Biological Control

Although natural enemies are important in regulating aphid populations, they alone may not be satisfactory for controlling plant virus diseases. Aphid populations on citrus are often too variable to provide sufficient natural enemies for effective vector control. One concept is to direct biological control activities to reduce migrant vector populations before they spread through susceptible crops. Given that alternative prey are available, natural enemies could reduce *T. citricida* populations to mitigate secondary spread of CTV (tree to tree within a field), especially if conservation and augmentation efforts are used. In South America, various natural enemies have been observed attacking *T. citricida*.

Chemical Control

Insecticidal control of *T. citricida* to slow spread of CTV is an unproven strategy. Although insecticides may not act quickly enough to prevent primary infection by viruliferous aphids, reduction of aphid populations would decrease secondary spread. Its effectiveness depends on longevity of suppression and extent of the treated area in relation to inoculum reservoir and migratory activity of the aphid. It should be cautioned that use of foliar insecticides can interfere with biological control agents and, ultimately, their use to protect citrus is temporary. Several systemic insecticides including Acephate Imidacloprid, Fastac, Karate and Pestac have been used against *T. citricida* with various residual effects. CTV is transmitted only by vectors that colonize citrus because it is phloem-limited.

Integrated Pest Management

A unique management strategy must be practiced for CTV in the presence of *T. citricida*. A strong regulatory component is necessary, covering both propagation and inoculum control. Insecticidal control of vector populations may be useful in specific situations such as in a citrus nursery, or to protect budwood sources. Some value may result from the use of selective insecticides working in tandem with natural enemies. In the final analysis, vector management should be one component of a disease management strategy including other available elements such as mild strain cross-protection; tolerant rootstocks; regulatory measures, isolation or protection of nursery stock; and citrus scions with tolerance or resistance to CTV.

DISEASES OF CITRUS IN AND THEIR MANAGEMENT STRATIGIES

Several diseases can affect the Citrus plants in Guyana and these can be grouped into two main types - **Fungal and Viral Diseases**.

Fungal Diseases

1. Footrot or Gummosis

This disease is caused by a soil-inhabiting fungus (*Phytophthora citrophthora*) which attacks the trunk of the tree. This causes the bark to rot and the eventual die back of the tree. Very often gum exudes from the affected area (**Figure 4**).

The main contributing factors to this disease are water logging and a susceptible rootstock e.g. Rough Lemon. It is essential therefore that in citrus orchards, good drainage be provided and wherever possible, rootstocks resistant to the disease such as Rangpur Lime should be used.

Gum exudes from stem of plant

Gummosis on trunk of plant

Fig 4. Typical symptoms of Gummosis

Chemical Control:
Control of this disease is only possible when it is detected and treated early. Treatment requires firstly the checking of the drainage and eliminating any deficiencies.
Further treatment consists of removing the infected bark and painting the exposed surface with a dressing of a copper fungicide such as Kocide or Cupravit made up as a paste of about 100g in 4 litres of water. (4 ozs. in I gallon of water).

Fungicides, such as Aliette (Fosetyl-Al) and Ridomil (Metalaxyl), can be used as a dressing or a spray at about 15g in 4 litres of water (0.5oz in I gallon of water).

2. Citrus Scab
This disease is caused by the fungus *Elsinoe fawcetti* which produces raised brown corky warts on the leaves, twigs and fruit of susceptible plants (**Figure 5**).

As Oranges and Grapefruits are fairly resistant to this disease, it is rarely seen in growing orchards, but is prevalent in the nurseries where Sour orange and Lemons are used as rootstocks.

Fig 5. Symptoms of Citrus Scab

Control
Cultural Control

- Proper Nursery management
- Sterilize nursery equipment

Chemical Control
Proper nursery management and regular spraying of Captan or Ridomil at about 5ozs (140 gms.) in I gallon (4L) could achieve control.

3. Viral Diseases of citrus
There are many virus diseases that attack the citrus tree but the one of main interest to Guyana at the present time is the CTV (**Figure 6**). On susceptible rootstocks, such as Sour Orange, the virus attacks the area at the bud union. With the severe strain of the virus, the tree could exhibit a quick decline, wilting, defoliation and death. On the other hand, with a less severe strain, there could be a more gradual die back with progressive wilting and yield reduction. Very often when the tree dies, there could be a large crop of small fruits still remaining attached to the dead branches. Both infected budwood and several species of aphids spread this disease.

Fig 6. Symptoms of CTV

Other viral diseases that are of significance are the citrus yellow mosaic virus(CMV) (**Figure 7**) and Citrus wilt or dieback (**Figure 8**)

Control can only be achieved by using tolerant rootstocks such as Carrizo Citrange, Cleopatra Mandarin, Rangpur Lime, Rough Lemon, Swingle Citrumelo and Volkameriana Lemon.

Fig 7. Citrus yellow mosaic virus

Fig 8. Citrus wilt (dieback)

Harvest Maturity Indices

A combination of external and internal indices is used to determine orange harvest maturity. The most commonly used external index is peel colour. Fruit are considered mature if they have a yellow-orange colour on 25% or
greater of the fruit surface. Internal harvest maturity indices include measuring the soluble solids content (i.e. sugars) and acidity of the juice. Flavor quality in oranges is related to the soluble solids: acid ratio and absence of off-flavor-causing compounds. The juice should have a % soluble solids of 8.5 or higher. Soluble solids content is determined by squeezing a few drops of juice on a hand-held refractometer (Figure 9).

Fig 9. Hand-held refractometer for determining juice % soluble solids content.

The juice should also have a soluble solids to acid ratio of 10:1 for the fruit to be considered mature and of good quality. This ratio is determined by dividing the % soluble solids content by the % acidity. In order to reduce fruit to fruit variability, the juice sample should be obtained from a total of 10 randomly selected fruit.

Each fruit should be cut in half (Figure 10), squeezed, and filtered to clarify the juice. A 10 ml sample of filtered juice is titrated with 0.1 N sodium hydroxide to an end point of 8.1. The volume of 0.1 N sodium hydroxide required to reach the pH end point of 8.1 is then multiplied by the factor of 0.0064 to obtain % acidity (i.e. % citric acid). Acidity is a more complex determination that requires a few simple laboratory supplies (i.e. biuret
and pH meter).

Harvest Methods

Oranges should be harvested using a pair of clippers or by carefully twisting and pulling the fruit from the tree so the button (calyx and disk) remains attached to the fruit (Figure 11). Stems left on the fruit at picking should be removed because they can puncture other fruit, causing postharvest decay and fruit spoilage. Careless picking that results in plugging (part of the rind pulls loose from the fruit) is unacceptable. All oranges are susceptible to plugging, but some cultivars are more likely to plug than others, especially ‘Pineapple’ oranges.

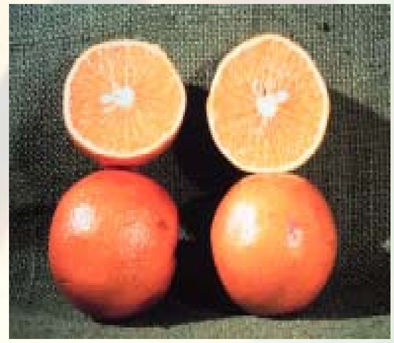

Fig 10. A total of 10 randomly selected oranges should be cut in half, squeezed, and the juice filtered to determine % soluble solids:acidity ratio.

Never shake the tree to harvest the fruit. Any fruit which falls to the ground is likely to be severely bruised and subject to postharvest decay. Ladders may be needed to facilitate harvesting of fruit borne on tall trees. Avoid rough harvesting practices which result in fruit bruising. It is a popular misconception that citrus fruit can withstand rough handling. Citrus is more durable than many other fruits, but it does bruise easily.

Fig 11. The button (calyx and disk) should remain attached to the fruit at harvest.

The harvested fruit should be carefully put into padded field crates, well ventilated plastic containers, or picking bags. Picking bags are either strapped around the waist or put over the shoulder and made with a quick-opening bottom. These harvesting containers can be made by sewing bags with openings on both ends, fitting fabric over the open bottom of ready-made baskets, fitting bags with adjustable harnesses, or by simply adding some carrying straps to a small basket (Figure 12).

When filled with fruit, the bags of oranges are typically emptied into larger field crates. Picking sacks are designed to empty from the bottom so that fruit can roll out of the sack onto the bottom of a larger field container or atop fruit already present, rather than being dropped. A strong wooden or plastic field container is preferred (Figure 13).

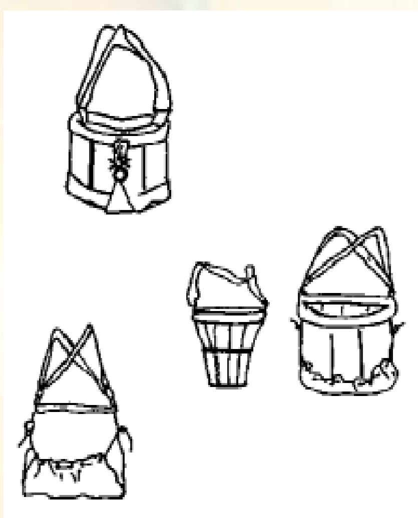

Fig 12. Various styles of picking bags used for harvesting oranges.

Fig 13. Strong wooden field crates that are stackable are ideal field containers.

Relative Humidity Management

Oranges are high in moisture content and susceptible to peel shrivel after harvest. In order to minimize postharvest water loss and preserve postharvest quality, oranges should be stored at their optimum RH of 90 to 95%. At a low RH, the peel becomes thin, dry, and shriveled and adversely affects the appearance of the fruit.

Peel De-Greening

Orange fruit produced in Guyana is often mature and of acceptable eating quality when the rind is still green. High temperatures and humidity result in internal fruit maturation, but the colouration of fruit peel usually is not fully developed. Many consumers, especially in export markets, associate external skin colour with internal flavor and believe oranges with a green-coloured peel is immature and not ready to eat. In order to improve external skin colour and market acceptance, oranges can be treated with ethylene, which is an effective de-greening agent. Ethylene treatment breaks down the green chlorophyll pigment in the peel surface and allows the yellow or orange carotenoid pigments to be expressed. This treatment is solely cosmetic in effect and does not alter the flavor of the fruit.

The general de-greening protocol involves exposing the green-skinned orange fruit to low concentrations of ethylene (usually between 1 to 10 ppm) at 20°C to 25°C (68°F to 78°F), 90% RH for several days. The optimal ethylene concentration and treatment duration varies by cultivar and growing conditions. Fruit that develops under high night temperatures usually needs a higher concentration of ethylene to de-green the peel.
However, excess ethylene can cause stem end rot and accelerate decay.

In order to achieve good de-greening results, adequate internal air movement is needed so the entire air volume within the treatment chamber is circulated every 2 to 3 minutes. The CO2 levels inside the treatment chamber should not be allowed to rise above 2000 ppm, as high CO2 will inhibit the effect of ethylene. The treatment chamber should be well insulated in order to maintain the desired ethylene concentration. Washing the fruit before de-greening is not advisable because it interferes with the de-greening process and increases the time of exposure to ethylene needed to colour the fruit.

A liquid ethylene-releasing compound, called ethephon [(2-chloroethyl) phosphonic acid], may be an effective alternative de-greening material. It is applied by dipping the fruit in a tank of clean water at room temperature with 500 ppm ethephon for 1 minute. It is important the water be properly sanitized with sodium hypochlorite (i.e. 150 ppm at a pH of 6.5) and a fungicide (i.e. 500 ppm benomyl, thiabendazole, or imazalil) to prevent
postharvest decay.

Valencia oranges are susceptible to stem-end rind breakdown. After de-greening, it is important to maintain a high RH (90%) and a temperature near 16°C (60°F) while temporarily holding the fruit before waxing or packing. A holding period is necessary for 12 to 24 hours before packing in which fresh, cool air is introduced into the room. If not properly aired and cooled, stem-end rind breakdown may appear on the oranges after running over the packing line.

Principal Postharvest Diseases

Due to Guyana's warm climate and high rainfall, postharvest diseases of oranges can be quite high and cause significant fruit loss. Postharvest decays may also limit export opportunities for Guyanese growers. Therefore, it is economically important to control postharvest diseases and maintain the quality of the fruit.

Postharvest decays are caused by latent (resting) or wound-induced fungal infections. Latent infections typically become established on the fruit prior to harvest, but exist in a resting or dormant state until the conditions are right for fungal growth after harvest. Wound-induced microbial infections usually take place after harvest, and begin in areas of the fruit which were injured during picking and/or handling. Oranges must be harvested and handled gently to avoid bruising and skin injury, which greatly accelerates postharvest microbial decay. Postharvest decay is also reduced by the use of appropriate pre-harvest and postharvest fungicides, proper sanitation of the wash water, and appropriate storage temperature and RH conditions.

Green Mold

Green mold, caused by the fungus *Penicillium digitatum*, is generally the worst postharvest disease of oranges. The fungus enters the fruit only through wounded areas and causes a rapid breakdown of fruit punctured or bruised during harvesting and packing. The initial symptom appears as a soft, watery, slightly discoloured spot (6-12 mm [0.2-0.5 in] in diameter) on the rind. The spot enlarges to 2-4 cm (0.8-1.6 in) in diameter within 24-36 hours at 24°C (75°F), and the rot soon penetrates into the juice vesicles. White fungal growth appears on the fruit surface, and after the spot enlarges to a diameter of about 2.5 cm, (1 inch) olive-green spores are produced (Figure 14). The sporulating area is surrounded by a broad zone of white fungal growth and an outer zone of softened rind. The entire fruit is soon covered with a mass of olive-green spores, which are easily dispersed by air currents or movement of the fruit. If the storage RH is low, the fruit shrinks to a wrinkled, dry mummy. If the RH is high, the fruit collapses into a soft, decomposing mass.

Green mold develops most rapidly at about 24°C. The rot can be almost completely inhibited by storing oranges at 0°C -1°C (32°F - 34°C). Adequate ventilation of the storage room is important because high concentrations of ethylene will increase the incidence of green mold. Also, preharvest and postharvest sprays of benzimidazole fungicides will reduce the amount of green mold.

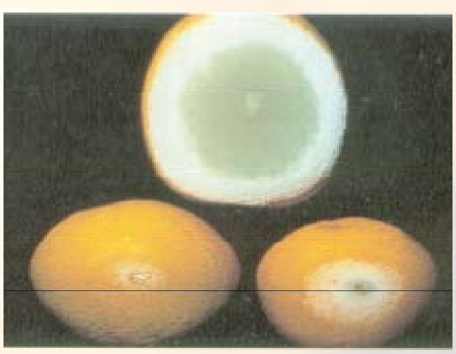

Fig 14. Different stages of green mold decay on orange fruit.

Blue Mold

Blue mold, caused by the fungus *Penicillium italicum*, is another common postharvest mold of orange fruit. Early symptoms are similar to green mold. It attacks injured areas of the peel and first appears as a soft, watery, slightly discoloured spot on the rind. Soon afterwards, a blue mold growth begins, surrounded by a zone of white fungal growth (Figure 15). The lesion enlarges more slowly than green mold. 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.

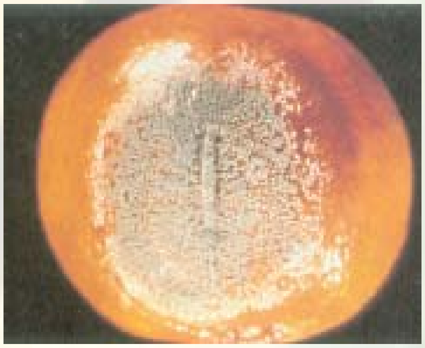

Fig 15. Blue mold decay of orange fruit.

Like green mold, blue mold develops most rapidly at about 24°C (75°F). However, blue mold grows better than green mold below 10°C (50°F) and may predominate over green mold in fruit held in cold storage. Healthy fruit in packed containers become soiled by spores shed from the diseased fruit. Unlike green mold, blue mold spreads in packed containers and results in nests or pockets of diseased fruit.

The incidence of blue mold can be reduced by following the same recommendations as described for control of green mold. Immediate cooling after packing significantly delays development of blue mold, especially if combined with effective fungicide treatments. Adequate ventilation of the storage room is important because high concentrations of ethylene will increase the growth of blue mold.

Black Rot

Black rot, caused by the fungus *Alternaria citri*, is a common postharvest orange disease. Navel oranges are particularly susceptible. Black rot usually occurs as a stem-end rot in oranges that have been stored for extended periods. However, in some cases there are no external symptoms of black rot, only an internal black rot of the center tissue (Figure 16). This is a problem for juicing, since only a small amount of rot will impart a bitter flavor to the juice.

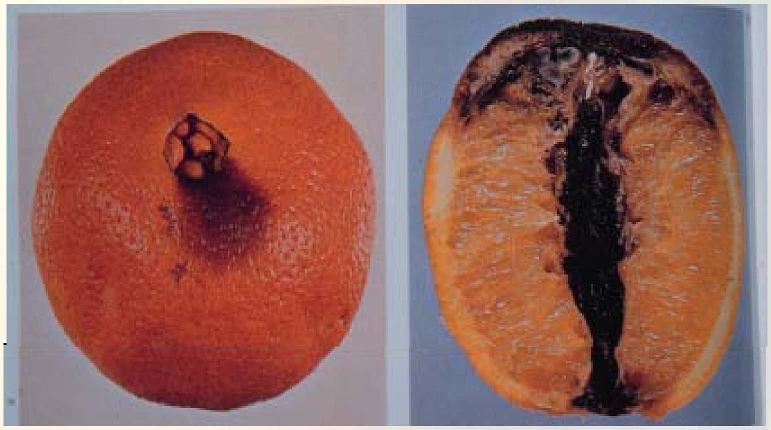

Fig 16. Black rot internal decay of Navel orange fruit.

Anthracnose

Anthracnose, caused by the fungus *Collectotrichum gloeosporioides*, usually appears on fruit previously injured or held too long in storage. Also, fruit that 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.

Symptoms generally appear as brown to black spots on the peel, 1.5 cm (.6 in) or more in diameter (Figure 17). The decay may be firm and dry, but if sufficiently deep it may cause the fruit to soften. Under humid storage conditions, the fungal spores associated with the peel lesions are pink or salmon-coloured, while under drier conditions they appear brown or black.

Phomopsis Stem-end Rot

Stem-end rot, caused by the fungus *Phomopsis citri*, is a serious type of decay on all orange cultivars. It is more prevalent in the humid coastal production areas than in drier in-land zones. Decay begins at the stem end of the fruit and will penetrate the rind and juice sacs. The infected tissue shrinks and a clear line of demarcation is formed at the junction between diseased and healthy rind (Figure 18). The disease does not spread from decayed to healthy fruit in packed cartons.

Fig 17. Anthracnose decay of Hamlin orange fruit.

Fig 18. Phomopsis stem-end rot of orange fruit.

Diplodia Stem-end Rot

Stem-end rot, caused by the fungi *Diplodia natalensis*, is a serious postharvest disease of oranges in Guyana. Spores lodge beneath the calyx at the time of flowering and remain dormant until the fruits are harvested. The fungus becomes active at the stem end of the fruit and symptoms appear within several weeks after harvest at ambient temperature. Symptoms include the formation of water-soaked spots near the stem end of the fruit, which turn blackish-brown. Fungal growth progresses rapidly through the spongy central axis of the fruit. The decay proceeds unevenly through the rind, producing finger-like projections of brown tissue (Figure 19). Decayed tissue is initially firm, but later becomes wet and mushy. Decay usually does not spread from infected to healthy fruit in packed containers.

Fig 19. Diplodia stem-end rot of oranges.

The incidence of stem end rot will be greater on fruit that requires a high concentration of ethylene to de-green the peel. Control of stem-end rot is obtained by preharvest fungicide sprays, postharvest application of imazalil, and low temperature storage. The decay is almost completely inhibited at temperatures below 10°C (50°F). Diplodia rot in oranges can also be retarded by postharvest applications of 2,4-dichlorophenoxy acetic acid at a dose of 500ppm, that retards senescence of the button and therefore the entry of the pathogen.

Brown Rot

Brown rot, caused by the fungus *Phytophthora*, is typically a postharvest problem on oranges when high amounts of rainfall occur during the later stages of growth. All cultivars are susceptible. Symptoms first appear as a light brown discolouration of the peel. The affected area is firm and leathery. White fungal growth appears on the fruit surface under humid conditions (Figure 20). Infected fruit have a characteristic pungent, rancid odour, which distinguishes this disease from other rots. Cool storage of the fruit will significantly retard the development of brown rot.

Fig 20. Brown rot with white fungal growth on the peel of an orange fruit.

Postharvest Disorders

Rind Staining

Soft-skinned oranges are susceptible to peel discolouration due to echanical abrasion incurred during harvesting or packing. The disorder is termed rind staining and the symptoms are brown or reddish-brown discolouration of the damaged areas of the peel. Fruit which are harvested over-mature are more likely to suffer from rind staining. Navel oranges are particularly susceptible to this disorder. Rind staining can be controlled by careful handling of the fruit during harvesting, transport and packing. Pre-harvest foliar applications of gibberellic acid may also reduce rind staining.

Oleocellosis (Oil Spotting)

Oleocellosis, or oil spotting, is a handling problem that normally does not appear until several days after harvest. It results from mechanical damage to the fruit that ruptures the oil glands in the peel. The extruded oil kills rind cells, causing them to turn brown. The spots may vary from less than 1.3 cm (0.5 in) in diameter to large, irregular areas involving much of the fruit's surface (Figure 21). The oil glands of the skin stand out prominently because of slight sinking of the tissues between them.

Turgid fruits are most likely to develop oleocellosis because the oil glands in peels high in moisture content are more easily ruptured. Fruit turgidity is greatest in the early morning and under foggy, wet conditions. Harvesting under such conditions or while dew is on the fruit should be avoided. Oleocellosis is also more severe in orange fruit harvested before it has lost its green colour. Navel oranges are particularly susceptible to oil spotting. Oil spotting can be prevented or reduced by picking fruit when the surface is completely dry, waiting to pick 2 or 3 days after a rain, using foam-lined or padded field containers, and having pickers wear cotton gloves.

Fig 21. Oleocellosis spots on the rind of a Valencia orange.

Stem-end Rind Breakdown

Stem-end rind breakdown (SERB) is a collapse and subsequent darkening of the rind around the stem end of oranges (Figure 22). A narrow band of rind around the stem usually remains undamaged. The collapse of tissue develops within a week of harvest and is due to excessive moisture loss from the rind prior to harvest and continued moisture loss and shriveling of the peel after harvest. Valencia oranges are particularly susceptible.

Fig 22. Stem-end rind breakdown symptoms on Navel orange.

During hot weather, water moves from the citrus rind back into the tree causing the fruit to wilt. Fruit that feels soft when harvested is more likely to develop SERB. Oranges borne on trees with a heavy crop of small fruit with thin rinds are more likely to develop SERB. Growers can reduce the incidence of SERB by irrigating Valencia oranges prior to harvest during hot dry weather conditions. If this is not possible, wet the fruit in the field containers bins and place them in the shade. Harvest and handle the fruit carefully, since bruised fruit with a damaged rind can lose moisture and shrivel at twice the rate of non-bruised fruit. Transport the fruit to the packing shed as soon as possible after harvest, followed by a wax treatment to prevent further moisture loss. The fruit should also be kept cool.