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2024–2025 Florida Citrus Production Guide: Decay Control of Florida Fresh Citrus[1]

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Citrus fruit decay is one of the most important constraints that affect fresh citrus quality and marketing values. It is most often caused by fungal or oomycete pathogens that grow and develop in hot and wet conditions typical of Florida. The most common postharvest fungal decays of Florida citrus are Diplodia stem-end rot (*Lasiodiplodia theobromae*), green mold (*Penicillium digitatum*), and Phomopsis stem-end rot (*Diaporthe citri*). Other fungal decays include sour rot (*Geotrichum citri-aurantii*), anthracnose (*Colletotrichum gloeosporioides*), blue mold (*Penicillium italicum*), and less frequently, Alternaria stem-end rot (black rot; *Alternaria alternata*). Decays by oomycete pathogens are mainly brown rot (primarily *Phytophthora palmivora* and *P. nicotianae*) occasionally causing commercially important losses of citrus fruit. Losses from these diseases can be reduced using the practices discussed below.

Degreening Management

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, leaving behind the characteristic orange and yellow of the peel. However, ethylene exposure also stimulates the development of Diplodia stem-end rot and anthracnose, with longer ethylene exposure or exposure to higher concentrations resulting in more decay. If degreening is necessary, fruit should first be drenched with a suitable fungicide and then degreened at 82°F–85°F (27.8°C–29.4°C) with 3–5 ppm ethylene and 90%–95% relative humidity. Degreen *only* as long as necessary to obtain adequate peel color, with treatment duration depending on fruit variety and the degree of color break. See "Recommendations for Degreening Florida Fresh Citrus Fruits" for more information.

Minimizing Fruit Injuries

Mechanical injuries to the fruit peel during fruit harvesting and subsequent handling are the principal sites for infection by wound-mediated pathogens such as *P. digitatum* (green mold), *P. italicum* (blue mold), and *G. citri-aurantii* (sour rot). To reduce pathogen infection and decay, care should always be taken to minimize fruit injuries during fruit harvesting, packing, storage, and shipping.

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Use pesticides safely. Read and follow directions on the manufacturer's label.

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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 at least daily 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 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 [71.1°C]) 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" for more information.

Citrus Decay Control Using Fungicides

The following fungicides can be used to control decay of citrus fruit. 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%) as a water suspension, or at 2,000 ppm (0.2%) in a water-based wax. The higher concentration of TBZ in wax is due to its reduced efficacy when mixed in wax compared to aqueous application.

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 nonrecovery 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 nonrecovery 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 nonrecovery 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 rots, and it is ineffective against sour rot and brown rot.

Concentration and Formulation—Imazalil should be applied at 1,000 ppm (0.1%) as a water suspension or at 2,000 ppm (0.2%) in a water-based wax. The higher concentration of imazalil in wax is due to its reduced efficacy when mixed in wax compared to aqueous application.

Methods of Application—These are identical to the recovery and nonrecovery 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.

Sodium o-phenylphenate (*SOPP*): SOPP reduces green mold and provides some control of sour rot and Diplodia and Phomopsis stem-end rots.

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

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 shorter than two minutes provide less decay control, while time 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 (20.0°C). The pH of aqueous solutions lacking hexamine must be maintained at 11.5–12.0 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 and Azoxystrobin: Fludioxonil and azoxystrobin are newer postharvest fungicides registered for use on citrus. The mixture of fludioxonil and azoxystrobin is marketed as Graduate A+. Fludioxonil is effective against Diplodia stem-end rot and green mold; azoxystrobin is effective for green mold control and has some activity against Diplodia stem-end rot. Graduate A+ provides good control for Diplodia stem-end rot, green mold, and *Penicillium* sporulation. It also mitigates the development of *Penicillium* resistance because fludioxonil and azoxystrobin have different chemical modes of action against fungal pathogens. Neither fludioxonil nor azoxystrobin control sour rot.

Concentration and Formulation—Graduate A+ should be applied at 1,200 ppm (600 ppm fludioxonil, 600 ppm azoxystrobin), both as a water suspension. However, the efficacy of these products incorporated into wax coatings under Florida conditions still needs to be determined.

Methods of Application—These are identical to the recovery and nonrecovery postharvest applications of TBZ described above. Fludioxonil and azoxystrobin are compatible with chlorine in fruit drenching treatment.

***Pyrimethanil*:** Pyrimethanil is a postharvest fungicide registered for citrus and marketed as Penbotec**.** It has good activity against Penicillium decay but less activity against Diplodia stem-end rot compared to TBZ, imazalil, and fludioxonil. Pyrimethanil can be used to manage Penicillium resistance development to TBZ/imazalil because it has a different mode of action.

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. See chapter 32, "Brown Rot of Fruit", for more details.

Summary of Fungicide Treatments

Effective fungicide treatments are summarized in Table 1 for the control of specific postharvest diseases that predominate during various months of the season. It is important to use fungicides with different modes of action (Table 2) to help prevent the development of pathogen resistance to the materials.

Temperature

One can delay fruit decay by cooling the fruit and maintaining the "cold chain" throughout transportation and distribution (Table 3). Such practices greatly slow fruit metabolism and reduce development of stem-end rind breakdown; visit "Stem-End Rind Breakdown of Citrus Fruit" for details. However, varietal and seasonal differences in susceptibility to chilling injury must be considered when selecting optimum temperatures. 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" 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 maintain fruit turgidity and freshness and enhance healing of minor injuries, thereby reducing susceptibility to green mold. When fruit are held in plastic containers, such as pallet boxes, the relative humidity should be 90%–95%. However, when fruit are packed in fiberboard cartons, the humidity should be lower (85%–90%) 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 UF/IFAS Postharvest Resources website and is updated as needed throughout the year. This site also includes links to other useful MRL sites—such as a global MRL database—and sites for specific markets including those of the European Union, Canada, and Japan. While these websites are useful starting points from which to gather information, the authors of this publication cannot guarantee their accuracy; always cross-reference with other knowledgeable sources.

Web Addresses for Links

BCGlobal MRL Database: https://bcglobal.bryantchristie.com/

EDIS Publication HS191, "Chilling Injury of Grapefruit and Its Control": https://edis.ifas.ufl.edu/publication/hs191

EDIS Publication HS761, "Chlorine Use in Produce Packing Lines": https://edis.ifas.ufl.edu/publication/CH160

EDIS Publication CIR 1170, "Recommendations for Degreening Florida Fresh Citrus Fruits": https://edis.ifas.ufl.edu/publication/HS195

EDIS Publication HS193, "Stem-End Rind Breakdown of Citrus Fruit": https://edis.ifas.ufl.edu/publication/hs193

UF/IFAS Postharvest Resources Website: https://irrec.ifas.ufl.edu/postharvest

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 lb/ac; Phostrol, 4.5 pints/ac[c]; ProPhyt[c], 4 pints/ac; copper[c], label rate)
Diplodia SER[d]	Sept–Dec	Bin drench (TBZ[e] or imazalil[f], 1000 ppm; Graduate A+[f], 1200 ppm) Packing line (TBZ, 1000 ppm aqueous, 2000 ppm water wax; Graduate A+, 1200 ppm aqueous)
Anthracnose	Sept–Nov	Bin drench (TBZ, 1000 ppm)
Green mold	Dec–June	Bin drench (TBZ or imazalil, 1000 ppm; Fludioxonil, 600–1200 ppm; Graduate A+, 1200 ppm) Packing line (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	Packing line (SOPP, 2%)
Phomopsis SER	Jan–June	Packing line (TBZ and/or imazalil, 1,000 ppm aqueous, 2,000 ppm water wax)
Alternaria SER	July–Sept	Packing line (Imazalil, 1,000 ppm aqueous, 2,000 ppm water wax)

[a] Postharvest materials are specified as ppm or % of active ingredient. Preharvest fungicides, except copper, are indicated as rates of formulation.
[b] Apply Aug–Dec, 30-day preharvest interval.
[c] Apply Aug–Dec, 0-day preharvest interval.
[d] SER: 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. Modes of action and pesticide details.

Pesticide	FRAC MOA[1]	Notes
Aliette WDG	P 07	Preharvest application. Do not exceed 4 applications/season or 20 lb/acre/year; for foliar application, do not exceed 500 GPA. Do not apply within 30 days of harvest.
Copper	M 01	Preharvest application. Use label rate.
Graduate A+	11/12	Do not make more than 2 applications to citrus fruit.
Imazalil (Examples: DECCOZIL EC-289, Freshgard 700, Fungaflor 500EC)	3	See label.
Penbotec 400SC	9	See label.
Phostrol	P 07	Preharvest application. Can cause phytotoxicity if applied above 90°F, at color break, or after rainfall.
ProPhyt	P 07	Preharvest application. Recommended application volume of 100–205 gal/acre.
Sodium o-phenylphenate (SOPP) (Examples: DECCOSOL 125, FreshGard 5)	--	See label.
Thiabendazole (TBZ) (Examples: Freshgard 598, Alumni, DECCO Salt No. 19)	1	See label.

[1] Mode of action class for citrus pesticides from the Fungicide Resistance Action Committee (FRAC) 2024. Refer to chapter 4, "Pesticide Resistance and Resistance Management," for more details.

Table 3. Optimum holding temperatures for maximum quality and shelf life of fresh Florida citrus fruit.

Citrus Type	Optimum Holding Temperatures
Grapefruit	50°F–60°F (10.0°C–15.6°C)
Lemons, limes	50°F (10.0°C)
Mandarin-type fruits	40°F (4.4°C)
Oranges	32°F–34°F (0.0°C–1.1°C)

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