Decay control of fresh citrus

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Citrus fruit decay is most often caused by fungal pathogens that grow and develop in the hot and wet conditions typical in Florida. The most common postharvest fungal decays of Florida citrus are Diplodia stem-end rot (Fig. 1, *Lasiodiplodia theobromae*), Phomopsis stem-end rot (*Phomopsis citri*), and green mold (Fig. 2, *Penicillium digitatum*). Sour rot (*Galactomyces citri-aurantii*), anthracnose (*Colletotrichum gloeosporioides*), blue mold (*Penicillium italicum*) and, less frequently, Alternaria stem-end rot (black rot) (*Alternaria alternata*) and brown rot (primarily *Phytophthora palmivora* and *P. nicotianae*) can also cause commercially important losses of citrus fruit. Losses from these diseases can be reduced using the practices discussed in the paragraphs to follow.

Fig 1. *Diplodia stem-end rot on grapefruit*

Fig 2. *Green mold on navel oranges*

EFFECTS OF DEGREENING

Citrus fruit harvested early in the season usually have inadequate color development and require 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, which is related to the length of the degreening treatment and ethylene concentration used. If degreening is necessary, fruit should first be drenched with a suitable fungicide and then degreened at 82°F to 85°F with 3 to 5 parts per million (ppm) ethylene and 90 percent 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. A 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 frequency. 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 packingline to prevent contamination of the line by fungal inoculum. Decayed fruit should not be left near the packinghouse because spores can be carried by wind and insects into the packinghouse. Decayed fruit should never be repacked within 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 (QA) compounds may also be used, but require a fresh water 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.

CITRUS DECAY CONTROL USING FUNGICIDES

The following fungicides can be used for decay control of citrus. Follow the label if the instructions are different from below because *the label is the law.*

Thiabendazole (TBZ): TBZ is applied with truck or bin drenchers and on the packinghouse line. Stem-end rot and green mold are both effectively controlled when TBZ is applied correctly. It also provides some anthracnose control, but does not control sour rot or black rot.

Concentration and formulation – TBZ should be applied 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.

Methods of application – TBZ is only slightly soluble in water; therefore, 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.

Imazalil: Imazalil is especially effective against green mold and against mold sporulation. Imazalil is less effective than TBZ for control of Diplodia and Phomopsis stem-end rot, and it is ineffective against sour rot and brown rot. It has some activity against Alternaria stem-end rot (black rot).

Concentration and formulation – Imazalil 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.

Methods of application – These are identical to the recovery and non-recovery postharvest applications of TBZ described above, except that some heating or other sanitizers (not chlorine) are applied in imazalil bin drenchers because chlorine and imazalil are not compatible. The efficacy of imazalil is reduced in water-based wax formulations.

SOPP: SOPP (sodium o-phenylphenate or o-phenylphenol [OPP]) reduces green mold and provides some control of Diplodia and Phomopsis stem-end rot, as well as sour rot.

Concentration and formulation – A 2 percent aqueous solution of SOPP applied at pH 11.5–12.0 is the most effective treatment. One formulation contains 2 percent SOPP, 0.2 percent sodium hydroxide for pH control, and 1 percent hexamine to minimize phytotoxicity. Water emulsion waxes with 1 percent SOPP are also available, but they have little fungicidal value. Residues are expressed in terms of o-phenylphenol.

Methods of application – 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 2 minutes provide less decay control, while time exceeding 2 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 12.0 to prevent peel injury. The maximum legal residue tolerance for SOPP may be exceeded if waxes containing SOPP are applied to fruit previously treated with aqueous applications of SOPP.

Fludioxonil: Fludioxonil is a 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. However, 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+®. The effectiveness of fludioxonil and the combined fludioxonil/azoxystrobin mixture against other decay organisms under Florida conditions is not yet established.

Concentration and formulation – Fludioxonil (Graduate®) should be applied at 600 ppm to 1,200 ppm, and Graduate A+® at 1,200 ppm total a.i., both as a water suspension. The efficacy of these products in a water-based wax under Florida conditions is not yet known.

Methods of application – These are identical to the recovery and non-recovery postharvest applications of TBZ described above. Fludioxonil and azoxystrobin are compatible with chlorine in fruit drenching treatment.

Preharvest Copper, Aliette®, Phostrol®, and ProPhyt®: These fungicides are applied before harvest for control of brown rot in fruit from blocks of trees that historically develop the disease or in seasons when climatic conditions favor brown rot development. Aliette® has a preharvest interval of 30 days before fruit can be harvested following fungicide application.

Table 1. Major postharvest decays, seasonal development, fruit susceptibility, and effective fungicide treatments

Disease	Months of prevalence	Treatments[a]
Brown rot	Aug-Dec	Preharvest (Aliette®[b], 5 lbs./a; Phostrol®, 4.5 pints/a[c]; ProPhyt®[c], 4 pints/a; copper[c], label rate)
Diplodia SER[d]	Sept-Dec	Bin drench (TBZ[e] or imazalil[f], 1000 ppm; Fludioxonil[f], 600-1200 ppm; Graduate A+®[f], 1200 ppm) Packingline (TBZ, 1000 ppm aqueous, 2000 ppm water wax; Fludioxonil, 600-1200 ppm aqueous; Graduate A+®, 1200 ppm aqueous)
Anthracnose	Sept-Nov	Bin drench (TBZ, 1000 ppm)
Green mold	Dec-June	Bin drench (TBZ or imazalil, 1000 ppm; Graduate A+®, 1200 ppm) Packingline (SOPP[g], 2%; TBZ and/or imazalil[h], 1000 ppm aqueous, 2000 ppm water wax; Graduate A+®[h], 1200 ppm aqueous)
Sour rot	Nov-Feb Apr-June	Packingline (SOPP, 2%)
Phomopsis SER	Jan-June	Packingline (TBZ and/or imazalil, 1000 ppm aqueous, 2000 ppm water wax)
Alternaria SER	July-Sept	Packingline (Imazalil, 1000 ppm aqueous, 2000 ppm water wax)

[a]Postharvest materials are specified as ppm or % of active ingredient. Preharvest fungicides except copper are incidated as rates of formulation.
[b]Apply Aug-Dec, 30-day preharvest interval.
[c]Apply Aug-Dec, 0-day preharvest interval.
[d]Stem-end rot.
[e]TBZ – thiabendazole.
[f]Use when TBZ residues are a problem for fruit going to juice.
[g]SOPP – sodium o-phenylphenate.
[h]Effective for sporulation control on fruit within packed cartons.

Table 2. Optimum holding temperatures for maximum quality and shelf life of fresh Florida citrus fruit	
Citrus type	Optimum holding temperatures (°F)
Grapefruit	50 – 60
Lemons, limes	50
Mandarin-type fruits	40
Oranges	32 – 34

Note: Somewhat lower temperatures can be used if fruit coatings are used that substantially restrict gas permeability (e.g., some shellac formulations).

SUMMARY OF FUNGICIDE TREATMENTS

Effective fungicide treatments are summarized in Table 1, page 9, for the control of specific postharvest diseases that predominate during various months of the season.

REFRIGERATION

Decay development can be delayed by refrigeration (Table 2). 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 fruit (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.

HUMIDITY CONTROL

Rapid handling of fruit at high relative humidities and application of a protective wax coating to retard desiccation are the best means of reducing fruit water loss. High relative humidity during handling, storage and transit helps to maintain fruit turgidity and freshness and enhances healing of minor injuries, thereby reducing susceptibility to green mold. When fruit is held in plastic containers, such as pallet boxes, the relative humidity should be 90 percent to 95 percent. However, when fruit is packed in fiberboard cartons, the humidity should be lower (85 percent to 90 percent) to prevent carton deterioration.

RESIDUE TOLERANCES

Because maximum residue limits (MRLs) for various export markets change frequently, growers, packers and shippers are encouraged to stay informed about such changes through their respective trade groups and through one or more web resources. A table of citrus MRLs for domestic and important export markets is posted on the University of Florida Postharvest Resources website (http://postharvest.ifas.ufl.edu) and is updated as needed throughout the year. This site also includes links to other useful MRL sites, such as the U.S. Foreign Agricultural Service's International MRL database (http://www.mrldatabase.com) and sites for specific markets, such as the European Union, Canada and Japan. While all these websites are useful as a starting point, no guarantee can be made as to their accuracy; always verify these values with other knowledgeable sources.

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