Control of stem-end rot of fresh citrus

By Mark A. Ritenour, Jiuxu Zhang and Megan M. Dewdney

Decay of fresh citrus fruit is most often caused by fungal pathogens that grow and develop in the hot and wet conditions typical in Florida. While green and blue molds (*Penicillium digitatum* and *Penicillium italicum*) and sour rot (*Galactomyces citri-aurantii*) are the most common postharvest citrus diseases worldwide, the subtropical conditions of Florida also favor other important decays such as diplodia stem-end rot (*Lasiodiplodia theobromae*, see Figure 1), phomopsis stem-end rot (*Diaporthe citri*), anthracnose (*Colletotrichum gloeosporioides*) and, less frequently, brown rot (primarily *Phytophthora palmivora* and *P. nicotianae*).

Of these diseases, not only has diplodia stem-end rot often caused the greatest postharvest losses in Florida, but the incidence of its occurrence appears to be increasing in recent years. This might partially be due to HLB increasing the amount of weakened and/or dead wood in the trees, which promotes growth and sporulation of *L. theobromae* and subsequent postharvest stem-end rot. Researchers at the U.S. Department of Agriculture in Fort Pierce found *L. theobromae* already present in fruit juice at harvest, and the presence of the fungus was positively correlated with fruit HLB symptoms. Therefore, grove practices that maximize tree health will also reduce postharvest decay pressure.

At one time, preharvest fungicides provided effective residual postharvest control of diplodia and other fruit decays, but those materials are no longer available, and no effective replacements yet have been discovered. Thus, it is more critical than ever that citrus fruit harvesters and postharvest handlers adhere to the practices described below to minimize the development of diplodia stem-end rot and other decays after harvest.

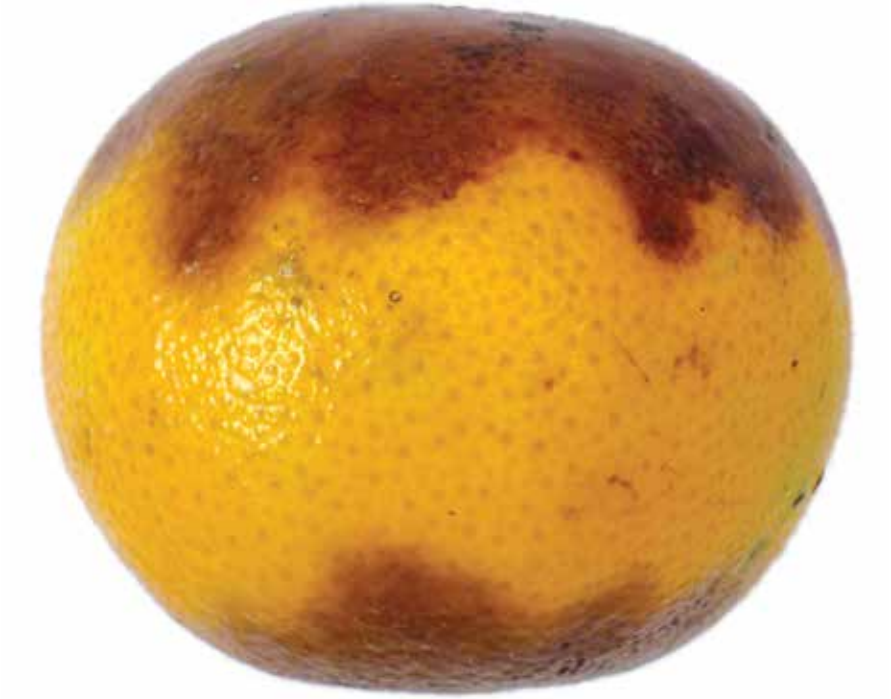

Figure 1. Diplodia stem-end rot on grapefruit

DEGREENING RECOMMENDATIONS

Postharvest decay can be reduced by minimizing degreening time and maintaining optimum degreening conditions. Citrus fruit harvested early in the season usually has inadequate color development and requires degreening before packing. During degreening, fruit are exposed to minute levels of a natural plant hormone (ethylene) that stimulates the breakdown of chlorophyll and unmasks the characteristic orange and yellow colors of the peel. However, ethylene exposure also increases the development of diplodia stem-end rot and anthracnose, becoming worse with longer degreening times and excessive use of ethylene.

If degreening is necessary, fruit should first be drenched with a suitable fungicide and then degreened at 82°F to 85°F with three to five parts per million (ppm) ethylene and 90 to 95 percent relative humidity — only as long as necessary to obtain adequate peel color (depending on fruit variety and degree of color break). See Recommendations for Degreening Florida Fresh Citrus

Fruits (http://edis.ifas.ufl.edu/hs195) for more information. An additional benefit of these degreening conditions is the promotion of a curing effect that reduces the development of green mold.

IMPORTANCE OF SANITATION

Effective sanitation practices during postharvest handling can greatly reduce decay incidence. All fruit, leaves and other trash should be removed from the floor and machinery in the packinghouse every day to reduce inoculum sources. Decayed fruit should be separated from healthy fruit immediately after dumping on the packing line to prevent contamination of the line by fungal inoculum. Decayed fruit should not be left near the packinghouse because spores can be carried readily by wind and insects into the packinghouse.

An approved sanitizing agent (e.g., chlorine, peroxyacetic acid, etc.) or hot water (at least 160°F) should be used to treat fruit-contact surfaces after the equipment is cleaned at the end of each day. Approved quaternary ammonia compounds may also be used, but require a freshwater rinse if used at concentrations above 200 ppm. Empty pallet boxes (pallet bins) should be clean and free of debris before each trip to the field.

If water dumps or soak tanks are necessary, free chlorine should be maintained in the water at about 100 ppm and near a pH of 7 for maximum effectiveness. See Chlorine Use in Produce Packing Lines (http://edis.ifas.ufl.edu/ch160) for more information.

REFRIGERATION AND CHILLING INJURY

Decay development can be delayed by refrigeration (Table 1). Low temperature is especially effective for suppressing fungal pathogens requiring high temperature for optimum growth, such as *L. theobromae*. However, varietal and seasonal differences in susceptibility to chilling injury must be considered when selecting temperatures for cooling, storing or transporting citrus fruits.

Chilling injury is a physiological disorder that occurs when most citrus fruits (especially grapefruit, lemons and limes) are stored at low — though not freezing — temperatures. It is most often characterized by areas of the peel that collapse and darken to form pits after at least three to six weeks at low shipping and storage temperatures. See Chilling Injury of Grapefruit and its Control (http://edis.ifas.ufl.edu/hs191) for more information.

If no fungicide(s) are used postharvest, then even more importance should be placed on harvesting fruit from as healthy trees as possible, avoiding delays in postharvest handling, minimizing or even skipping degreening entirely, maintaining sanitary conditions throughout the process, cooling the fruit to optimum temperatures quickly and shipping to destination markets quickly.

Table 1. Optimum holding temperatures for maximum quality and shelf life of fresh Florida citrus fruit

Citrus type	Optimum holding temperatures (°F)
Grapefruit	50 to 60
Lemons, limes	50
Mandarin-type fruits	40
Oranges	32 to 34

Note: Somewhat lower temperatures can be used if fruit coatings are used, depending on their gas permeability.

FUNGICIDES TO CONTROL DECAY

Postharvest fungicides are commonly used to control citrus fruit decay in Florida. It is generally recommended that fruit receive a fungicide drench if there will be a 24-hour delay before running the fruit

on a packing line. Fruit commonly receive a fungicide treatment on the packing line and/or incorporated into the wax. The following fungicides are effective in controlling diplodia stem-end rot and other decays on citrus fruit. Remember to always follow the fungicide label because *the label is the law*.

Thiabendazole (TBZ): TBZ is applied with truck or bin drenchers and on the packinghouse line at a concentration of 1,000 ppm (0.1 percent) as a water suspension or at 2,000 ppm (0.2 percent) in a water-based wax. Besides stem-end rot, green mold is also controlled, and to a lesser extent, so is anthracnose. Because TBZ is only slightly soluble in water, suspensions must be constantly agitated to ensure uniformity of solution concentration during application.

TBZ can be applied as a recovery drench on unwashed fruit before degreening, or as a non-recovery spray or drip on washed fruit that has been damp-dried with absorber (donut) rolls or by other methods. Recovery drenches should contain chlorine at the proper pH to control fungal contamination, and the concentration of TBZ must be monitored periodically. Following a non-recovery water application of TBZ to washed fruit, excess fungicide suspension may have to be removed with absorber rolls if dryer capacity is inadequate. Brushing after non-recovery water applications reduces fungicide residues. Fruit should not be brushed or rolled in the dryer after waxes are applied, except for a half turn midway through the drying operation.

Brushing after non-recovery water applications reduces fungicide residues.

Imazalil: While imazalil is often slightly less effective against diplodia stem-end rot than TBZ, it is especially effective against green mold and its sporulation. It also has some activity against alternaria stem-end rot (black rot). It should be applied at 1,000 ppm (0.1 percent) as a water suspension or at 2,000 ppm (0.2 percent) in a water-based wax. The application method is the same as mentioned above with TBZ, except that some heating or other sanitizers (not chlorine) must be used in bin drenchers or recirculated systems because chlorine and imazalil are not compatible.

Fludioxonil: Fludioxonil is a relatively new postharvest fungicide registered for use on citrus that is marketed as Graduate® and is effective against diplodia stem-end rot and green mold. Compared to imazalil, it is not as effective by itself in controlling mold sporulation, but good sporulation control is achieved when it is combined with azoxystrobin; such a formulated mixture is labeled for postharvest decay control of citrus and marketed as Graduate A+®. However, if azoxystrobin or another strobilurin fungicide is used in the field, then it is best not to use this combination because of the resistance risk.

Fludioxonil (Graduate®) should be applied at 600 to 1,200 ppm, and Graduate A+® at 1,200 ppm (600 ppm fludioxonil, 600 ppm azoxystrobin), both as a water suspension. The efficacy of these products in a water-based wax under Florida conditions is not yet known. The effectiveness of fludioxonil and the combined fludioxonil/azoxystrobin mixture against other decay organisms under Florida conditions is not yet established. The application method is the same as mentioned above with TBZ.

SOPP: Sodium o-phenylphenate or o-phenylphenol (SOPP) reduces green mold and provides some control of diplodia and phomopsis stem-end rot, as well as sour rot. It is most effective as a 2 percent aqueous solution at pH 11.5 to 12. One formulation contains 2 percent SOPP, 0.2 percent sodium

hydroxide for pH control and 1 percent hexamine to minimize phytotoxicity.

SOPP may be applied as a soap or foam to replace the detergent during washing. This application provides less fungicidal efficacy than an aqueous flood recovery treatment, but it helps kill inoculum from decayed fruit on the brushes and reduces the chance of infecting healthy fruit during the washing process. Unwashed or washed fruit treated with a foam or flood of SOPP should be rinsed with fresh water after treatment.

Application times less than two minutes provide less decay control, while times exceeding two minutes may cause peel injuries. Washer brushes should be rinsed at the end of each day's run to remove SOPP residues that may cause matting of the brushes. Concentrations of SOPP solutions applied with hexamine should be maintained near 2.5° with a Brix hydrometer standardized at 68°F. The pH of aqueous solutions lacking hexamine must be maintained at 11.5 to 12 to prevent peel injury.

LOOKING TO THE FUTURE

With HLB continuing to impact tree health and potentially promoting development of diplodia and possibly other postharvest decays, further research into better preharvest control methods is needed. In addition, work is progressing to develop additional methods to control these diseases after harvest, such as evaluating treatments with essential oils or the use of heated fungicide treatments. It is hoped that further development of an integrated, systems approach to controlling diplodia and other postharvest diseases will better assure the arrival of high-quality, decay-free citrus from Florida.

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