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Citrus Production Fundamentals 2026-2029

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Citrus Production

Fundamentals 2026-2029

Citrus Production Fundamentals 2026–2029

EFFECTIVE AND SAFE CITRUS PRODUCTION STRATEGIES
FOR USE IN COMMERCIAL GROVES ONLY

Before using any pesticide:
Read the complete label and the general instructions in this guide.

This publication was developed by UF/IFAS citrus faculty at research and education centers and county Extension offices across Florida, and the main campus.

Lauren M. Diepenbrock, Megan M. Dewdney, and Tripti Vashisth.

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Table of Contents

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2026–2029 Florida Citrus Production Guide: Introduction[1]

Lauren M. Diepenbrock, Megan M. Dewdney, and Tripti Vashisth[2]

Over the past decade, Florida citrus production practices have changed dramatically due to the challenges presented by huanglongbing (HLB). As we have learned more about this disease, how it is spread by the Asian citrus psyllid, and the overall effects on citrus tree health, it is increasingly evident that management of this disease requires changes to *all* aspects of citrus production. Several factors must all be considered together when developing a site-specific management plan for citrus production in the presence of HLB. Part of the *Florida Citrus Production Guide* will continue to be updated annually with the latest information to help growers refine their production practices using the latest research-based findings proven to be effective for Florida citrus production. Starting in 2026, the *Florida Citrus Production Guide* will be available as two separate booklets. The first booklet will provide information that does not change frequently such as personal protective equipment (PPE) guidelines and the biology of many of the insects, diseases, and horticultural practices that are part of citrus production. This will be updated every 3 years. The second booklet will be updated annually and include any pertinent updates to legislation that impact Florida citrus production and all pesticide and PGR tables that were previously incorporated into each chapter. This allows for rapid updates to incorporate new knowledge.

In this edition, greasy green has been included as a new symptom of greasy spot and has been added to chapter 32, "Greasy Spot." Refer to that chapter in booklet 1 and the associated chemical management table in booklet 2 for management recommendations. Readers may also see a new group of insecticides, IRAC Group 30, now available ("Pesticide Resistance and Resistance Management" chapter). One chemistry, Zivalgo, is available for use in Florida citrus in this insecticide group. It has been evaluated by UF/IFAS entomologists for efficacy against citrus leafminer and Asian citrus psyllid, with recommendations available in booklet 2 for effective rates.

In addition to changes in production practices needed to manage emerging pest problems in Florida, the regulatory environment is also constantly changing. New rules for Worker Protection Standards (WPS) were fully implemented in January 2018, including important changes to worker training, reporting, and posting of pesticide applications. Likewise, compliance with the Food Safety Modernization Act (FSMA) Produce Safety Rule (PSR) was required by January of 2020 for all farm sizes. This rule established minimum food safety standards to be implemented by growers, packers, and harvesters of fresh produce. Compliance with these rules directly impacts day-to-day production practices and costs to Florida citrus growers. The requirements of these rules are explained in the chapters on the WPS and food safety.

Overall, the goal of the *Florida Citrus Production Guide* is to serve as a reference for information needed to guide decision-making in Florida citrus-growing operations. **It is not intended to replace agricultural product labels that contain important usage information and should be immediately accessible for reference. Violations of directions for use printed on the label are against state and federal laws. Always read and follow label instructions.** Likewise, state and federal regulations on topics such as the WPS are constantly changing, and not all the information needed to ensure compliance can be covered in this guide. The WPS chapter in this guide covers some of the important highlights of these rules. **It is imperative that growers obtain copies of and follow the detailed rules outlined in the regulatory documents referenced in this guide.** The *Florida Citrus Production Guide* provides general guidance and is NOT the final regulatory document that should be followed.

For specific information on pest identification, biology, damage, or nonchemical management techniques, refer to Ask IFAS/EDIS and other UF/IFAS, USDA, and Florida Department of Agriculture and Consumer Services (FDACS) publications. In addition to the authors listed throughout the *Florida Citrus Production Guide*, the citrus Extension specialists, faculty, and Extension agents listed below can provide assistance with citrus production practices.

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2026–2029 Florida Citrus Production Guide: Useful Telephone Numbers[1]

Jason A. Ferrell and Frederick M. Fishel[2]

National Pesticide Information Center (NPIC)

1-800-858-7378, 11 a.m.–3 p.m. Eastern time, Monday–Friday. Provides general information on pesticide products, recognition and management of pesticide poisoning, toxicology, and environmental chemistry.

CHEMTREC®

CHEMTREC® is the Chemical Transportation Emergency Center. It is operated by the Chemical Manufacturers Association to assist people in handling chemical emergencies, such as large chemical spills or leaks.

Register at their website: https://www.chemtrec.com/our-services/emergency-response/chemical-response-call-center

Then, call their telephone number during chemical emergencies: 1-800-424-9300.

UF/IFAS

Pesticide Information Office: 352-392-4721

UF/IFAS Citrus Research and Education Center: 863-956-1151

Florida Department of Agriculture and Consumer Services

Division of Plant Industry: 352-395-4700

Pesticide Certification/Licensing Office: 850-617-7870

Florida's Poison Control Centers

1-800-222-1222

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2026–2029 Florida Citrus Production Guide: Fresh Fruit Pesticide Residue Limits[1]

Mark A. Ritenour[2]

Current production practices often include the use of various pre- and postharvest chemicals, many of which are pesticides. To be used, these materials must be labeled for use on citrus (see "Pesticides Registered for Use on Florida Citrus") and used only according to label instructions. Chemical residues on the fruit after harvest are a concern to regulators and the public alike because of their potential negative health effects. Therefore, the United States and other countries set maximum residue limits (MRLs) on fresh produce for various chemicals. By US law, such materials must be applied according to label instructions, but doing so also means it is unlikely for US MRLs to be exceeded. However, when exporting product to a country that has lower MRLs than the United States, the use of these pesticides usually must be modified or discontinued to keep from exceeding the other country's tolerances. When no MRL or default tolerances are stated, any detectable residue will constitute a violation. The limit of detection for chemical residues on citrus fruit is often between 0.01 and 0.05 ppm, depending on the testing laboratory and chemical of interest. Violations may lead to rejected loads of product, restrictions on future shipments, and even increased scrutiny or requirements for the entire industry.

Because MRLs change frequently, see the UF/IFAS Postharvest Resources website for the most current list of MRLs (in parts per million) for various chemicals used on fresh Florida citrus destined for the United States and important export countries. This information is intended as an initial reference source, and no guarantee is made of its accuracy. Always verify these values with other knowledgeable sources within specific markets of interest. This website includes links to specific MRL databases for select countries and to a BCGlobal MRL database for the most comprehensive list of MRLs for all commodities and markets.

Web Addresses for Links

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

UF/IFAS Postharvest Resources:
https://irrec.ifas.ufl.edu/postharvest/pesticide-residues-and-maximum-limits/

[1] This document is HS1301, one of a series of the Department of Horticultural Sciences, UF/IFAS Extension. Original publication date July 2017. Revised annually. Most recent revision August 2026. Visit the Ask IFAS website at https://ask.ifas.ufl.edu for the currently supported version of this publication.

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2026–2029 Florida Citrus Production Guide: Pesticide Resistance and Resistance Management[1]

Lauren M. Diepenbrock, Megan M. Dewdney, and Ramdas Kanissery[2]

Populations of animals, fungi, bacteria, and plants possess the ability to respond to sustained changes or stresses in their environment in ways that enable the continued survival of the species. Such environmental stresses include physical factors (e.g., temperature or humidity), biological factors (e.g., predators, parasites, or pathogens), and environmental contaminants. In any population, a small percentage of individuals will be better able to respond to new stresses because of unique traits or characteristics that they possess. Consequently, those individuals will survive, reproduce, and become more common in a population. This phenomenon is commonly referred to as "survival of the fittest."

Many pest species, such as the citrus rust mite, are exceptionally well equipped to respond to environmental stresses because of their short generation time and large reproductive potential. The use of chemical sprays to control insects, mites, bacterial and fungal diseases, and weeds of citrus creates a potent environmental stress. There are now many examples of pests, pathogens, and weeds that have responded by developing resistance to one or more pesticides. Pesticide-resistant individuals are those that have developed the ability to tolerate doses of a toxicant that would be lethal to the majority of individuals. The resistance mechanisms can vary according to pest species and/or the class of chemical to which the pest is exposed. Resistance mechanisms for insects include an increased capacity to detoxify the pesticide once it has entered the pest's body, a decreased sensitivity of the target site that the pesticide acts upon, a decreased penetration of the pesticide through the cuticle, or sequestration of the pesticide within the organism. The main resistance mechanism for fungal pathogens is a change in the target site so that the pathogen is less susceptible or fully resistant. With repeated or intense exposure to herbicides, some weeds develop resistance because only individuals that are capable of detoxifying the chemical persist over time. A single resistance mechanism can sometimes provide defense against different classes of chemicals; this is known as *cross-resistance*. When more than one resistance mechanism is expressed in the same individual, this individual is said to show *multiple resistance*.

Of the factors that affect the development of resistance, including the pest's or pathogen's biology, ecology, and genetics, only the operational factors can be manipulated by the grower. The key operational factor that will delay the onset of pesticidal resistance and prolong the effective life of a compound is assuring the survival of some susceptible individuals to dilute the population of resistant individuals. The following operational procedures should be on a grower's checklist to steward sound pesticidal resistance management for acaricides, insecticides, fungicides, antibiotics, and herbicides:

1. Never rely on a single pesticide class.
2. Integrate chemical control with effective and complementary cultural and biological control practices.
3. Always use pesticides at recommended rates and strive for thorough coverage.
4. When there is more than one generation of pest, alternate different pesticide classes.
5. Do not use tank mixtures of products that have the same mode of action.
6. If control with a pesticide fails, do not re-treat with a chemical that has the same mode of action.

Reports of resistance have been documented for certain acaricides used to control citrus rust mite and fungicides used to combat diseases in Florida. Resistance is also likely to be found in weeds with repeated exposure to certain herbicides. Resistance to Benlate developed in the greasy spot fungus shortly after the product was introduced about 30 years ago and is still widespread. More recently, we have discovered that there is QoI fungicide (Table 2) resistance in the greasy spot fungus. This is a developing story, but caution should be used when choosing this class of fungicide, and a mixture of modes of action is advised. Benlate resistance also occurs in the scab fungus in isolated situations and is stable. In tangerine groves with Alternaria brown spot, resistance has been detected to strobilurin fungicides (Gem, Headline, and Quadris [formerly Abound] and contained in the mixtures Pristine, Priaxor, and Amistar Top), but no resistance has developed to ferbam. Unfortunately, ferbam was deregistered in 2025, removing a valuable resistance management tool.

Dicofol resistance in citrus rust mite was detected throughout the citrus industry about 10 years ago, but resistance proved to be unstable, and usage of dicofol has continued. Agri-mek tolerance in citrus rust mite is of concern, and growers should follow sound resistance management practices when using this product. Recent studies have shown reduced susceptibility to several insecticides in populations of Asian citrus psyllid after repeated exposure to similar materials, but that susceptibility can be restored by rotating modes of action used in management programs. Resistance management is crucial to the management of this insect. Glyphosate-resistant weeds are becoming commonplace in many production systems with the repeated use of this popular preemergence herbicide, highlighting the need to rotate materials for weed management.

The following tables are provided to aid in the rotation of pesticides with different modes of action within a season or from year to year. There are separate tables for insecticides/acaricides, fungicides/antibiotics, and herbicides. The information in these tables was derived from information produced by the Insecticide Resistance Action Committee (IRAC), the Fungicide Resistance Action Committee (FRAC), and the Herbicide Resistance Action Committee (HRAC). Each table lists the number (or letter in the case of herbicides) of the group code for each pesticide class, the group name or general description of that group of pesticides, the common name of pesticides used in citrus production that belong to each group, and examples of trade names of pesticides for each common name listed. When using the table to rotate between using products with different modes of action, choose products with a different group code than previously used in the grove during the current growing season. In the case of insecticides/acaricides, many of these pesticides are broken into subgroups. It is unclear whether cross-resistance will occur between these subgroups. When possible, it is recommended to rotate with an entirely different group. (Note: The IRAC and FRAC mode of action systems both use a similar numbering system. There is no cross-resistance potential between the insecticides and fungicides.) Products with broad-based activity such as sulfur and oil are not included in this list because the development of resistance to them is not likely.

Web Addresses for Links

FRAC: https://www.frac.info/

HRAC: https://hracglobal.com/tools/classification-lookup

IRAC: http://www.irac-online.org/

Table 1. Insecticides and miticides used in Florida citrus grouped by mode of action.

IRAC Group[1]	Subgroup	Group Name	Common Name	Trade Name
1	1A	Carbamates	carbaryl oxamyl	Sevin Vydate, ReTurn
	1B	Organophosphates	acephate dimethoate malathion naled phosmet	Orthene, Acenthrin, Avatar PLX, Bracket Dimethoate Malathion Dibrom Imidan
3	3A	Pyrethroids	bifenthrin fenpropathrin zeta-cypermethrin	Brigade Danitol Mustang
4	4A	Neonicotinoids	acetamiprid clothianidin imidacloprid thiamethoxam	Actara, Admire Pro, Advise, Alias, Assail, Belay, Couraze, Imida E-Ag, Impulse, Macho, Montana, Nuprid, Pasada, Platinum, Prey, Torrent, Widow
	4D	Butenolides	flupyradifurone	Sivanto, Altus
5		Spinosyns	spinosad spinetoram	Spintor Delegate
6		Avermectins	abamectin	Abacus, Abba, Agri-mek, Clinch, Epi-mek, Reaper, Zoro
7	7A	Juvenile Hormone Analogues	methoprene	Extinguish Ant Bait
	7B	Fenoxycarb	fenoxycarb	Precision
	7C	Pyriproxyfen	pyriproxyfen	Knack
10	10A	Hexythiazox	hexythiazox	Savey
11	11A	*Bacillus thuringiensis* (*Bt*)	*Bt* var. aizawai *Bt* var. kurstaki	Various Various
12	12B	Organotin miticides	fenbutatin oxide	Vendex
	12C	Propargite	propargite	Comite
15		Benzoylureas	diflubenzuron	Micromite
16		Buprofezin	buprofezin	Applaud, Centaur
18		Diacylhydrazines	methoxyfenozide	Intrepid
21	21A	METI acaricides	pyridaben fenpyroximate	Nexter Portal, Apta
23		Tetronic/Tetramic acid derivatives	spirodiclofen spirotetramat	Envidor Movento, Senstar
28		Diamides	chlorantraniliprole, cyantraniliprole	Exirel, Verimark, Voliam Flexi (one component)

IRAC Group[1]	Subgroup	Group Name	Common Name	Trade Name
30		Meta-diamides & Isoxazolines	plinazolin	Zivalgo
UN		Unknown MOA	bifenazate	Acramite
			cryolite	Kryocide
			dicofol	Kelthane
[1] Mode of action based on the Insecticide Resistance Action Committee (IRAC) Mode of Action Classification v. 11.4 (2025).				

Table 2. Fungicides and antibiotics used in Florida citrus grouped by mode of action.

FRAC Group[1]	Group Name	Common Name	Trade Name
1	MBC—fungicides (Methyl benzimidazole carbamates)	thiabendazole	Many (TBZ)
3	DMI—fungicides (Demethylation inhibitors)	difenoconazole fenbuconazole imazalil mefentrifluconazole propiconazole	Amistar Top, Miravis Top, Acadia ESQ, Luna Flex, Tycoon, and others Enable 2F, Indar 2F Many Cevya, Provysol, Veltyma Many
4	PA—fungicides (Phenylamides)	metalaxyl mefenoxam	Ridomil, ReCon, Regulate, MetaStar, Xyler Ultra Flourish, Ridomil Gold, Subdue, Mefenoxam 2 AQ, ReCon Bold, Stergo MX, others
7	SDHI—fungicides (Succinate-dehydrogenase inhibitors)	boscalid fluopyram fluxapyroxad pydiflumetofen	Pristine, Endura, Bonafide, Empire Luna Sensation, Luna Flex, Broadform, Velum Priaxor Xemium, Republic, Tesaris Miravis Top
11	QoI—fungicides (Quinone outside inhibitors)	azoxystrobin trifloxystrobin pyraclostrobin	Quadris (formerly Abound) and others, Graduate A+, Amistar Top Gem, Broadform, Compass, Luna Sensation, Venus Headline and others, Pristine, Priaxor Xemium, Veltyma
12	PP—fungicides (Phenylpyrroles)	fludioxonil	Graduate, Graduate A+, Pilato SC
19	Polyoxin	polyoxin D zinc salt	OSO 5% SC, Ph-D
40	CAA—fungicide (Carboxylic acid amides)	mandipropamid	Revus Orondis Ultra
41	Tetracycline antibiotic	oxytetracycline	Fireline, Mycosheild ReMedium TI, Rectify
43	Benzamides	fluopicolide	Adorn, Presidio

FRAC Group[1]	Group Name	Common Name	Trade Name
48	Polyene	natamycin	BioSpectra 100SC
49	OSBPI—oxysterol binding protein homologue inhibition	oxathiapiprolin	Orondis Orondis Ultra
M 01	Inorganic	copper	Many
P 01	Benzothiadiazole (BTH)	acibenzolar-S-methyl	Actigard 50WG
P 07	Phosphonates	fosetyl-Al phosphorous acid and salts	Aliette, Linebacker Many
[1] Mode of action based on the 2025 Fungicide Resistance Action Committee (FRAC) Mode of Action Classification.			

Table 3. Herbicides used in Florida citrus grouped by mode of action.

HRAC Group[1]	Group Name/Chemical Family	Common Name	Trade Name(s)
A (1)	Aryloxyphenoxy-propionates Cyclohexanediones	fluazifop-p-butyl sethoxydim	Fusilade Poast
C1 (5)	Triazines Uracils	simazine bromacil	Caliber, Princep, Simazine Hyvar, Krovar
C2 (5)	Ureas	diuron	Direx, Karmex, Krovar
D (22)	Pyridiniums	paraquat	Gramoxone
E (14)	N-Phenyl-triazolinones N-Phenyl-imides	carfentrazone-ethyl flumioxazin saflufenacil	Aim Chateau EZ Treevix
F1 (12)	N-Phenyl heterocycles	norflurazon	Solicam
F2 (27)	Triketones	mesotrione	Broadworks
G (9)	Glycine	glyphosate	(Various) e.g., Roundup, Gly Star
H (10)	Phosphinic acids	glufosinate-ammonium	Rely 280, Scout
K1 (3)	Dinitroanilines	oryzalin pendimethalin	Surflan Prowl
L (29)	Alkylazines	indaziflam	Alion
O (4)	Phenoxy-carboxylates	2,4-D	Embed Extra
[1] Mode of action based on the 2025 Herbicide Resistance Action Committee (HRAC) Mode of Action Classification. HRAC/Weed Science Society of America (WSSA) numerical codes for this classification are provided in parentheses.			

[1] This document is ENY-624, one of a series of the Department of Entomology and Nematology, UF/IFAS Extension. Original publication date December 1995. Revised annually. Most recent revision August 2026. Visit the Ask IFAS website at https://ask.ifas.ufl.edu for the currently supported version of this publication.

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2026–2029 Florida Citrus Production Guide: Pesticide Application Technology[1]

Masoud Salyani[2]

Spraying Trees

Sprayer Selection

Most Florida citrus applications are made with air-carrier ground sprayers. These sprayers may be truck/tractor-mounted, tractor-drawn (p.t.o./engine-driven), or self-propelled. They may be equipped with a positive or nonpositive displacement pump to pressurize the spray liquid and generate spray droplets by hydraulic nozzles, air-shear nozzles, or rotary atomizers. Spray droplets are normally transported by sprayer airflow, generated with one or more axial-, centrifugal-, or cross-flow fans. The air is directed toward the canopy by a series of fixed, adjustable, or moving deflectors (oscillators). Some sprayers use a short or tall tower attachment to discharge a portion of the spray-laden air close to the upper parts of the tree canopy. Sprayers may use mechanical and/or hydraulic agitation systems.

The differences in size, shape, design features, and construction material of the sprayers could result in substantial variation in the price of the spray equipment. Nevertheless, a higher price does not necessarily mean a better sprayer or guarantee more satisfactory spray coverage. A pesticide can be expected to be effective if the right material is applied, at the right amount, on the right target, at the right time, with the right sprayer, and under the right weather conditions. A cheap sprayer, adjusted and operated properly, may result in better pest control than a sophisticated sprayer used improperly under adverse weather conditions.

Sprayer Air Capacity

Because air-blast applications depend on the sprayer air stream to deposit the spray on the tree, the air volume and velocity must be sufficient for efficient droplet transport, acceptable penetration inside the canopy, and satisfactory spray coverage. However, air-carrier sprayers have a wide range in air capacities (5,000–100,000 cfm). While larger sprayers generate much more air volume than smaller ones, they may not provide any improvement in spray coverage, and in some cases, too much air may adversely affect spray deposition by increasing spray runoff from the leaf surface.

As the fan power requirement changes with the cubic factor of the airflow rate (fan speed), excessive air capacities dramatically increase the needed horsepower for fan operation. A 10%–20% increase in fan speed increases the fan power demand by 33.1%–72.3%, respectively. On the other hand, a 10%–20% decrease of the speed reduces the power requirement by 27.1%–48.8%, respectively. Higher energy demand of the fan requires purchasing a larger sprayer or operating the fan at higher rotational speeds. These practices would increase capital investment, fuel consumption, and operating costs. Therefore, smaller fans or lower rotational speeds should be used as much as possible. Using lower air volumes could offer substantial savings in energy expenditure and cost of spray applications. Certainly, small trees and lightly foliated canopies do not require large sprayers. Reduction of fan speed is a practical method for decreasing pesticide waste and application cost in spraying small and low-density trees. It should be noted that sprayers must be recalibrated if they are used at lower fan speeds.

Nozzle Arrangement

In Florida citrus applications, it has been a common practice to direct 2/3 of the spray volume to the upper half of the tree and 1/3 to the lower half. However, this practice is no longer recommended when spraying small trees or using large airblast sprayers. The 2/3-1/3 nozzle arrangement has shown no significant improvement in overall spray deposition or pest control as compared to 1/2-1/2 (uniform) nozzle arrangement. The latter may also minimize errors in nozzle selection. Sprayer air deflectors, nozzle orientation, and number of nozzles should be adjusted to match the size and shape of the canopy and minimize spray wastage (see Figure 1).

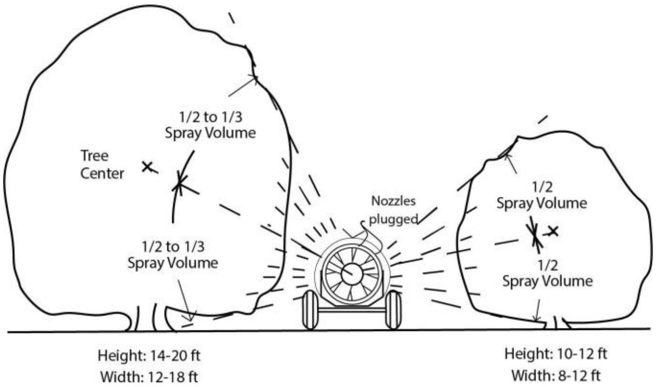

Figure 1. Recommended nozzle arrangement and spray volume distribution.
Credit: UF/IFAS

For low-volume rates (less than 100 gal/acre), reducing the number of nozzles and using smaller disc and core sizes rather than spraying at higher ground speeds may improve spray deposition. For high-volume rates (greater than 250 gal/acre), increasing the number of nozzles and spraying at higher ground speeds, instead of using fewer large disc and core sizes, may give higher deposition efficiency. Deposition efficiency of mid-volume rates (100–250 gal/acre) is less sensitive to these application variables.

Sprayer Calibration

Application errors can originate from either incorrect tank concentration of the pesticides (mixing error) or incorrect sprayer output per unit area (calibration error). The latter may be due to travel speed, nozzle pressure, or the use of improper, defective, and worn nozzles. However, by proper matching of the sprayer discharge rate, swath width, and travel speed, calibration errors can be mitigated. Sprayer calibration can be carried out by (a) determining the amount of the tank mix used to spray a known area; (b) operating the sprayer in a fixed place and measuring the amount of discharged liquid (water) for a specified time; or (c) collecting the nozzle discharge and determining the output for a time period. Application rate is then determined by calculations. If the rate is not acceptable, then sprayer and/or application parameters need adjustment. See UF/IFAS Circular 1435, "Calibration of Airblast Sprayers," for details. The use of high-capacity nozzles at low pressures to achieve low-volume application rates, one-sided calibration of the sprayer for two-sided operations and vice versa, calibration at closed pressure settings, and intermittent operation of the nozzles can introduce errors in application rates. Sprayers using positive displacement pumps (diaphragm, piston, etc.) have more potential for application error compared to sprayers using centrifugal pumps, particularly at high-volume rates.

Application Rate Adjustment

The maximum per-acre rate of pesticides given in this publication is based on applications to mature citrus trees that have reached containment size (hedgerow status). Smaller trees can be sprayed with the same concentration of agrichemical, but using fewer nozzles (see Figure 1). This should provide spray deposition approximately comparable to that of mature trees, with lower spray volume and active ingredient per acre.

The spray volume rate can be calculated from Equation 1:

$$VR = \frac{(495) \times (SO)}{(GS) \times (RS)}$$

Where:

VR = Spray Volume Rate (gal/acre)
SO = Sprayed Output (gal/min)
GS = Ground Speed (mile/h)
RS = Tree Row Spacing (ft)

Equation 1.

The actual applied rate of pesticides for small trees would be a fraction of the maximum rate per acre, as shown in Equation 2.

$$PRS = \frac{(VRS) \times (PRM)}{(VRM)}$$

where:

PRS = Actual applied rate of pesticides for small trees (pt or lb/acre)
VRS = Spray volume rate for small trees (gal/acre)
VRM = Spray volume rate for mature trees (gal/acre)
PRM = Pesticide rate for mature trees (pt or lb/acre)

Equation 2.

Further reduction in spray usage may be obtained by shutting the nozzles (manually or automatically) when passing by the gaps between adjacent trees. The above adjustments match the sprayer output with the tree size while providing adequate spray coverage and lowered off-target spray movement.

Spray Volume and Ground Speed

Lower spray volumes can deposit as much or more pesticide on the canopy than dilute rates. This is because spray runoff from leaf surface decreases and more material remains on the canopy. Lower volumes involve the use of smaller-orifice nozzles that provide smaller droplet sizes and more uniform spray distribution on the leaf surface. However, variability of spray distribution within the canopy and drift potential increase as spray volume decreases. With existing spray equipment and for average-size trees, a volume rate of about 250 gal/acre may be a good compromise for controlling most pests of economic importance, except some scale insects. The volume rate may be reduced further if higher pesticide concentration is more important than thorough wetting for controlling certain pests (see the label for limitations).

Increasing the ground speed can reduce the runoff from leaf surfaces in locations close to the sprayer. This effect can result in increased spray deposition and may be more pronounced with high-volume rates and large-orifice nozzles. On the other hand, hard-to-reach areas of the canopy may not have enough exposure for adequate spray penetration and deposition. The higher the sprayer air volume, the more potential it may have for high-speed applications. However, because variability of deposition increases at higher speeds, a ground speed of about 2.5 mph may be a reasonable speed for most citrus sprayers operating under average grove conditions.

Weather Conditions

The effectiveness and safety of spray applications largely depend on weather conditions during the application. High wind velocities can decrease spray coverage while increasing the variability of deposition and off-target drift. Pesticides should not be applied when wind velocity exceeds 10 mph or when it blows toward an adjacent residential area or susceptible crop. While calm conditions are desirable for spray deposition, temperature inversion may create severe drift problems. Vertical movement of the air during unstable weather conditions can increase the chance of spray drift, but dilution of the drift cloud makes it less serious than concentrated drift clouds generated under inversion conditions.

The size of the water-based droplets reduces constantly as they move from the sprayer. The evaporation becomes faster under hot and dry conditions and may become critical for low-volume applications. By using larger-orifice nozzles and/or lower spray pressures, droplet size can be increased and spray drift decreased.

LV/ULV Spray Guidance

The US Environmental Protection Agency and the Florida Department of Agriculture and Consumer Services allow the use of a pesticide on an agricultural site in a manner that results in the application of the same or less amount of active ingredient(s) to the site as specified on the product label but with less diluent than is specified on the product label if certain conditions are met:

1. The use of less diluent is not specifically prohibited on the product label; and
2. All other precautionary statements regarding product mixing, loading, and preparation, application methods, rates, frequency, preharvest intervals, tolerances, field reentry intervals, protective clothing or equipment requirements, product packaging and transportation requirements, and storage and disposal practices are complied with.

Typically, pesticide product labels include advisory language encouraging the user to apply the product in a solution of sufficient volume to achieve complete coverage of foliage. Coupled with this language, manufacturers suggest a range of spray volumes necessary to achieve adequate foliage coverage. However, unless the label contains language such as "do not use less than *x* gallons of water volume per acre," it is acceptable for the grove manager to use less volume than suggested by the range on the label. Growers should be cautious, however, and recognize the fact that crop damage occurring as a result of the use of less diluent than recommended on the label is solely their responsibility. Therefore, it is strongly recommended that this use pattern be tested on a small crop area before implementing widespread application.

Spraying Weeds

Herbicide Applicators

Herbicides are mostly applied with boom sprayers. These sprayers work on the same principles as tree sprayers and consist of a tank, pump, flow (pressure) regulator, agitation system (hydraulic or mechanical), nozzle manifold (boom), and a set of nozzles. However, compared to tree sprayers, herbicide applicators normally are equipped with smaller PTO-driven pumps (centrifugal, roller, or piston) and lower hydraulic pressures (10–50 PSI).

The pump should be resistant to wear and corrosion. It must have enough capacity (gal/min) and pressure (PSI) for both nozzle output and hydraulic agitation. This requires at least 20% greater capacity beyond the combined nozzle demand. Most pump manufacturers recommend not exceeding 70%–80% of the pump's capacity for continuous operations. Agitation is more critical for wettable powders and water-dispersible formulations. Inadequate mixing of these products could result in nonuniform concentration of the herbicide in the tank, nozzle clogging problems, and over- or underdose output from nozzles. Overdosing of blocks with young trees can result in severe stunting and/or phytotoxicity. Tanks without sharp corners minimize the chance for product settlement. Herbicide applicators equipped with mechanical agitation systems perform better than those with hydraulic agitation, but they are more expensive.

Regardless of differences in the design and price of the sprayers, the success of weed control largely depends on the choice of herbicide, timing of the application, and proper maintenance, calibration, and use of the equipment. More information on the selection and timing of herbicide application can be found in a later chapter of this guide, HS-107, "Weeds." The following sections provide information on proper nozzle selection and calibration of herbicide applicators.

Nozzle Selection

In Florida, nearly all boom sprayers are equipped with hydraulic pressure nozzles. These nozzles are available in many sizes, shapes, and materials and may be color-coded or identified by a number. A typical nozzle assembly consists of nozzle body, strainer (screen), tip (orifice), and cap (tip holder). Strainers vary in mesh size based on the size of the nozzle orifice (opening). Smaller openings (lower capacities) require finer mesh to minimize nozzle clogging.

Nozzles differ significantly in durability, flow rate, droplet spectrum, and distribution pattern. Brass and nylon nozzle tips are the least expensive but are relatively soft and wear rapidly; therefore, they are not suitable for spraying abrasive tank mixes such as wettable powders. On the other hand, ceramic and hardened stainless steel tips are more expensive but have excellent wear life and are very resistant to abrasive and corrosive chemicals.

For a given nozzle type, flow rate (capacity) depends on the tip orifice size and operating pressure. In nozzle manufacturers' catalogs, nozzle flow rates (GPM) are usually listed for a few selected pressures (PSI). It should be noted that all the tabulations are based on spraying water. When calibrations are based on water, the equivalent GPM of the heavier or lighter solutions should be calculated from Equation 3.

$GPMw = GPMs \times CF$

where:

$GPMw$ = Equivalent nozzle capacity for water

$GPMs$ = Desired nozzle capacity of heavier or lighter

solution

CF = Correction factor for solution density

= square root of specific gravity (SG)

Equation 3

$$PSI_1 = PSI_2 \times \left[\frac{GPM_2}{GPM_1}\right]^2$$

where:

PSI_2 = Correct operating pressure

PSI_1 = Recommended pressure

GPM_2 = Desired flow rate

GPM_1 = Flow rate at PSI 1

Equation 3.

Most nozzles perform satisfactorily around 30 PSI; however, recommended pressure of each specific nozzle should be determined from its manufacturer's catalog. If the desired GPM could not be obtained at the recommended pressure, then the pressure should be adjusted. Because nozzle flow rate varies in proportion to the square root of the pressure (Equation 4), only minor adjustment could be achieved by changing pressure. Major adjustments require the use of smaller or larger nozzles.

$$GPA = \frac{GPM \times 5{,}940}{GS \times NS}$$

or

$$GPM = \frac{GPA \times GS \times NS}{5{,}940}$$

where:

GPA = Application rate (gal/acre)

GPM = Flow rate per nozzle (gal/min)

GS = Sprayer ground speed (mile/h)

NS = Nozzle spacing (in)

Equation 4.

Droplet size spectra and distribution patterns of nozzles vary substantially and largely depend on nozzle type, flow rate, operating pressure, and spray angle. Flat fan nozzles generate relatively smaller droplets, whereas drift-reducing nozzles produce larger droplets. Extended-range nozzles adjust the droplet size over a wide range of nozzle pressures. Flooding nozzles produce a wide spray angle and flat pattern. Nozzles with solid or hollow cone spray patterns may also be used in some postemergence herbicide applications.

Most of the available nozzles have spray angles ranging from 65° to 140°. The nozzle's designated angle corresponds to the rated pressure. Spray angle increases or decreases at higher or lower pressures, respectively.

Nozzle wear not only increases the angle and output, but it also distorts spray distribution pattern to some extent.

Spray Distribution

Unlike tree sprayers, nozzles used on herbicide equipment should be uniform (same type, material, capacity, and spray angle). Using a variety of nozzles on a boom results in uneven distribution patterns. However, herbicide applicators used in citrus may include an off-center nozzle tip (at the end of the boom) to extend the coverage beyond the end of the boom and cover the area around the tree trunk. It is normally mounted on a swivel body, a few inches beyond the last main nozzle.

Nozzles that generate tapered-edge patterns (e.g., flat fan) need some pattern overlap in order to obtain a reasonably uniform distribution across the spray swath. The amount of pattern overlap depends on nozzle spacing, boom height, and spray angle. Nozzles used on citrus herbicide applicators are normally mounted on 10–12 inch centers and operated at a height of 12–14 inches. Smaller spray angles require higher nozzle (boom) height in order to achieve acceptable pattern overlap (usually 30%–50%). Some nozzles may require 50%–100% pattern overlap. Nozzle catalogs normally specify optimum spacing, height, and overlap for each nozzle type. For a given nozzle flow rate, an improper boom height setting or vertical movement of the boom will result in uneven distribution (untreated bands or larger-than-desired treatment areas) across the spray swath.

Herbicide Sprayer Calibration

Application rate depends on nozzle flow rate (function of orifice size and operating pressure), number of nozzles, row spacing, and ground speed. Equations 5 and 6 show the relationships among these factors for broadcast and directed sprays, respectively.

$$GPA = \frac{GPM \times NN \times 495}{GS \times RS}$$

where:

NN = Number of nozzles

RS = Row spacing (ft)

Equation 5.

$$GS = \frac{TD \times 60}{TT \times 88}$$

where:

GS = Sprayer ground speed (mile/h)

TD = Travel distance (ft)

TT = Travel time (sec)

Equation 6.

The quality of calibration depends on accuracies of the nozzle flow rate and ground speed measurements. To ensure accurate nozzle flow rate, flow regulator(s) and pressure gauge(s) must be in working order. The latter should have a reasonable range in order to provide accurate readings of the system pressure.

Because nozzle capacity tabulations (in catalogs) are based on pressure at the nozzles, the gauge closer to the nozzles should be used in calibration. In-line strainers and nozzle filters (screens) should be clean in order to avoid any restriction in the nozzle flow. Calibration procedures are similar to those mentioned for tree sprayers. They include (a) determining the amount of the tank mix (gallons) used to spray a known area (acres), (b) operating the sprayer in a fixed position and measuring the amount of discharged water (tank refill gallons) for a given time (minutes), or (c) determining the nozzle discharge rate (gal/min). If the calculated GPA was not the same as the desired GPA, then ground speed and/or nozzle pressure should be changed. The latter could only be used for minor adjustments. See UF/IFAS factsheet HS-1012, "Citrus Herbicide Boom Sprayer Calibration," for more information.

To determine the ground speed, see UF/IFAS Circular 1435, "Calibration of Airblast Sprayers," for details of procedures for ground speed measurement.

Best Management Practices (BMPs) for Pesticide Applications

As mentioned earlier, pesticides can be expected to be effective if the right material is applied at the right amount, on the right target, at the right time, with the right sprayer, and under the right weather conditions. Read the product label for specific information, pertinent regulations, and safety recommendations. Follow the federal, state, and local government laws and regulations carefully. The following general BMP guidelines apply to most spraying practices.

1. Identify the nature of the pest that is causing the problem (consult with an Extension agent, plant pathologist, entomologist, etc.).

- Determine whether it is located on the canopy or in the root system, outside or inside the canopy, and on the upper or lower leaf surface.
- In case of weeds, identify their types and whether they are spread under trees or in the row middle.
- Learn about pest biology and its interaction with trees and fruit growth stage.
- Find out if the pest could be controlled by cultural practices and/or nonchemical methods.
- If chemical control is the preferred method, what category of pesticides may provide the desired solution?

2. Find out about the timing of the application.

- Scout the grove/field to establish the pest threshold level.
- Determine the optimum application window for effective control of the pest.
- Try to apply the pesticide when the pest is most vulnerable. It is very important to deal with pests at the most vulnerable biological or growth stages in their life cycles. Pesticide applications beyond the optimum window are likely to result in less efficacious pest control.
- Make sure the application will be completed several hours before a rain shower.

3. Select an appropriate pesticide (insecticide, fungicide, herbicide, etc.).

- Make sure the selected pesticide has been proven effective against the specific pest and registered for the intended use.
- Choose the least persistent and lowest toxicity pesticide.
- Make sure it will not generate phytotoxicity or pest resistance under intended use conditions.
- Check its compatibility with other products that will be included in the tank mixture.
- Learn about proper storage of the material to prevent chemical breakdown and fire hazards (read the label).
- Some pesticides specify the use of specific adjuvants to improve physical and/or chemical properties of the product. Select the right adjuvant and use it at the right rate in order to achieve the desired objective.

4. Determine the right amount (application rate) for the intended application.

- This information could be found on the label. It is usually specified as gallons, pints, pounds, or ounces of the product per grove or treated acre.
- Consider the application time and the target growth stage for suggested dose transfer.
- Adjust the rate according to the tree size, row spacing, pest pressure, and other pertinent factors.

5. Use properly calibrated equipment.

- Make sure the sprayer is in good working condition. Examine the pump, nozzles, manifolds, hoses, regulators, pressure gauges, etc. Clean all nozzle screens and inline strainers.
- Read the label for limitations on spray droplet size (spray classification category) and suggestions for drift mitigation near the sensitive areas. Select the right nozzle type, size, and pressure for the job. Make sure the selected nozzles are consistent with the label's spray quality recommendation (i.e., very fine, fine, medium, coarse, very coarse, or extremely coarse). Use nozzles that generate a minimal percentage of smaller drift-prone droplets at the specified operating pressure. Consider using "low-drift" nozzles when available.
- Check nozzle spacing, nozzle angle, and boom height to make sure there is sufficient pattern overlap for uniform spray coverage.
- In airblast applications, adjust the orientations of nozzles and air deflectors to direct the spray cloud onto the tree canopy only.
- Check the functionality of the sprayer agitation system (mechanical or hydraulic). Some formulations have specific mixing requirements.
- Be careful about the order of material addition into the tank. Usually, adjuvants are added before pesticides. Refer to the product label for recommended mixing order.
- Use only clean water free from dirt, sand, algae, etc. Algae quickly clog the strainers and nozzles. Sand and other abrasive particles expedite pump and nozzle wear. Other contaminants may react with the pesticide and reduce its effectiveness. Water pumped from ditches or ponds should be filtered before filling the tank.
- Examine the uniformity of the tank mixture. This is more critical when using wettable powder or dry formulations, particularly with irregularly shaped tanks featuring sharp corners. Premixing the chemicals in a small container could help uniform mixing in the sprayer tank.
- Follow the label recommendations for avoiding drift from highly volatile formulations.
- Use an appropriate ground speed based on the tractor/sprayer capabilities, terrain conditions, boom stability requirements, etc. Make sure the intended ground speed will be achieved during the application. Check the tire pressure.
- Monitor the operation of the nozzles during the application. Observe the output pattern of nozzles periodically. Nozzle clogging and changes in nozzle pressure and ground speed will affect the actual application rate.
- Carry spare nozzles, screens, washers, etc. for quick adjustments/repairs in the field.

6. Apply pesticide under the right weather conditions.

- If possible, avoid spraying during hot, dry, or windy weather conditions. Nighttime applications could increase spray deposition and reduce drift.
- Avoid spraying during stable (inversion) conditions (early morning and early evening) when there is little or no vertical mixing of the air. These conditions generate concentrated drift clouds and increase the chance of drift fallout.
- Stop spraying a few hours before rain showers. Allow sufficient time for sprays to dry and form reasonably durable deposits.
- Monitor wind direction and do not spray when there are sensitive crops/areas immediately downwind.
- Keep records of air temperature, relative humidity, wind speed, and wind direction. These records as well as equipment and application information may be very helpful in dealing with drift-related litigation.

7. Follow the safety instructions.

- Read the most recent product label. Look at the signal word (Danger, Warning, Caution). It gives an indication of the pesticide toxicity level.
- Learn about the environmental hazards (effects on wildlife, water resources, etc.) associated with using the product.
- Read the label for recommended personal protective equipment (coveralls, boots, gloves, goggles, respirators, etc.). Wear protective clothing during equipment calibration, loading, mixing, spraying, and cleanup.
- Before mixing and applying the pesticide, learn about using first aid and medical treatment in an accident.
- Minimize the spray mixture leftover and rinsate (mix right amount as needed).
- If possible, use formulations that are packaged in returnable or refillable containers.
- Clean the sprayer shortly after task completion. This practice not only increases equipment life but also reduces the chance of pesticide cross contamination.
- Rinse and dispose of the pesticide containers properly as directed by the label.
- Follow all safety guidelines related to the operation of the equipment (tractor, sprayer, nurse tank, etc.).
- If available, use sprayers equipped with a canopy sensing system (UF/IFAS factsheet HS-872, "Sensor-Controlled Spray Systems for Florida Citrus"). The system helps to direct the pesticide to the intended target more precisely, thereby reducing pesticide wastage and environmental contamination.

8. Prevent point-source pollution of pesticides.

- Store your pesticides in a properly constructed and secured storage room. The storage area should have a smooth floor with no connection to a drainage system. It should be equipped with nonabsorbent sturdy shelves, a first aid kit, a fire extinguisher, measuring cups/jugs, and absorbent inert material (to confine spillage). It should display hazard classification symbols, clear instructions for dealing with spillage, and emergency phone numbers. Note that the locker containing personal protective equipment should not be located inside the storage area.
- Store the empty packages/containers of solid/liquid pesticides inside the storage room and dispose of them in a legal way (never burn or bury in the field).
- Use a lockable and securely fixed box to transport the pesticides to the field safely. Do not leave pesticides in a place that is accessible to unauthorized users or children. In case of accident, contact emergency phone numbers.
- Make sure the sprayer tank lid is closed tightly and the tank, pump, strainers, manifolds, and nozzles do not leak. Use antidrip nozzles.
- Fill the tank in a bounded filling station or in the field (away from surface water). If filling in the field, use a tray to collect any accidental spill. Do not overfill the tank and do not insert the water pipe/hose inside the tank (avoid tank mix contact with water supply). Load powder formulations through induction hopper, if available.
- Rinse empty containers during filling, using the rinsing nozzle or a water hose. Pour the rinsate in the tank.
- Clean the sprayer in a bounded area (with collection system) or in a grassy field (away from surface water). Never drain undiluted spray liquid in the field.
- Do not spray in the buffer zones around lakes, water wells, or along streams and drainage ditches.
- Do not use an airblast sprayer for spraying small trees or bushes. Use a recirculating tunnel sprayer or similar equipment to minimize spray losses to the environment.

Web Addresses for Links

UF/IFAS Circular 1435, "Calibration of Airblast Sprayers": https://doi.org/10.32473/edis-ae238-2003

UF/IFAS factsheet HS-872, "Sensor-Controlled Spray Systems for Florida Citrus": http://ufdc.ufl.edu/IR00002701/00001

UF/IFAS factsheet HS-1012, "Citrus Herbicide Boom Sprayer Calibration": https://doi.org/10.32473/edis-hs252-2005

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2026–2029 Florida Citrus Production Guide: Best Management Practices for Soil-Applied Agricultural Chemicals[1]

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Over the past few decades, certain pesticides and nitrates have been detected in some shallow groundwater locations on the sandy ridge soils of central Florida. Federal and state regulatory agencies emphasize the need to protect groundwater and all drinking water supplies and, in turn, have restricted the timing and use of certain widely used agricultural chemicals. As a result of these concerns and more stringent regulatory policies and best management practices (BMPs), growers will have to assume increasingly more responsibility for the crop management practices they choose. The fate of the environment depends, in part, on the agricultural chemicals they use. Specific BMPs are currently being implemented to optimize crop production and environmental protection for both ridge and flatwoods citrus production; this state-sponsored, voluntary program encourages citrus growers to develop and adopt site-specific BMP plans for controlling agrichemical contamination of state water resources. Growers who formally adopt BMPs and can produce a documented plan will receive a waiver of liability from the state for any inadvertent environmental contamination events. Many different environmental factors and management components can be involved in the BMP plan.

To prevent or reduce the movement of chemicals to groundwater, users must consider many different site-specific BMPs, including the following: integration of crop and pest management strategies, product selection, application rates, timing, placement in relation to the root system, weed cover, soil properties, and irrigation management strategies.

Application Rates, Frequency, Timing, Placement, and Other Considerations

Integrated pest management (IPM) requires (1) monitoring activities for the presence and abundance of pests within the grove, (2) determining whether pest population densities are high enough to cause economic loss, and (3) selecting a profitable, worker-safe, and environmentally compatible management option. Pesticide application should only be considered after the results of monitoring activities have been completed and other potential causes of tree or grove decline are evaluated and corrected. In addition, a truly integrated strategy requires consideration of pesticide selection, when the choice exists, prior to application.

Pesticide selection should be based not only on cost-effectiveness but also on mode of action rotation; consideration of the latter helps avoid resistance buildup, toxicity to nontarget species, and product solubility, persistence, and leaching potential of the pesticide in question. This consideration also requires regulating the irrigation schedule based on soil type and other site characteristics. Various sources of information are available for identifying specific soil types and ideal irrigation schedules to help in predicting and minimizing movement and leaching potential of most citrus agrochemicals.

Once a need for pest control has been established and a chemical has been selected, the grower must decide on rate and timing of application. Agricultural chemicals should be applied only at the labeled or recommended rates. Lower rates applied more frequently combined with sound irrigation management practices can significantly reduce chemical movement beyond the root zone. Split applications of pesticides or fertilizers will reduce the amount applied at any one time, thereby reducing the amount that might be leached at a given time.

Controlled release (encapsulated) formulations, when available, also provide the advantage of reduced leachability.

The timing for application of most pest management/crop production chemicals should not be based on the calendar but on pest population biology, abundance, and tree growth periods. Applications during the summer rainy season should be avoided whenever possible. In some instances, pests may require treatment during times when rainfall can be expected, but if heavy rainfall is imminent, application should be delayed and subsequent irrigations adjusted to account for rainfall amounts.

Most soilborne pests are associated with citrus roots. For pesticide applications targeting soilborne pests and diseases, pesticide efficacy occurs primarily within the zone of application and, to a much lesser degree — due to the systemic activity of these pesticides — within and around roots outside of the zone of application. Because a large majority of fibrous roots grow within the top 24–30 inches of soil and decrease in abundance from the tree trunk to the row middle, pesticide placement to maximize under-canopy coverage is of critical importance. Pesticide placement under the tree canopy targets the areas of highest fibrous root and pest density. This placement can significantly improve overall pest control and minimize leaching. Tree skirts may need to be raised by pruning to improve application equipment access under the tree canopy.

Cultural practices that promote excessive vegetative growth, such as overwatering and excessive nitrogen fertilization, can intensify some pest problems and should be avoided in the control of some plant diseases (e.g., Alternaria brown spot). Under-canopy weed growth may reduce pesticide effectiveness by interception or absorption of pesticide residues targeted for citrus roots or pests in the soil. Under-canopy weeds also interfere with microsprinkler operation and prevent uniform coverage of chemigated compounds. At the individual tree level, excessive irrigation, when coupled with unmanaged weed growth, can promote localized deep soil penetration of soil-applied pesticides or fertilizers, resulting in groundwater contamination.

Soil and Chemical Properties

The potential for leaching of agricultural chemicals below the root zone depends on both soil and chemical characteristics. Persistence, sorption, and water solubility are the primary characteristics of chemicals that determine leaching potential. Organic matter is one of the most important soil characteristics in determining the leaching potentials of many agricultural chemicals. Rates of leaching are lower for soils with high organic matter content. Deep Ridge sands, low in organic matter (typically less than 1%), are particularly vulnerable to leaching. A list of vulnerable soils that allow chemicals to be easily leached may be obtained from the Natural Resources Conservation Service (NRCS, formerly Soil Conservation Service).

Chemical persistence is the length of time required for a material to break down and is often expressed in terms of half-life. Half-life is the amount of time required for one-half of the applied pesticide to be broken down in the soil. Pesticides in the soil are bound to soil particles, particularly organic matter, through a process called sorption. This binding slows their movement through the soil. A useful means of quantifying pesticide sorption on soils is the partition coefficient (K_{oc}): the relative affinity or attraction of a pesticide to soil materials. Pesticides with a high K_{oc} are strongly adsorbed and thus less subject to leaching.

Chemicals with shorter half-lives and higher K_{oc} values are less likely to contribute to groundwater contamination. If possible, more leachable products should be used during the drier seasons. Products with short half-lives and high K_{oc} values should be reserved for periods of high rainfall, if needed.

Irrigation

Both rain and irrigation water move agricultural chemicals through the soil. Hence, it is important to consider best irrigation management practices that minimize water movement below the root zone. Failure to irrigate properly may jeopardize the future use of some important soil-applied chemicals. The ability of soils to hold water affects their ability to retain pesticides and nutrients. Many Ridge soils have a low water-holding capacity and a high hydraulic conductivity, which allows water to easily percolate through the soil. These soils require frequent irrigation. If more water is applied than is used by the tree, water will move below the root zone. Repeated irrigation or rainfall events will leach soluble nutrients and pesticides below the root zone where they become both economic losses and potential pollutants of groundwater.

Excessive irrigation and rainfall can also promote population buildup of some pests such as *Phytophthora* spp., *Alternaria* spp., and various weeds. Reduced residence time of pesticide compounds in shallow soil horizons contributes to losses in production efficiencies and pest control efficacy. To avoid premature leaching from the root zone, soil-applied fungicides, nematicides, insecticides, herbicides, and fertilizers should be targeted to under-canopy areas of highest fibrous root density and should not be followed by excessive irrigation. Given the sandy, permeable nature of citrus soils and their low soil organic matter content, irrigation schedules based on soil moisture deficits are likely both to improve pest control and grove response to treatment by maximizing retention of toxic concentrations in the citrus tree root zone as well as to prevent problems of environmental contamination.

Best water-use management practices currently rely upon the use of accounting methods or the use of soil water sensors (e.g., tensiometers, capacitance probes, or other sensors) and irrigation apps to determine how much irrigation water to apply per irrigation event and when to apply it. Irrigation based on tensiometers will likely require the instruments to be installed at two depths in the well-drained soils of the central ridge. Irrigation will be scheduled when either tensiometer reaches a specified set point of soil water depletion. The deeper tensiometer can be monitored to ensure that no water moves below the root zone. To irrigate on a budget, one needs a computer on which to input daily rainfall, irrigation, and evapotranspiration data. The set points for irrigation are based on accumulated daily depletion of available soil water throughout the profile and on tree growth stage. The irrigation app provides the guideline for when water content in the root zone reaches a critical point (e.g., below 25% to 33% of available water), thereby prompting an irrigation event to occur.

The water-holding capacity of the soil and the diameter and application rate to the wetted under-canopy area are necessary data to determine the duration of irrigation that would wet to only the appropriate root zone depth. Data on the water-holding capacity of citrus soils can be found in UF/IFAS publications SL456, "Nutrition of Florida Citrus Trees, 3rd Edition: Chapter 2. Production Areas, Soils, and Land Preparation"; Circular 1127, "Citrus Fertilizer Management on Calcareous Soils"; HS1306, "Fertigation for Citrus Trees"; or in the soil survey report for each county.

Total volume of irrigation water — not necessarily duration (irrigation run time) of the sprinklers — is important in driving the movement of chemicals through the soil profile. Careful planning and management of irrigation can improve pesticide and fertilizer efficacy and reduce the potential for groundwater contamination. For more information on microirrigation management, see UF/IFAS Circular 1413, "Control and Automation in Citrus Microirrigation Systems"; Bulletin 265, "Field Evaluation of Microirrigation Water Application Uniformity"; and HS958, "Management of Microsprinkler Systems for Florida Citrus."

Web Addresses for Links

UF/IFAS Bulletin 265, "Field Evaluation of Microirrigation Water Application Uniformity": https://edis.ifas.ufl.edu/publication/AE094

UF/IFAS Circular 1127, "Citrus Fertilizer Management on Calcareous Soils": https://edis.ifas.ufl.edu/publication/CH086

UF/IFAS Circular 1413, "Control and Automation in Citrus Microirrigation Systems": https://doi.org/10.32473/edis-ch194-2002

UF/IFAS publication HS958, "Management of Microsprinkler Systems for Florida Citrus": https://doi.org/10.32473/edis-hs204-2004

UF/IFAS publication HS1306, "Fertigation for Citrus Trees": https://edis.ifas.ufl.edu/publication/HS1306

UF/IFAS publication SL456, "Nutrition of Florida Citrus Trees, 3rd Edition: Chapter 2. Production Areas, Soils, and Land Preparation": https://edis.ifas.ufl.edu/publication/SS669

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2026–2029 Florida Citrus Production Guide: Interpreting PPE Statements on Pesticide Labels[1]

Jason A. Ferrell and Frederick M. Fishel[2]

This document helps you understand the revised PPE statements now part of labels on pesticide products used on farms, forests, nurseries, and greenhouses.

Background

Many personal protective equipment (PPE) statements on pesticide labels have been changed as a result of the Worker Protection Standard for Agricultural Pesticides (WPS). These revised statements are more precise on the type of PPE that must be worn by pesticide handlers (mixers, loaders, and applicators). The terminology used to describe the required PPE is now more consistent from label to label. The tables accompanying this document list label statements used to describe the PPE required for use by mixers, loaders, and applicators.

The column headed Acceptable PPE describes the options the pesticide handler has when the label statement lists a specific item of PPE. The tables are grouped by subject as follows:

Table 1: Body Protection

Table 2: Hand Protection

Table 3: Eye Protection

Table 4: Foot Protection

Table 5: Respiratory Protection

Table 6: Head Protection

Table 1. Personal protective equipment (PPE) statements (body protection).

Label Statement	Acceptable PPE
Long-sleeved shirt and long pants	Long-sleeved shirt and long pants, or
	Woven or nonwoven coverall, or
	Plastic- or other barrier-coated coverall, or
	Rubber or plastic suit
Coverall worn over short-sleeved shirt and short pants	Coverall worn over short-sleeved shirt and short pants, or
	Coverall worn over long-sleeved shirt and long pants, or
	Coverall worn over another coverall, or
	Plastic- or other barrier-coated coverall, or
	Rubber or plastic suit
Coverall worn over long-sleeved shirt and long pants	Coverall worn over long-sleeved shirt and long pants, or
	Coverall worn over another coverall, or
	Plastic- or other barrier-coated coverall, or
	Rubber or plastic suit
Chemical-resistant apron worn over coverall or over long-sleeved shirt and long pants	Chemical-resistant apron worn over coverall or long-sleeved shirt and long pants, or barrier-coated coverall, or suit
	Plastic or other barrier-coated coverall, or
	Rubber or plastic suit
Chemical-resistant protective suit	Plastic- or other barrier-coated coverall, or
	Rubber or plastic suit
Waterproof suit or liquid-proof suit	Plastic- or other barrier-coated coverall, or
	Rubber or plastic suit

Table 2. Personal protective equipment (PPE) statements (hand protection).

Label Statement	Acceptable PPE
Waterproof gloves	Any rubber or plastic gloves sturdy enough to remain intact throughout the task being performed
Chemical-resistant gloves	Barrier-laminate gloves, or
	Other gloves that glove selection charts or guidance documents indicate are chemical-resistant to the pesticide for the period of time required to perform the task
Chemical-resistant gloves such as butyl or nitrile	Butyl gloves, or
	Nitrile gloves, or
	Other gloves that glove selection, charts, or guidance documents indicate are chemical-resistant to the pesticide for the period of time required to perform the task

Table 3. Personal protective equipment (PPE) statements (eye protection).

Label Statement	Acceptable PPE
Protective eyewear	Shielded safety glasses, or
	Face shield, or
	Goggles, or
	Full-face respirator

Label Statement	Acceptable PPE
Goggles	Goggles, or
	Full-face respirator

Table 4. Personal protective equipment (PPE) statements (foot protection).

Label Statement	Acceptable PPE
Shoes	Leather, canvas, or fabric shoes, or
	Chemical-resistant shoes, or
	Chemical-resistant boots, or
	Chemical-resistant shoe coverings (booties)
Chemical-resistant boots	Chemical-resistant boots

Table 5. Personal protective equipment (PPE) statements (respiratory protection).

Label Statement	Acceptable PPE
Cartridge respirator	Respirator with organic vapor-removing cartridge and pesticide prefilter, or
	Respirator with canister approved for pesticides, or
	Air-supplying respirator
Air-supplying respirator or self-contained breathing apparatus (SCBA)	Air-supplying respirator, or
	Self-contained breathing apparatus
Dust/mist filtering respirator	Dust/mist filtering respirator, or
	Respirator with dust/mist filtering cartridge, or
	Respirator with organic vapor-removing cartridge and pesticide prefilter, or
	Air-supplying respirator
Canister respirator (gas mask)	Respirator with canister approved for pesticides, or
	Air-supplying respirator

Table 6. Personal protective equipment (PPE) statements (head protection).

Label Statement	Acceptable PPE
Chemical-resistant hood or wide-brimmed hat	Rubber or plastic-coated safari-style hat, or
	Rubber or plastic-coated firefighter-style hat, or
	Plastic- or other barrier-coated hood, or
	Rubber or plastic hood, or
	Full hood or helmet that is part of some respirators

[1] This document is PI-16, one of a series of the Department of Agronomy, UF/IFAS Extension. Original publication date December 1995. Revised annually. Most recent revision August 2026. Visit the Ask IFAS website at https://ask.ifas.ufl.edu for the currently supported version of this publication. This publication was adapted from *Coverall, Gloves, and Other Skin Protection*, *Protective Eyewear*, and *Respirators*, which were produced through cooperative efforts of the US Environmental Protection Agency (EPA), the Extension Service, and the US Department of Agriculture (USDA). For additional information, contact the UF/IFAS Pesticide Information Office, PO Box 110710, Gainesville, FL 32611-0710, (352) 392-4726.

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

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2026–2029 Florida Citrus Production Guide: Quick Reference Guide to the Worker Protection Standard (WPS)[1]

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For the complete details of the WPS, refer to *How to Comply with the 2015 Revised Worker Protection Standard for Agricultural Pesticides: What Owners and Employers Need to Know.*

Introduction

The Worker Protection Standard (WPS) is a regulation originally issued by the US Environmental Protection Agency (EPA) in 1992 and most recently revised in 2015. This regulation is primarily intended to reduce the risks of illness or injury to workers and pesticide handlers resulting from occupational exposures to pesticides used in the production of agricultural plants on agricultural establishments (i.e., farms, forests, nurseries, and enclosed space production facilities such as greenhouses). Workers are generally those who perform hand-labor tasks in pesticide-treated crops, such as harvesting, thinning, and pruning. Handlers are usually those who are in direct contact with pesticides through activities such as mixing, loading, or applying pesticides.

The WPS requires agricultural employers and commercial pesticide handler employers to provide specific information and protections to workers, handlers, and other persons when WPS-labeled pesticide products are used on agricultural establishments in the production of agricultural plants. It also requires owners of agricultural establishments to provide certain protections for themselves and their immediate family, requires handlers to wear label-specified clothing and personal protective equipment when performing handler activities, and requires owners to take measures to protect workers and other persons during pesticide applications. Owner and immediate family exemptions are defined in “Worker Protections Standard: Responsibilities and Compliance” and in the EPA “How to Comply Manual” linked in the resources at the end of this chapter.

Duties for All Employees

These requirements apply to agricultural employers and commercial pesticide handler employees, except for the pesticide safety, application, and hazard information requirements that apply only to agricultural employers.

Antiretaliation

Employers must not retaliate against a worker or handler who attempts to comply with the WPS, files a complaint, or provides information in an investigation of alleged WPS noncompliance.

Minimum Age Requirements

There is a prohibition on anyone under 18 years old from being a pesticide handler or doing early-entry work during a restricted-entry interval (REI). Ensure that early-entry workers and all handlers are at least 18 years old.

Pesticide Safety, Application, and Hazard Information

An agricultural employer must display or make certain information available on the establishment. Commercial pesticide handler employers do not have to comply with information display requirements.

1. Display or make available all of the information listed in #2 together in an easily accessible ("central") location on the agricultural establishment.
2. The information includes
- EPA WPS safety poster or equivalent information, which must be kept current.
- The following application information: product name, EPA registration number, and active ingredient; crop or site treated, location, and description of the treated area; date, start and end times of the application, and duration of restricted-entry interval (REI).
- A copy of the safety data sheet (SDS) for the formulated product for each WPS-labeled pesticide applied.
3. In addition, display the EPA WPS safety poster (or equivalent) where decontamination supplies are located at permanent sites and where decontamination supplies are provided for 11 or more workers.

4. Allow workers and handlers unrestricted access to all of the information and keep all of the displayed information current and legible.
5. Display the EPA WPS safety poster or equivalent information before an application takes place and for 30 days after the REI expires.
6. Display the SDS and application information within 24 hours of the application and before workers enter treated areas. This information must be displayed for 30 days after the REI expires and kept in records on the agricultural establishment until 2 years after the REI expires.
7. Provide the SDS and application information upon request of a worker, handler, designated representative, or medical personnel within 15 days.

Pesticide Safety (WPS) Training

Ensure that workers are trained annually before performing tasks in a pesticide-treated area (REI in effect within the last 30 days). Ensure that handlers are trained before performing any handler activity. There is no grace period for worker or handler training.

1. Train workers and handlers annually.
2. Present training using EPA-approved materials either orally from written materials or audiovisually.
3. Trainers must be certified applicators, have completed an EPA-approved train-the-trainer program, or be designated by the state or tribal pesticide enforcement agency.
4. Training must be delivered in a manner the employees can understand, and the trainer must be present and respond to questions.
5. Maintain training records on the establishment for 2 years from the training date for each worker and handler required to be trained on the agricultural establishment.

Separate from the pesticide safety training, employers must tell workers and handlers where to find the following on the worksite: EPA WPS safety poster (or equivalent), application information, SDSs, and decontamination supplies.

Decontamination Supplies

1. Establish accessible decontamination supplies located together within ¼ mile of all workers (when required) and handlers.
- 1 gal of water per worker and 3 gal of water per handler at the beginning of each work period for routine and emergency decontamination
- Plenty of soap and single-use towels (Note: hand sanitizers and wet towelettes are insufficient)
- A clean coverall (or other clean change of clothes) for handlers

2. Provide water that is safe and cool enough for washing, eye-flushing, and drinking. Do not use water that is also used for mixing pesticides unless steps are taken to ensure safety.
3. Provide handlers with decontamination supplies where personal protective equipment (PPE) is removed at the end of a task.
4. Provide handlers with decontamination supplies at each mixing and loading site.
5. When a product requires protective eyewear for handlers, and/or when using a closed system under pressure, provide the following in mixing and loading areas: a system that can deliver gently running water at 0.4 gal per minute for at least 15 minutes or 6 gal of water in containers suitable for providing a gentle eye-flush for about 15 minutes.
6. When applying a product that requires protective eyewear, provide 1 pt of water per handler in portable containers that are immediately available to each handler.
7. Do not put worker decontamination supplies in areas being treated or under an REI.
8. For handlers, decontamination supplies must be kept outside the treated area, or any area under an REI, unless they are protected from contamination in closed containers.

Employer Information Exchange

1. Before any application, commercial pesticide handler employers must make sure the owner/operator of an agricultural establishment where a pesticide will be applied is aware of the following:
- Location and description of area to be treated;
- Date of application, estimated start time and estimated end time of the application;
- Product name, EPA registration number, active ingredient(s), and REI;
- Whether the product label requires both oral warnings and treated area posting; and
- All other safety requirements on labeling for workers or other people.

2. Owners/operators of agricultural establishments must make sure any commercial pesticide handler employer they hire is aware of the following:
- Specific location and description of any treated areas where an REI is in effect that the commercial handler may be in or walk within ¼ mile of; and
- Restrictions on entering those areas.

The commercial pesticide employer must pass this information along to the handler doing the work.

Emergency Assistance

If there is reason to believe a worker or handler has been exposed to pesticides and needs emergency medical treatment during or within 72 hours of the application, employers must do the following:

1. Promptly make transportation available to an appropriate emergency medical facility.
2. Promptly provide to the treating medical personnel the following information related to each pesticide product to which the person may have been exposed:
- Safety Data Sheet
- Product name, EPA registration number, and active ingredient(s)
- Description of how the pesticide was used on the agricultural establishment
- Circumstances that could have resulted in exposure to the pesticide

Additional Duties for Worker Employers

These restrictions apply to agricultural employers who employ workers.

Restrictions during Applications

During pesticide applications, keep workers and everyone other than appropriately trained and equipped handlers out of the treated area (for all types of applications) and out of

1. The application exclusion zone (AEZ) for outdoor production, or
2. A specified area that varies by the type of application until the ventilation criteria are met for enclosed space production.

Restricted-Entry Intervals (REIs)

Do not direct or allow any worker to enter or remain in the treated area until the REI has expired and all posted warning signs are removed or covered. Read the exceptions in the full reference.

Notice about Applications

1. Orally warn workers and post warning signs in treated areas if required by the pesticide labeling.
2. If not, post warning signs if the REI is greater than
- 48 hours for outdoor production, or
- 4 hours for enclosed space production.
3. For all other applications, either orally warn workers or post warning signs.

Posted Warning Signs

1. Post legible 14" × 16" WPS-design warning signs no more than 24 hours prior to an application; keep posted during REI; and remove or cover before workers enter and within 3 days after the end of the REI.
2. Post signs so they can be seen at all reasonably expected entrances to treated areas.
3. Warning signs can be smaller than 14" × 16" under certain conditions. All warning signs must meet specific requirements.

Oral Warnings

1. Before each application, tell the following to workers who are on the establishment (in a manner they can understand):
- Location and description of treated area;
- Date and times that entry is restricted; and
- AEZ, REI, and not to enter during REI.
2. Workers who enter the establishment after application starts must receive the same warning at the start of their work period.

Additional Duties for Handler Employers

These requirements apply to commercial pesticide handler employers and agricultural employers who employ handlers.

Application Restrictions and Monitoring

1. Do not allow handlers to apply a pesticide so that it contacts, directly or through drift, anyone other than appropriately trained and equipped handlers.
2. Handlers must suspend applications when anyone other than appropriately trained and equipped handlers enters the AEZ.
3. When anyone is handling a highly toxic pesticide with a skull and crossbones, maintain sight or voice contact every two hours.
4. Make sure a trained handler equipped with labeling-specific PPE maintains constant voice or visual contact with any handler in an enclosed space production site (e.g., greenhouses, high tunnels, indoor grow houses) while applying a fumigant.

Specific Instructions for Handlers

1. Before handlers do any handling task, inform them in a manner they can understand of all pesticide labeling instructions for safe use.
2. Ensure that the handler has access to product labeling during the entire handling task.

Equipment Safety

1. Inspect pesticide handling equipment before each day of use and repair or replace as needed.
2. Allow only appropriately trained and equipped handlers to repair, clean, or adjust pesticide equipment that contains pesticides or residues, unless they are not employed on the establishment. See Additional Agricultural Employer Duties for information regarding non-employed persons.

Personal Protective Equipment (PPE) Handlers Must Use

1. Provide handlers with the PPE required by the pesticide labeling, and be sure it is
- Clean and in operating condition;
- Worn and used according to the manufacturer's instructions;
- Inspected before each day of use; and
- Repaired or replaced as needed.
2. When a respirator is required by product labeling, provide handlers with
- A medical evaluation to ensure the handler is physically able to safely wear the respirator;
- Respirator training in compliance with the Occupational Safety and Health Administration's (OSHA's) Respiratory Protection Standard; and
- A fit test to ensure the respirator fits correctly.
- Keep records on the establishment of these items for 2 years.
3. Take steps to avoid heat-related illness when labeling requires the use of PPE for a handler activity.
4. Provide handlers a pesticide-free area for
- Storing personal clothing not in use;
- Putting on PPE at start of task; and
- Taking off PPE at end of task.
5. Do not allow used PPE to be taken home.

Care of PPE

1. Store and wash used PPE separately from other clothing and laundry.
2. If PPE will be reused, clean it before each day of reuse, according to the instructions from the PPE manufacturer, unless the pesticide labeling specifies other requirements. If there are no other instructions, wash in detergent and hot water.
3. Dry the clean PPE before storing.
4. Store clean PPE away from personal clothing and apart from pesticide-contaminated areas.

Replacing Respirator Purifying Elements

1. Replace particulate filters or filtering facepiece respirators when any of the following conditions is met:
- When breathing becomes difficult;
- When the filter is damaged or torn;
- When the respirator label or pesticide label requires it; or
- After eight total hours of use, in the absence of any other instructions or indications of service life.
2. Replace vapor-removing cartridges/canisters when any following condition is met:
- When odor/taste/irritation is noticed;
- When the respirator label or pesticide label requires it (whichever is shorter);
- When breathing resistance becomes excessive; or
- After eight total hours of use, in the absence of any other instructions or indications of service life.

Disposal of PPE

1. Discard, do not clean, coveralls and other absorbent materials that are heavily contaminated with pesticide having a signal word "DANGER" or "WARNING." When discarding PPE, ensure that it is unusable as apparel or made unavailable for further use.
2. Follow federal, state, and local laws when disposing of PPE that cannot be cleaned correctly.

Instructions for People Who Clean PPE

The handler employer must inform people who clean or launder PPE

1. That PPE may be contaminated with pesticides;
2. Of the potential for harmful effects of exposure to pesticides;
3. How to protect themselves when handling PPE;
4. How to clean PPE correctly; and
5. Decontamination procedures to follow after handling contaminated PPE.

Additional Agricultural Employer Duties

Before allowing persons not directly employed by the establishment to clean, repair, or adjust pesticide application equipment, provide the following information:

1. The equipment may be contaminated with pesticides;
2. The potentially harmful effects of pesticide exposure;
3. How to handle equipment to limit exposure to pesticides; and
4. How to wash themselves and/or their clothes to remove and prevent exposure to pesticide residues.

Employer Responsibilities for Supervisors and Labor Contractors

Employers must provide sufficient information to supervisors and/or labor contractors to ensure compliance with the revised WPS. Specify

- The tasks supervisors/labor contractors must do; and
- The information they must provide to workers/handlers.

Employers are liable for a penalty under FIFRA if a supervisor or labor contractor acting for them fails to comply with the revised WPS requirements.

Additional Information and Web Addresses for Links

UF/IFAS publication PI294, "Worker Protection Standard (WPS) Responsibilities and Compliance": https://edis.ifas.ufl.edu/publication/PI294

UF/IFAS publications from the PIO: https://edis.ifas.ufl.edu/units/pesticide_information_office

EPA, *How to Comply with the 2015 Revised Worker Protection Standard for Agricultural Pesticides: What Owners and Employers Need to Know.* EPA 735-B-16-001. United States Environmental Protection Agency (2016): https://www.pesticideresources.org/migrated/wps/htc/htcmanual.pdf

EPA, "Worker Protection Standard Application Exclusion Zone": https://www.epa.gov/pesticide-worker-safety/worker-protection-standard-application-exclusion-zone

[1] This document is CPMG-07, one of a series of the Pesticide Information Office, UF/IFAS Extension. Original publication date December 1995. Revised annually. Most recent revision August 2026. Visit the Ask IFAS website at https://ask.ifas.ufl.edu for the currently supported version of this publication.

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2026–2029 Florida Citrus Production Guide: Food Safety Requirements and Considerations for the Florida Citrus Grower[1]

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Introduction and Objective

Florida citrus growers have long implemented *Good Agricultural Practices (GAPs)* for preharvest practices (e.g., in the field) established to prevent, minimize, or eliminate contamination and hazards to human health. Essential components of the GAPs process include careful planning, implementation, and documentation of required steps and procedures that together analyze and minimize risks from biological, chemical, and physical hazards.

The development of GAPs is based on sound science, including peer-reviewed scientific literature as well as outbreak investigations related to various fresh produce commodities. The Produce Safety Rule (PSR) of the Food Safety Modernization Act (FSMA) formalized and codified many of the previously voluntary GAPs that growers had practiced for many years. GAPs related to citrus will continue to evolve as new information is discovered. Growers represent the first link in the farm-to-table food chain. Growers who develop and maintain a strong GAPs program will be well-positioned to meet the evolving market-driven demands and regulatory requirements.

The objective of this chapter is to present general GAPs principles and PSR requirements needed to plan, execute, and document production practices that will prevent, minimize, or eliminate risks that can result in contamination. The materials contained in this chapter are a combination of recommendations based on the best available science and minimum standards outlined in the PSR. The distinction between voluntary GAPs recommendations and PSR requirements is made in this chapter by the deliberate use of the words "must" and "should," where "must" is used to denote PSR requirements and "should" is used to denote voluntary GAPs. This chapter will be reviewed and updated as new risk data emerges; it is not a comprehensive list of all PSR requirements.

Background

GAPs represent important procedures that Florida citrus growers should follow to minimize the potential for fruit contamination and meet specific requirements of the PSR. Florida's citrus growers, processors, and fresh-fruit packers have invested considerable resources in developing and implementing food safety protocols to participate in third-party audit programs. Many growers document production, harvest, and transportation practices as part of their normal operations to mitigate the potential for foodborne illnesses, and packers also adhere to their own food safety requirements. Citrus juice processors implement the *Hazard Analysis and Critical Control Point Program (Juice HACCP),* which is required by the FDA (21 CFR Part 120). Farm owners and managers who produce citrus intended for fresh-squeezed juice should also be aware of and follow the Juice HACCP regulation in that rule.

GAPs are a prerequisite of these fresh-citrus packing and juicing food safety requirements. Combining a GAPs program that has been developed, supervised, and properly implemented with PSR requirements protects the health of consumers and the producer's investment in the product.

In general, GAPs programs address three types of hazards:

1. Biological
2. Chemical
3. Physical

Biological hazards, including human *pathogens* such as bacteria, viruses, and parasites, can lead to widespread foodborne illness if practices are not in place to minimize or eliminate product contact with such contamination. There are many routes biological hazards may take to contaminate produce. Biological contamination can occur by contact of fruit with feces. Direct contact may occur from untreated or improperly treated manure used as soil amendments or from animal feces contacting fruit in the grove. Indirect contact can include transfer from contaminated soil, water, bins, gloves, equipment, and hands or clothes of field workers onto produce during production, harvesting, or handling.

Chemical hazards can include residues of agrochemicals, sanitizers, and pathogen toxins that may be present in or on fruit. While agrochemicals can enhance the production of horticultural commodities and are valuable tools for growers, it should be documented that materials were applied only according to label instructions.

Physical hazards can include hard or sharp objects in food that may result in personal injuries. Such objects, if present, are removed during the sorting and culling of citrus fruit.

While acknowledging the potential for chemical and physical hazards to be present, the FSMA PSR focuses mainly on biological hazards and relies on the proper implementation of GAPs programs to prevent the introduction of chemical or physical hazards into the food supply.

GAPs Topics

Management and Personnel Responsibility

Food safety is a shared responsibility. The collective efforts of growers, harvesters, processors, packers, shippers, and regulators of fresh and processed citrus products are essential to ensure a safe and wholesome product. Each company must specifically designate an individual or team responsible for implementing food safety programs and ensuring compliance with the requirements of the PSR. For absentee landowners not directly involved with citrus production, grove caretaking companies or independent consultants may serve in this role through a contractual agreement.

Worker Training, Health, and Hygiene

Proper worker hygiene is critical for the successful implementation of GAPs. Without it, employees who work with citrus fruit may increase the risk of transmitting foodborne illness. A review highlighting information and field sanitation requirements (OSHA Standard 1928.110) is available from OSHA and expands on many of the subjects discussed below.

Supervisor Training Requirements

The PSR requires at least one supervisor or representative to receive food safety training at least equivalent to the standardized curriculum recognized as adequate by the FDA. Successfully completing a Produce Safety Alliance Grower Training Course is one way to fulfill this requirement. Day-to-day duties and many other key food safety responsibilities can be delegated to qualified staff or third parties, but these duties should be overseen by a responsible supervisor or representative.

Worker Training

An employee training program is essential to ensure workers are aware of food safety risks, understand how to identify and reduce risks, and can carry out food safety practices correctly. All personnel must receive food safety training appropriate to their specific job duties before starting work and at least once annually. The date and time the training is conducted, the names of personnel trained, and the training content must be recorded.

Training programs must include principles of food safety, health, and personal hygiene (e.g., general cleanliness, proper handwashing). Workers must know symptoms of foodborne illness and policies regarding sick employees. They must also be trained to recognize contaminated fruit and contact surfaces (i.e., visible fecal matter) and not to harvest any fruit that may be contaminated, including fruit that is dropped during harvest. Workers must be trained to inspect harvest containers and equipment for contamination and to know the procedures for correcting problems, such as cleaning, sanitizing, and proper storage of tools and equipment.

Handwashing and Sanitary Facilities

Proper management of toilet and handwashing facilities is required in the field and can significantly reduce the risk of contaminating produce by encouraging good hygiene practices. A minimum of one toilet and one handwashing facility must be maintained for every 20 employees. For both regulatory compliance and workers' convenience, handwashing and bathroom facilities must be located within a one-quarter-mile walk or a five-minute drive. For details, see these rules on field sanitation:

- OSHA standard, 29 CFR part 1928.110, and
- Florida Administrative Code, Rule 64E-14.016.

GAPs for Facilities to Support Worker Hygiene

- All employees who handle produce or food contact surfaces must receive proper hygiene and food safety training upon hiring and be retrained annually after that. Any responsible supervisor or representative may train employees.
- Toilet and handwashing facilities must be provided during harvesting activities.
- Handwashing facilities must be furnished with running water. Water should be potable (best practice) but, at a minimum, must meet the standards of no detectable generic *E. coli* in 100 mL.
- Handwashing facilities must be furnished with soap, single-use towels, and a hand drier or a receptacle for used towels. One must monitor the facilities when in use.

- Toilet facilities must be maintained in clean condition. Documentation of maintenance and servicing of toilet and handwashing facilities should be kept. Cleaning and servicing of toilets must be conducted in a manner to prevent contamination or accidental spillage.
- Portable toilets should be placed outside the immediate crop production area (best practice) but within ¼ mile of where workers will be working. At a minimum, toilets must be placed in a manner that prevents the contamination of fruit with human waste.
- Wash water and garbage must be contained for proper disposal after use.
- Have a mitigation plan in place so that workers know the company response policy in case of a sewage spill.

GAPs for Worker Health and Hygiene

- Workers who display symptoms of infectious disease must either be assigned tasks that prevent them from coming in direct contact with fruit or food contact surfaces, or be sent home.
- Workers with visible open wounds or sores should cover them sufficiently (e.g., hand wounds should be bandaged and gloved) to prevent bodily fluids from contacting fruit.
- Hands must be washed before starting work, putting on gloves, after eating, smoking, or using the restroom, sneezing or coughing, and any other time they might become contaminated.
- If worn, gloves must be maintained in clean condition and changed when they become soiled or torn.
- Store harvest gloves and equipment properly (off the ground in a designated, clean area) when using the bathroom or on breaks. Do not carry gloves, aprons, or equipment into the toilet facility.
- Eating, drinking, and tobacco use must be limited to non-fruit-production areas.

Water

Citrus production relies on water supplies for several field operations, including irrigation, freeze protection, and the application of agrochemicals. Water is also used for washing hands and equipment. These applications can result in water being a source of contamination through direct or indirect methods, so policies and procedures must be in place to minimize risks. Water that is intended or likely to contact fruit or fruit contact surfaces is called *agricultural water* and presents a higher level of risk than water that does not contact fruit or fruit contact surfaces. Different sources of *agricultural water* can also present different levels of risk, with untreated surface water representing a higher level of risk than groundwater or treated water. These risk factors should be weighed when considering the best uses of different water supplies (e.g., using higher-risk water sources for lower-risk applications and vice versa). For example, untreated surface water could be used for seepage or under-canopy irrigation, where contact is not likely. In contrast, groundwater, municipal water, or properly treated surface water must be used for handwashing by harvest workers. For more information regarding water GAPs, refer to UF/IFAS publication FSHN06-02, "Food Safety on the Farm: Good Agricultural Practices and Good Handling Practices — Water."

Water for Field Use

Agricultural water must be of safe and adequate sanitary quality for its intended use and meet all applicable federal, state, and local laws and regulations.

Any agricultural water used during growing, harvest, or holding of citrus must meet the requirements outlined in 21 CFR § 112.40. The newly published final rule on agricultural water shifted the requirements from testing as a sole driver of decision-making around water quality to a more systems-thinking approach. Now growers must conduct an Agricultural Water Assessment to evaluate their water system for different characteristics outlined in §112.43 and determine whether their water is of safe and adequate sanitary quality for its intended use. Growers must decide whether mitigation measures or corrective measures are necessary or whether to discontinue use of the water. Harvest and postharvest agricultural water requirements remain the same: water sources must be tested to ensure water meets the standard of no detectable *E. coli* per 100 mL sample, and the standard must be maintained throughout its use.

See the FDA website for more information about the final changes to Subpart E of the FSMA Produce Safety Rule regarding preharvest water and the Agricultural Water Assessment.

Requirements and Best Practices

- Agricultural water for pre- and postharvest water sources and distribution systems must be assessed for potential food safety hazards at least annually, with consideration given to the type of water source (e.g., surface, ground); control and protection of each source (e.g., deep well, shared canal); application method (e.g., drip, overhead); crop characteristics and environmental conditions that increase susceptibility to contamination; adjacent land use; and maintenance issues, including keeping the source free of debris, trash, and domestic animals.
- Water used in foliar applications can be obtained from (1) municipal, treated water sources, (2) groundwater obtained from a properly constructed well in good condition, or (3) surface water that is suitable for its intended use (e.g., as shown through microbial testing and visual inspection).
- Water sources used for foliar applications should be routinely tested, as needed, and water quality records

maintained. Treated water and municipal water do not require testing; however, water treatments must be monitored and recorded to demonstrate effectiveness.
- Well water used for foliar applications should be drawn from properly engineered and protected sources. Wells should be properly cased and above grade. Wells must be inspected for cracks, leaks, and so forth; records of repairs must be kept.
- If available, results of a microbial analysis of a water source from a public entity, such as the local water authority, may serve as acceptable documentation in place of testing by the grower and should be kept on file.
- Animals should be excluded from surface water used for foliar application to the extent possible.
- As much as possible, the time should be extended between the last foliar application of agricultural water and harvest to allow time for microbial die-off.

Water Contamination Risk from Adjacent Land

Adjacent lands used for recreation, landfills, concentrated animal operations, or other uses and activities may pose a risk for runoff or leaching of microbiological or chemical contaminants. Producers should work with local watershed authorities to understand watershed issues and consider mitigation strategies, such as berms or ditches, where necessary to minimize runoff.

GAPs for Managing Water Sources and Adjacent Land Use

- Risks from adjacent land and water should be identified and documented as part of the annual inspection of your agricultural water source(s). Such risks can include landfill sites, sewage treatment facilities, septic tanks and leach fields, or surrounding farm operations such as dairy farms or compost producers.
- Preventive or corrective actions should be taken and documented if water contamination sources are identified. Such actions can include the construction of physical barriers (berms, ditches, or fencing) or the use of a catch basin. You must inspect your water sources annually to ensure mitigation steps are still functioning as intended.

Land Use and Soil Amendments

Land use prior to grove establishment and patterns of adjacent land use can have food safety implications. The grower has no control over historical uses, but awareness of potential problems may help determine if mitigation is needed and what control options are feasible.

Biological soil amendments of animal origin are identified in the PSR as the soil amendments most vulnerable to microbial contamination. Manure or biosolids can serve as effective and safe fertilizers if proper treatment and application procedures are in place. Such treatment procedures can include composting to reduce microbial pathogens in number, thereby reducing the risks associated with their presence in soil amendments. The PSR outlines criteria to determine whether a biological soil amendment of animal origin is considered treated or untreated, and such designation determines the allowable application methods and minimum application-to-harvest intervals. Only specific composting methods can be used to produce treated amendments, and specific treatment conditions must be monitored and documented. Currently, the FDA does not intend to take exception to growers using (raw) manure in compliance with National Organic Program (NOP) standards. The NOP standard is 90 days from the last application to harvest for tree fruit. Additional research and risk assessments are being conducted to further determine an appropriate time interval between the application of raw manure and crop harvest. The PSR allows the use of Class A biosolids. Detailed GAPs related to manure and biosolids are available in the UF/IFAS publication FSHN10-02, "Food Safety on the Farm: Good Agricultural Practices and Good Handling Practices — Manure and Municipal Biosolids." Preventing fruit from touching the ground greatly reduces the potential for contamination. In cases where fruit may fall to the ground, they must never be harvested for use in the fresh market.

GAPs for Soil Amendments and Land Use

- Avoid planting citrus on land previously used for any operations engaged in risk-accumulation practices, such as landfills, or areas previously spread with contaminated wastes or those of an unknown industrial use.
- If needed, question state/local officials or conduct a title search or environmental assessment to establish whether previous land use involved the disposal of chemical or biological wastes.
- Documents should be kept for the application of soil amendments, including the source of the soil amendment, treatments, compost producer, amount used, and information on when and how it was applied.
- The type of soil amendment, application, and the time interval between application and harvest should also be kept. The interval between application and harvest should be as long as feasible, with adequate consideration to other crops nearby.
- Obtain a certificate of conformance annually from compost suppliers to demonstrate the compost treatment process meets PSR requirements for treated compost.
- Apply treated compost in a way that prevents contact with fruit.

- Untreated compost should never be applied in a way that it contacts fruit during application.
- Compost must be handled and stored in a location and manner to minimize the potential for contamination of citrus fruit and surface waters.

Animal Control

Wildlife and domestic animals — including but not limited to dogs, cats, cattle, rodents, hogs, deer, reptiles, amphibians, and birds — may serve as sources of contamination. While minimizing animal contact with fresh produce also minimizes the risk of product contamination, wildlife is challenging to control in grove settings. Growers should balance these management efforts with their responsibility for environmental stewardship; this is commonly referred to as co-managing food safety and ecological health.

Domestic Animals

The activities of domestic animals are the easiest to manage. Their access into production, packing, and equipment storage areas should be prevented. If a domestic animal is not totally excluded (e.g., in the case of guide or guard dogs), reasonable precautions should be taken to prevent contamination.

Wild Animals

Growers are not expected to take extraordinary measures to exclude all animals from outdoor growing areas or destroy wildlife habitats. However, if there is a reasonable possibility that animals will contaminate crops, the grove areas should be monitored for evidence of animal intrusion immediately prior to harvest and as needed throughout the year. Fruit visibly contaminated with feces must not be harvested.

GAPs for Managing Contamination Risks from Domestic and Wild Animals

- Maintain fencing or other barriers to prevent intrusion by neighboring cattle or other domestic livestock, as appropriate.
- Have a policy in place to mitigate fecal material deposited by domestic animals in the grove to the extent possible.
- To the extent possible, minimize animal attractants by discarding old equipment and containers and removing excess water from the field.
- Inspect storage areas for rodents, birds, and insects and use pest control procedures (e.g., traps, screens, etc.) to minimize pests.
- Keep cull and debris piles away from crop production areas.
- Have a policy in place to look for and mitigate risks from fecal material deposited by wild animals in the grove to the extent possible.
- Fruit with visible fecal contamination should be removed from the grove and must never be harvested for the fresh market.

Agrochemical Use

Agrochemicals such as sanitizers, disinfectants, fungicides, insecticides, and herbicides can enhance the production, quality, and safety of horticultural commodities when used according to their product labels. The EPA closely regulates pesticides, and the approval of each formulation includes specific limitations regarding the means by which the agrochemical may be applied, conditions of application, labeled rates, target organisms against which the chemical may be employed, use restrictions, and requirements for pesticide disposal and its containers.

The EPA also has the responsibility to determine tolerances or exemptions from tolerances for pesticide residues on raw agricultural commodities in the United States. Residue tolerances for export markets are regulated and enforced by their respective countries. Proper pesticide use involves close working relationships among citrus growers, packers, shippers, and processors.

This GAPs chapter is not intended to provide guidance for pest management practices (for this guidance, refer to other chapters of this guide).

Pesticides

- As part of GAPs documentation, labels and safety data sheets (SDS) of pesticides used should be kept on file, and a detailed written procedure for the application of all pesticides should be recorded.
- Pesticides must be used in a manner consistent with their label, including for the purpose specifically identified on the label.
- Florida law requires maintaining specific records for Restricted Use Products (i.e., products for which use and application are restricted to certified applicators or under the direct supervision of such) that include the EPA registration number, the date each pesticide was applied, the quantity used, and where and how the application was made.
- Verify proper licensing and registration of subcontractors, custom applicators, crop advisors, and so forth.
- Document compliance with the EPA's Worker Protection Standard.

For additional information and requirements, see the Florida Department of Agriculture and Consumer Services (FDACS) webpage about pesticide applicator certification and licensing. Meet all federal, state, and local pesticide application, field posting, preharvest interval, and documentation requirements.

Field Sanitation, Harvest, and Transport

Fresh produce can become contaminated when contacted by soil, fertilizers, water, workers, and harvesting equipment during growing and harvest activities. General sanitation of the bins and equipment is necessary to prevent fruit contamination with biological hazards.

GAPs for Harvest Bins and Equipment

- Harvesting equipment, such as gloves, hand tools, and picking sacks, should be routinely cleaned and sanitized as appropriate.
- Document procedures and schedules for cleaning and sanitizing equipment used in the field. At a minimum, a cleaning record is required for fruit-contact tools and equipment.
- Picking bins should be kept free of debris and contaminants.
- Bins should be used only for the purpose of holding and transporting fruit. Any out-of-service bins used for storage need to be clearly marked and never returned to service.
- Inspect bins regularly for evidence of animal intrusion and fecal matter. Cleaning and sanitizing should occur on a routine, documented basis.
- Separate, segregate, and dispose of fruit if exposed to oils or chemical contaminants from harvesting equipment.
- Exclude all fruit that have touched the ground or are visibly contaminated with fecal matter.

Transportation

Proper transport of fresh produce will help reduce the potential for biological hazards.

GAPs for Transportation

- Good hygienic and sanitation practices should be used when loading, unloading, and inspecting produce.
- Inspect transportation vehicles for obvious dirt and debris before loading. The vehicle should be cleaned and sanitized if evidence of debris, animal manure, or other raw animal by-products exists.
- Load produce carefully to minimize physical damage.

Traceability and Recordkeeping

A written food safety plan is central to successfully implementing any GAPs program, although the PSR does not require a full food safety plan. Having records to document these practices, and the resulting traceability benefits, are vital to the GAPs process. Documentation, including records of all corrective actions, is required to prove to regulatory agencies, handlers, and retailers that you are following GAPs. Such documentation is important to demonstrate that proper procedures (e.g., cleaning and sanitation) were followed.

Traceability is an important part of GAPs documentation. *Traceback* is the ability to track food back to its source. *Trace forward* is the ability to identify all receivers of your citrus fruit from a given grove or source. It is critical that growers establish tracking systems from the earliest stages that follow their fruit within the distribution system. This system includes supply-chain partners involved in processing, packing, storing, shipping, and transporting Florida citrus fruit. Both traceback and trace forward actions are necessary to identify the potential source of any safety problems that might occur and for supply-chain partners to implement targeted recalls efficiently and effectively. GAPs forms should be readily available or collected together in a single location for ease of rapid access in the event that fruit is associated with an alleged contamination issue. For more information about preparing for and conducting a recall, see UF/IFAS publication FSHN0410, "The Food Recall Manual."

Basic sample recordkeeping forms are available online, but these are not intended to replace other required state report forms or forms prescribed by your packer or processor as part of their quality management systems. While they represent excellent examples, forms should be adapted to fit individual operation needs.

In addition to the documentation and recordkeeping indicated in this chapter, each load of harvested product should include the source of the product, the date of harvest, farm identification, and a record of who handled the product. These may include properly completed Trip Tickets.

GAPS for Traceability and Recordkeeping

- Ensure a food safety plan and a traceability plan are in place.
- Organize all documentation so that records can be accessed quickly — at least within 24 hours of request from a regulatory body.
- Demonstrate that the product can be traced one step forward and one step back.
- Include tracking information with each citrus load (fruit source, harvest date, harvest crew, etc.). This information can usually be satisfied with a properly completed Trip Ticket.

Summary

It is important to ensure the food safety of all citrus commodities in order to minimize food safety risks and maintain consumer trust. As with other commodities, producers of Florida citrus should follow the guidelines and requirements outlined above. Audit tools generally follow these guidelines quite closely, although individual customers often impose requirements of their own that should be addressed.

Web Addresses for Links

UF/IFAS publication FE603, "2021 Handbook of Florida Water Regulation: Water Wells": https://edis.ifas.ufl.edu/fe603

UF/IFAS publication FSHN0410, "The Food Recall Manual": https://edis.ifas.ufl.edu/publication/FS108

UF/IFAS publication FSHN06-02, "Food Safety on the Farm: Good Agricultural Practices and Good Handling Practices — Water": https://edis.ifas.ufl.edu/publication/FS136

UF/IFAS publication FSHN10-02, "Food Safety on the Farm: Good Agricultural Practices and Good Handling Practices — Manure and Municipal Biosolids": https://edis.ifas.ufl.edu/publication/FS150

EPA's Worker Protection Standard: https://www.epa.gov/pesticide-worker-safety/agricultural-worker-protection-standard-wps

FDACS, Pesticide Applicator Certification and Licensing: https://www.fdacs.gov/Business-Services/Pesticide-Licensing/Pesticide-Applicator-Licenses/Pesticide-Applicator-Certification-and-Licensing

FDA's FSMA Final Rule on Pre-Harvest Agricultural Water: https://www.fda.gov/food/food-safety-modernization-act-fsma/fsma-final-rule-pre-harvest-agricultural-water

Florida Administrative Code, Rule 64E-14.016: https://flrules.org/gateway/ruleno.asp?id=64E-14.016

OSHA Standard 1928.110: https://www.osha.gov/laws-regs/regulations/standardnumber/1928/1928.110

Produce Safety Alliance Grower Training Course: https://producesafetyalliance.cornell.edu/training/grower-training-courses

Sample Recordkeeping Forms for Traceability, Produce Safety Alliance: https://producesafetyalliance.cornell.edu/sites/producesafetyalliance.cornell.edu/files/shared/documents/Records-Required-by-the-FSMA-PSR.pdf

Trip Ticket Forms: https://www.flrules.org/gateway/ChapterHome.asp?Chapter=20-2

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2026–2029 Florida Citrus Production Guide: Crop Insurance Policies Available to Citrus Growers[1]

Ariel Singerman[2]

Production risk is one of the main risks that growers are subject to. A grower can combine the same inputs every year and yet obtain different yields each time. The main source of risk and therefore the extent to which yields may differ from year to year in crop production stems from the unpredictable nature of weather, pests, and diseases.

Another source of risk for growers is market or price risk. Because growers are typically price takers, they are exposed to the supply-and-demand market forces for inputs and outputs. Thus, commodity prices can vary each year and even within a given season. In addition, growers seldom know for certain the prices of farm inputs and outputs at the time they must make decisions about how much inputs to use or what and how much of various outputs to produce. Therefore, market risk includes risks derived from cyclical and seasonal price fluctuations of agricultural products, trade restrictions (i.e., market access), subsidies, and currency exchange rates. Contracts with buyers and suppliers can mitigate market risk, but when selling a commodity, contracts can also limit a price increase that would benefit the grower.

In this chapter, I describe the main crop insurance policies available to citrus growers and provide examples that illustrate the calculations involved. The commonality among all policies is that by purchasing crop insurance, the grower transfers part of the risk in exchange for a premium (which is the cost of purchasing insurance).

Crop Insurance as a Tool for Managing Risk

Federal crop insurance is provided through a partnership between public institutions and private companies. The Risk Management Agency (RMA) acts on behalf of the Federal Crop Insurance Corporation (FCIC) to administer all federal crop insurance programs. The RMA designates private insurance companies to market, underwrite, and adjust claims for crop insurance policies. It is important to realize that premium rates and insurance terms and conditions are established by the FCIC. Therefore, the premium for a specific policy and coverage level is the same across companies; insurance companies compete only with their knowledge, customer service, and related insurance products. In addition, to increase participation in the program, the federal government subsidizes crop insurance premiums.

The Basics

At the time of enrollment, the grower chooses a certain coverage level, which determines two components of the policy. First, it determines the guarantee or liability (the amount at which the grower is insuring for). Second, the coverage level chosen also determines the deductible (the amount of loss for which the grower will not receive an indemnity). In the event of a loss, any level below the guarantee will trigger an indemnity. Figure 1 illustrates the basics of how crop insurance works with a 1-acre example. Assume a grower expects revenue to be $1,775 and chooses a 60% coverage level. His choice of coverage level sets the guarantee at $1,065 and establishes the premium the grower will pay for insuring at such level. If, for example, the grower experiences a 50% loss, the actual farm revenue will be $888. The indemnity will then be equal to $177, which is the difference between the guarantee and the actual farm revenue.

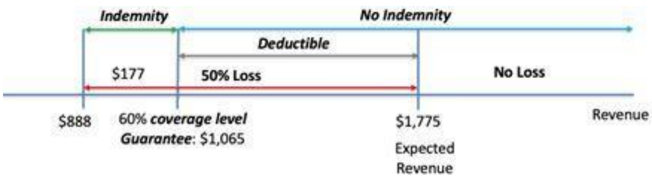

Figure 1. Illustration of the basic concepts involved in crop insurance for a 1-acre farm.
Credit: Ariel Singerman, UF/IFAS

Crop Insurance Policies for Citrus

There are two insurance policies specifically available for Florida citrus growers based on maximum reference dollar amounts set by the RMA: tree insurance and fruit/crop insurance. In addition, Catastrophic Risk Protection (CAT) is available for both policies and is set at 50% coverage and 55% of the reference dollar amount. Thus, the coverage is very limited because payments are only triggered for losses that are greater than 72.5% (=1 - 50%

× 55%) of the maximum reference dollar amount. The advantage of CAT, however, is that it has a low cost: $358 for early- and mid-season oranges and $392 for late-season oranges per county regardless of acreage.

Tree insurance is based on reference prices established by the RMA that differ according to tree age. For example, orange trees older than six years have a reference price of $100 per tree. Causes of insurable loss under this policy are excess moisture, flooding, freeze, and wind. Coverage levels range from 50% to 75% in 5% increments. For example, the premium subsidy for 60% coverage is 64%, so the grower has to pay the remaining 36%.

Citrus fruit/crop insurance is based on a reference maximum dollar amount per acre. This policy offers coverage for fruit from trees that are at least five years old. Insurable causes of loss under this policy are excess wind, fire, freeze, hurricane, hail, and tornado. Growers can choose coverage levels ranging from 50% to 85% in 5% increments. Table 1 illustrates how the fruit dollar-amount policy works using 1 acre of late-season oranges from nine-year-old trees located in Polk County. The reference maximum dollar amount established by the RMA for 2025 is $1,775 per acre. Assuming the grower chooses a 60% coverage level, the guarantee is set at $1,065 and the deductible at $710. The calculations in Table 1 also show the total premium is $39, but because crop insurance is subsidized, the grower only needs to pay $14 per acre. In the case of a 50% loss, the amount lost would equal $888, triggering an indemnity of $177 so as to provide the guarantee of $1,065. Note that the Florida Citrus Fruit Dollar Plan will be terminated following the 2026 crop year.

Whole Farm Revenue Protection (WFRP) is available nationwide and provides coverage against losses in farm revenue for the entire farm. In other words, all farm revenue is insured together under one policy. Thus, individual commodity losses are not considered. The approved revenue amount under this policy is the lower of (1) historic farm revenue (five-year average based on tax records) or (2) expected revenue. Coverage level ranges from 50% to 85% in 5% increments. Eligibility criteria include having no more than $2 million in expected revenue from animals and animal products; having no more than $2 million from greenhouse and nursery products; and having no more than $17 million in insured (i.e., approved) revenue.

The federal premium subsidy for WFRP depends on how many commodities are grown on the farm and the level of coverage chosen (see Table 2). Farm diversification affects not only the premium subsidy but also the premium rate.

Table 3 illustrates how WFRP works for a 1-acre farm located in Polk County. For comparison purposes, the values chosen are similar to those in the previous example. Assuming the farm generated $1,800 in revenue each of the past five years and is expected to generate $1,775 next year, the approved revenue is $1,775. Assuming the grower chooses a 60% coverage level, the guarantee is set at $1,065 and the deductible at $710. Table 3 illustrates the calculations for three different examples regarding the number of commodities grown on the farm. Note that the premium subsidy is 80% in all three cases (because the coverage level is 60%).

In case of a 50% loss (as in the example for the fruit dollar amount policy above), the amount lost would equal $888, triggering an indemnity of $177.

Even though the numbers used for the examples in the fruit dollar amount policy and WFRP were purposely made to be the same, it is important to realize the significant differences between the policies and the type of coverage they offer. One of the main differences is that WFRP is based on the insured farm's records, not on an amount the RMA establishes. In addition, the dollar-amount policy covers production risk (decrease in yield), whereas WFRP covers production and market risk (decrease in both yield and price).

In crop year 2022, the RMA started offering Actual Production History (APH) to Florida citrus growers for insuring their crop; it provides coverage for yield losses based on a farm’s historical records. However, the price used to establish the premium and liability amount for each combination of crop, type, and grove practice is set by the FCIC. Growers can elect to insure at a lower price than established or, alternatively, can provide a contract price, if available. APH coverage levels range from 50% to 85% in 5% increments. Causes of insurable loss under this policy include excess wind, drought, freeze, hail, hurricane, tornado, fire, diseases (if specified in the special provisions), and postbloom fruit drop provided recommended disease control measures are applied. Coverage is offered for fresh and processed oranges and grapefruit, fresh mandarins/tangerines, tangelos, and tangors grown in central and southwest Florida counties. Coverage for fresh and processed lemons is available in some counties.

The basis to establish the guarantee and premium in APH is called the APH approved yield, which consists of the average of the grower’s yield records for the last 10 seasons, called APH database. Growers need to provide at least four years of yield records to obtain APH coverage. If such records are not available, the grower will be assigned transitional yields (T-yields) — an estimated yield figure based on historical average county yields — for each missing year. The number of years for which the grower has records available will determine what percentage of transitional yield is used to complete the missing years. To determine whether any adjustments to the APH database are warranted either due to alternate bearing or downward trend patterns, the insurance company will perform high variability tests. Note that the RMA instructed insurance companies to exclude 2022/23 from high variability tests calculations given the catastrophic weather events during that season.

Table 4 illustrates the estimated amounts of APH premium and indemnity at the 60%, 70%, and 80% coverage levels when using Polk County as an example (in lieu of farm-level records). Table 4, Panel A shows the values needed for computing the premium and indemnity. For example, the FCIC established the price for early- and mid-season oranges at $12.29 per box. Thus, the value of production per acre was set at $1,942 (=$12.29 per box times the estimated Polk County APH of 158 boxes per acre). The assumed realization of yield in 2024/25 of 79 boxes per acre implies that there would have been a loss of 50% relative to the APH yield. Thus, the value of the production to count (and the loss) would have been $971 per acre. Table 4, Panel B shows the guarantee, liability, deductible amounts, and the amounts for the farmer premium and indemnity for the three different coverage levels. Panel B also shows that a grower who would have chosen 60% (70%) [80%] coverage would have had to pay $11 ($31) [$87] per acre as the premium, and should the yield be 79 boxes per acre, the grower would receive $197 ($393) [$578] per acre as indemnity.

As citrus yield continues to follow a downward trend in Florida due to the combined impact of HLB and weather shocks, it is important to keep in mind that blocks with trees that are eight years of age or older are required to have produced at least 100 boxes per acre in any of the three previous years to be insurable under APH. A grower could request the RMA regional office for a determined yield to insure acreage not meeting such a requirement. However, the determined yield may not exceed 80% of the average yield for the entire APH database, as stated as part of the APH Special Provisions.

Conclusion

Dollar-amount policies for insuring citrus trees and fruit are based on reference prices established by the RMA, not on farm's records as with WFRP or APH. In addition, the coverage that dollar-amount policies provide is for specific perils. WFRP allows eligible growers to insure their entire farm revenue under one policy. Importantly, a dollar-amount policy covers production risk (decrease in yield), whereas WFRP covers production and market risk (decrease in both yield and price). The APH policy offers coverage against yield losses based on farm records for the past 10 seasons and, therefore, could be advantageous given the continuous impact of HLB on citrus yield in Florida.

Table 1. Fruit dollar-amount policy example for 1 acre in Polk County, Florida.

Line #	RMA Terminology	
(1)	Age class	9-year-old
(2)	Commodity	Oranges
(3)	Commodity type	Late season
(4)	Intended use	Juice
(5)	Ref. maximum dollar amount	$1,775
(6)	Coverage level	60%
(7)	Guarantee [(5)×(6)]	$1,065
(8)	Deductible [(5)-(7)]	$710
	Base Premium Calculation	
(9)	Basic rate	0.041
(10)	Rate differential factor	0.901
(11)	Base premium rate [(9)×(10)]	0.037
(12)	Total premium [(7)×(11)]	$39
(13)	Subsidy percent	64%
(14)	Subsidized amount [(12)×(13)]	$25
(15)	Grower premium [(12)-(14)]	$14
	Indemnity Calculation	
(16)	Assumed production damage	50%
(17)	Loss value [(5)×(16)]	$888
(18)	Indemnity [(7)-(17)]	$177

Table 2. Premium subsidy for each level of Whole Farm Revenue Protection (WFRP) coverage and number of commodities grown on the farm.

	Coverage Level							
	50%	**55%**	**60%**	**65%**	**70%**	**75%**	**80%**	**85%**
Minimum # Commodities Required	1	1	1	1	1	1	3	3
Basic Subsidy for 1 Commodity	80%	80%	80%	80%	80%	77%	68%	53%
Subsidy for 2 Commodities	80%	80%	80%	80%	80%	80%	71%	56%

Table 3. Whole Farm Revenue Protection (WFRP) example for 1 acre in Polk County, Florida.

Line #	RMA Terminology	
(1)	**Allowable Revenue***	**Amount**
	Year 1	$1,800
	Year 2	$1,800
	Year 3	$1,800
	Year 4	$1,800
	Year 5	$1,800
(2)	Average	$1,800

(3)	Expected revenue	$1,775		
(4)	Approved revenue [min((2),(3))]	$1,775		
(5)	Coverage level	60%		
(6)	Guarantee [(4)×(5)]	$1,065		
(7)	Deductible	$710		
	Base Premium Calculation			
		Example I	**Example II**	**Example III**
		100% Early	**50% Early** **50% Mandarins**	**33% Early** **33% Mandarins** **33% Grapefruit**
(8)	Weighted commodity rate	0.03	0.043	0.060
(9)	Commodity factor	1.00	0.5	0.333
(10)	Diversity factor	1.00	0.668	0.523
(11)	Premium rate [(8)×(10)]	0.03	0.029	0.032
(12)	Total premium [(6)×(11)]	$32	$31	$34
(13)	Subsidy percent	80%	80%	80%
(14)	Subsidized amount [(12)×(13)]	$26	$25	$27
(15)	Grower premium [(12)-(14)]	$6	$6	$7
	Indemnity Calculation			
(16)	Assumed loss	50%		
(17)	Loss value [(4)×(16)]	$888		
(18)	Indemnity [(6)-(17)]	$177		
*subject to Revenue Index factor: 0.8 cap and 1.2 cap				

Table 4. Actual Production History (APH): Illustration of the calculation of the premium and indemnity for the 2024/25 season for 60%, 70%, and 80% coverage for 1 acre of 'Valencia' oranges when using Polk County, Florida, as an example.

A. Parameters needed for computing the APH premium rate and indemnity.

Parameters	**Value**
Price per box	$12.29
APH yield 2024/25	158
Value of production	$1,942
Assumed yield in 2024/25	79
Yield loss relative to APH yield	50%
Value of production to count	$971
Loss value	$971

B. APH premium and indemnity for 60%, 70%, and 80% coverage.

	Coverage (%)		
	60%	**70%**	**80%**
Guarantee (in boxes)	95	111	126
Liability	$1,168	$1,364	$1,549
Deductible	$774	$578	$393
Basic rate	0.0393	0.0393	0.0393
Rate differential factor	0.702	1.377	2.51
Unit residual factor	1	1.067	1.157
Total premium	$31	$75	$168
Government subsidy percent	64%	59%	48%
Government subsidized amount	$20	$44	$81
Farmer premium	$11	$31	$87
Indemnity	$197	$393	$578

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2026–2029 Florida Citrus Production Guide: Rootstock and Scion Selection[1]

Ute Albrecht, Fernando Alferez, John M. Chater, and Mongi Zekri[2]

When preparing for a new planting or replanting, an important factor to consider is the choice of rootstock and scion. Choosing the proper rootstock and scion combination can result in higher economic returns without any additional cost. The rootstock affects scion vigor, canopy architecture, yield, fruit size and quality, disease susceptibility, tolerance to abiotic stress (cold, drought, wind), and pest tolerance. However, tree growth, yield, and fruit quality interact strongly with climate, soil type, tree spacing, and other abiotic and biotic factors, often producing inconsistent reports on rootstock performance in different areas.

Rootstock selection should be based on soil type, soil pH, pest and disease pressure, desired tree spacing and size control, and other horticultural traits. Many new rootstock selections are now available, replacing the historically used rootstocks. Therefore, limited information exists on their long-term performance under different environmental conditions and different cultural management practices. Also important is the choice of scion to be used in combination with the selected rootstock. Several novel scion varieties have been released by the breeding programs at UF/IFAS and the USDA. These novel varieties are expected to have better field performance, disease tolerance, and fruit quality, making some selections suitable for the fresh-fruit market. Many of the newest scions are managed by the New Varieties Development and Management Corporation (NVDMC). This program makes advanced citrus selections available to growers and nurseries for trial and potential early commercialization. Check the NVDMC Varieties webpage for the newest commercially available varieties.

Soil Characteristics

Choosing the right rootstock for your soil type is critical. Rootstocks performing satisfactorily on the well-drained sandy soils of the central Florida ridge may not be suitable for the wet “flatwoods” soils of the southwest and eastern Florida citrus production areas. Equally important is the ability to tolerate conditions of high pH and salinity.

Unfortunately, few rootstocks have shown to be as adaptable to suboptimal soil conditions as sour orange. For example, although Cleopatra mandarin can tolerate conditions of higher salinity and alkalinity better than most rootstocks, it is not well suited for poorly drained soils which can have suboptimal effects on fruit quality. It has been reported that Cleopatra mandarin produces smaller fruit when planted in these soils than do other rootstocks.

Volkamer lemon and C-22, a Californian cultivar also known as ‘Bitters’, are also considered tolerant of calcareous soils. C-35, Carrizo, and Swingle are among the poorest performing rootstocks in the presence of high pH and salinity. Swingle does not perform well in poorly drained, heavy soils such as on the Florida east coast and in southwest Florida. US-942, which has been among the most propagated rootstock since 2018, seems to perform well both in southwest Florida and in central ridge production sites. US-812 also performs well in both production regions and appears to outperform US-942 in terms of juice quality. Among the newer rootstocks, US SuperSour 4 (SS4) appears to be promising, although large-scale data are not yet available.

Rootstock Effects on Pests and Diseases

Many of the newer rootstock cultivars are hybrids of trifoliate orange, thereby inheriting some degree of tolerance to phytophthora. In respect to the *Phytophthora-Diaprepes* root weevil complex, US-802, US-897, US-942, UFR-4, and UFR-5 are more tolerant in comparison with other common rootstocks. Unfortunately, damage from phytophthora is exacerbated in roots already compromised by huanglongbing (HLB). Although thus far no rootstock has shown to induce the desired levels of tolerance to HLB, trees grown on some rootstock cultivars produce good yields under high HLB pressure and exhibit lower-than-average rates of fruit drop. These rootstocks include US-942, US-812, UFR-4, UFR-5, and the Californian cultivars C-54 (‘Carpenter’) and C-57 (‘Furr’). X-639, developed in South Africa in the 1950s, can produce healthy and vigorous trees despite HLB, but fruit production may be low during the early production years. Whereas most of the newer available rootstocks are tolerant to citrus tristeza virus, little is known regarding tolerance to blight, except for US-896, US-812, and US-942, which are considered tolerant. Two of the historically used rootstocks, Carrizo and Kuharske (a seedling of Carrizo), are susceptible to blight. Decline may become evident after eight or more years in the field.

In 2015, five rootstocks with improved tolerance to HLB were released by the USDA: US-1279, US-1281, US-1282, US-1283, and US-1284. All five are hybrids of mandarin and trifoliate orange, produce medium-sized trees, and appear to be adapted to Florida's flatwood soils. In 2018, the USDA released three new SuperSour rootstocks, US SuperSour 1 (SS1), US SuperSour 2 (SS2), and US SuperSour 3 (SS3). SS1 performs well with sweet orange on both the ridge and east coast flatwoods, whereas SS2 and SS3 perform well on the ridge and the east coast flatwoods, respectively. All three SuperSour rootstocks induced higher yield than standard sour orange in the presence of HLB under the tested conditions. Two more SuperSour rootstocks, SS4 and SS5, were released in 2023 because of their superior performance relative to standard sour orange and other rootstocks. Among the released SuperSour rootstocks, only SS2 exhibits good genetic uniformity among seedlings; the other SuperSour rootstocks are propagated by tissue culture.

Among the newer UF/IFAS rootstock releases are UFR-1, UFR-2, UFR-4, UFR-5, UFR-6, UFR-15, UFR-16, and UFR-17, which are managed by the Florida Foundation Seed Producers, Inc. (FFSP). See the FFSP webpage on Citrus Rootstocks for more information.

Large-scale commercial field trials evaluating the effect of systemic delivery of oxytetracycline by trunk injection showed strong positive tree responses, regardless of the rootstock. Although the extent of responses to OTC injection can vary by rootstock, effects generally do not affect other aspects of rootstock performance. For example, vigorous rootstocks will continue to increase grafted tree vigor compared to dwarfing rootstocks.

Tree Spacing and Size

Trees should be spaced based on the expected size of the tree and lifespan of the grove. A more densely planted grove may provide earlier economic returns despite an initially higher investment. C-22, US-897, and UFR-6 rootstocks produce relatively small trees, which should be spaced at 6–8 feet within the row and 15 feet between rows. The only rootstock producing an even smaller tree is 'Flying Dragon', allowing for an in-row spacing of 5–7 feet as well as closer between-row spacing, if feasible. However, Flying Dragon is a slow-growing rootstock that is not recommended for commercial growers. Yield efficiency and quality of fruit on these small-tree-size-inducing rootstocks are usually high compared with some of the more vigorous rootstocks. Most of the other available rootstocks will induce trees of average size with a recommended spacing of 8–12 feet and will produce fruit of intermediate to high quality. If the desired grove architecture is for a larger in-row spacing of trees (12–15 feet), rootstocks such as US-802, X-639, Volkamer lemon, and rough lemon are appropriate. The high vigor of these rootstocks may be advantageous in that they allow a tree to cope better with the damaging effects of HLB compared with less vigorous trees. Although yield will be high on these rootstocks, fruit quality will generally be lower, which may be disadvantageous when used in combination with some scion varieties. Under the current HLB-endemic growing conditions, it is advisable to plant trees at higher densities than in the past as the disease appears to stunt growth, reducing overall productivity per unit land.

Check the "Florida Citrus Rootstock Selection Guide" for more information on spacing.

Rootstock/Scion Combination

Choice of rootstock will also depend on the scion variety selected for the new planting. An excellent example is sour orange, which is susceptible to tristeza virus when used in combination with sweet orange and most other scion varieties. Although sour orange is still among the most propagated rootstocks (DPI Citrus Budwood Annual Report), it is not recommended for extensive use in Florida because of the endemic presence of the tristeza virus. Most of the more recently released rootstocks have been evaluated in combination with few scion varieties, mainly sweet oranges, and it is recommended to be cautious when choosing new combinations as any potential graft incompatibilities may take several years to manifest. Mandarins have the most uncertainty when it comes to graft incompatibilities.

One trend increasingly followed by industry and researchers is to develop high-quality sweet orange varieties that reach commercial maturity in early and mid-season with reduced production costs. Higher fruit quality and maturation standards achieved earlier would also reduce the need for juice blending with late varieties. Moreover, developing varieties with an early maturation window and improved internal fruit quality would allow replacement of Hamlin, which is particularly sensitive to citrus canker and HLB. New varieties have been developed through irradiation, somaclonal selection, and other techniques by UF/IFAS and the USDA. Among the newer UF varieties are the early Valencia somaclone Valquarius and the Florida EV1 and EV2. Juice quality of EV1 is typical of Valencia in sugar and acid content, color, and flavor; however, its fruit are difficult to peel and slightly seedier than standard Valencia. Fruit matures from December to January in central Florida, about 8–12 weeks earlier than standard Valencia. Yield, juice quality, and maturity dates (February/March) for Vernia, a midseason sweet orange somaclone, are also desirable compared to standard

Valencia. An attractive feature of Vernia is that fruit often have the highest color score of any orange at time of harvest. These scions, EV1, EV2, and Vernia, have not been performing well in the HLB environment in central and south Florida in recent years, but could be excellent selections for north Florida and for citrus under protective screen (CUPS) growers.

Although not new, Midknight and Delta are also noteworthy choices. These South African selections reach commercial maturity several weeks before traditional Valencia oranges grown in Florida. Midknight trees are less vigorous than other Valencia selections and grow well on Carrizo and Swingle rootstocks. Delta trees are more vigorous, and because fruit has lower Brix than other Valencia selections, Swingle and Carrizo rootstocks are recommended for this scion. So far, no information is available about the performance of these two varieties on newly released rootstocks from UF/IFAS or the USDA.

Other interesting varieties are the OLL series (OLL-4, OLL-8, OLL-20, OLL-DC-3-36, and OLL-DC-3-40), which are late-maturing varieties that have demonstrated relatively higher pound solids and yields at several sites. OLL-20 has demonstrated high color and exceptional flavor and was released due to input from a major processor. Among the late-season varieties, Valencia UF B9-65 has superior quality in terms of yield and pound solids, and there is some evidence of better performance in the HLB environment compared to conventional Valencia budline selections. The variety US Sun Dragon, released by the USDA, is orange-like and HLB-tolerant, and it may have potential for the juice market.

Other scions with potential for the fresh-fruit industry include LB8-9 (Sugar Belle®) as the most promising variety. These trees are vigorous and relatively tolerant to HLB and *Alternaria*. Mature trees can reach 20 feet in height, depending on the rootstock. This makes regular pruning, hedging, and topping challenging but imperative to maximize light exposure and achieve good yield. Fruit matures from late November to early January and may be seedy, depending on cross-pollination incidence. Fruit is semi-easy peeling (peel is tighter toward the bottom of the fruit), and retention is good and well past normal market maturity. Some growers have reported fruit softening in trees, although the severity of this problem seems to vary every year and OTC trunk injections seem to improve fruit quality. It appears to be more prevalent in fruit from trees with a heavy load, and fruit softening is more common in the bottom end of the fruit, when the peel is thinner. HLB-affected fruit can also become misshapen later in the season, affecting fresh market packout. Growers in north Florida do not have the same problem as those in central and south Florida. Efforts are underway to understand and alleviate this fruit disorder, with OTC trunk injection helping, although not on a whole-tree level. Sugar Belle® has exceptional fruit quality (over 15 Brix some years), with low limonin after processing, which is an important trait for juice processing. Titratable acidity can be rather high (up to 1.2%.

Tango, an irradiated mandarin, is an excellent low-seeded (virtually seedless) variety with good internal color. Compared with Early Pride, Tango performs better in terms of HLB tolerance. Fruit matures in December but does not degreen well, and the response to postharvest ethylene is poor if not enough chilling hours accumulate during the season, especially in central and south Florida. Growers in north Florida do not seem to have major problems with coloration of this variety. However, Tango has had a problem with Brix at multiple locations in central Florida. One of the newest varieties in the UF/IFAS germplasm of fresh-fruit varieties is Marathon mandarin, which is seedless and easy to peel. Marathon obtained its name from its exceptional ability to hold long on the tree. Its fruit maturity can come relatively early. Marathon has shown exceptional HLB tolerance for tree health in a demonstration block on sour orange rootstock at the UF/IFAS CREC, but granulation is a problem.

Other commercial protected varieties managed by the NVDMC with interest for the fresh market include Roe tangerine, Mandalate, and UF-Glow. Roe, like Bingo, is low-seeded and easy peeling, resembles a traditional Florida tangerine, which matures around Thanksgiving, and has good tree retention (holding through January), but it requires clipping. Mandalate is a seedless, easy-to-peel, and juicy Mediterranean mandarin that shows some tolerance to HLB and is especially interesting for northern Florida counties in the Panhandle and Big Bend regions with climatic characteristics more like the Mediterranean. UF-Glow is also seedless and easy peeling. An early variety that matures by mid-October, it is self-fertile and cold tolerant, and it shows some HLB tolerance.

Web Addresses for Links

DPI Citrus Budwood Annual Report: https://ccmedia.fdacs.gov/content/download/120276/file/24-25-annual-budwood-report-final.pdf

UF/IFAS publication SP248, "Florida Citrus Rootstock Selection Guide": https://ask.ifas.ufl.edu/publication/HS1260

Florida Foundation Seed Producers, Inc. (FFSP), Citrus Rootstocks: https://ffsp.net/varieties/citrus/citrus-rootstocks/

NVDMC Varieties: https://nvdmc.org/nvdmc-varieties/

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2026–2029 Florida Citrus Production Guide: Grove Planning and Establishment[1]

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Main Points

- Plan all aspects of a new planting in coordination with your management program.
- Prepare soil and irrigation/fertigation infrastructure before planting.
- Use only good-quality plant material for planting.
- Careful planning prior to grove establishment will result in higher productivity and profitability.

"It's complicated."

Every choice in grove management affects other aspects of management, and many of these decisions must be made even before the grove is planted. For instance, decisions on planting density will have to consider the rootstock and the scion variety, because plant vigor will determine how quickly the space between plants will be filled. Because these choices are irreversible for the lifetime of the planting, each of them should be considered together, fitting each piece while considering the whole puzzle. This chapter addresses the most important decisions that should be made before and immediately after planting, and it refers to other chapters with more detailed information on specific management topics. The most important factors before planting fall into (1) site selection and (2) grove planning and preparation. Planting and early tree care are also essential to long-term grove success. Coordinated planning of all aspects of grove establishment and careful planting establishment can set you up for success and reduce frustrations in the future.

Site Selection

Every potential site has some challenges when establishing a new grove. In this section, we will discuss the most important factors to consider when selecting a site, including pest and disease history, soil type, and quality of available water for irrigation.

Pest and Disease History

Soilborne pests tend to persist over many years. Make sure you know whether the site has a history of phytophthora or *Diaprepes* root weevil. Poorly drained soils are more likely to have phytophthora, even if there are no records for the site. When sites are available that do not have histories of these problems, it is better to choose those sites. In the site preparation section, this publication will discuss measures to manage sites with a history of soilborne pests or diseases for when you cannot choose another site.

Management of neighboring groves must also be considered because it can greatly affect disease pressure, especially from HLB. If neighboring groves are managed poorly, high psyllid populations will likely be present in your grove at most times during the year. Having no citrus nearby or having well-managed groves with active psyllid management is better.

Soil Fertility

Several soil characteristics affect soil fertility. These include pH, organic matter, and cation exchange capacity. Although most native Florida soils used for citrus plantings historically had a low pH in the upper 6 inches, at present many have a higher pH. This is because most irrigation water is alkaline and raises the pH over time in soils that have been irrigated for crop production. The optimum pH of soil and irrigation water is between 6.0 and 6.5.

Cation exchange capacity (CEC) is a measure of how well the soil holds most mineral nutrients. Most soils used for citrus production in Florida are sandy and have a very low CEC, usually between 0 and 2 (meq per 100 g soil). Below we will discuss approaches to managing low-CEC soils. Soil organic matter affects both nutrient- and moisture-holding properties of the soil. Most soils in Florida's citrus production areas have low organic matter (between 0% and 1%). A higher content of soil organic matter is generally preferred, because in most cases it will lead to higher CEC and water-holding capacity.

Soil Moisture

It can be difficult to achieve a happy medium of soil moisture in Florida soils. Upper layers of sand drain rapidly after rain or irrigation, leading to water deficits. However, high water tables or clay pans with poor drainage may result in waterlogging in the deeper layers of the soil. Waterlogging reduces the amount of oxygen that is available for root respiration and therefore inhibits root growth. In addition, growth of harmful microbes may occur in this oxygen-limited environment. If these conditions last for longer than 72 hours, root death is likely to occur. Root injury and senescence also open up infection sites for soilborne pathogens, such as phytophthora, which can further reduce root growth. Information on the history of flooding in the selected site will help assess whether waterlogging is likely to occur. In flood-prone regions, it is imperative to raise beds and establish a drainage system consisting of furrows, ditches, or tile drains.

Water Access and Quality

Access to water for irrigation is essential for citrus production in Florida. The site must have permits for well or surface-water pumps. Additionally, pump volume capacity must meet the maximum volume needed for the planting. Chapter 13, "Irrigation Management of Citrus Trees," of this guide provides more information on determining the volume of water needed to irrigate the area supplied by the available pumps. Irrigation output capacity is especially important in areas where irrigation is used for freeze protection. If sufficient water volumes cannot be delivered during the freeze, the system will fail. Consider the available infrastructure when choosing the site.

The quality of the water available for irrigation is as important as the available quantity. The best-quality water should not be alkaline nor contain high levels of bicarbonates. The specific concentration at which bicarbonates begin to affect citrus root growth is not known, but lower concentrations should be preferred over higher concentrations. Some evidence suggests that concentrations higher than 100 ppm of bicarbonates will negatively affect root growth. Any grower using non-surface irrigation water should consider approaches to remediate bicarbonate levels.

Weather — Freeze Risk

When freezes occur, they can result in great economic losses and set a grove back by years in terms of production. The risk of freezing temperatures is the major reason for the expansion of citrus production areas southward since their initial establishment in northern Florida. The history of freezes is a good way of understanding the future risk of freeze events in a particular location. Most freezes in Florida are advective, meaning they result from cold air that moves in fronts from the North. These freezes pose regional risks, but the risk is higher farther north. Sites close to a large body of water may have some relief from an advective freeze if they are on the leeward side, because the water will warm the cold air as it crosses. However, some freeze events are convective, which means that they result from warm air dissipating upward as colder air settles. In a convective freeze, topography makes all the difference. Lower-lying areas between hills are more likely to accumulate cold air in frost pockets and are therefore more prone to freezes than sites that are elevated above their surroundings. Especially in northern production areas, frost pockets should be anticipated and adequately prepared to avoid major crop losses. The risk of freezing should be considered when choosing the planting site, as well as when choosing rootstock and scion varieties and irrigation systems. See chapter 19, "Citrus Cold Protection," for more details.

Grove Planning and Preparation

No site is perfect. In this section, we discuss ways to overcome challenges presented by a selected site as well as approaches to reduce risks and improve productivity.

Grove Design

Before the site is prepared and the irrigation system is installed, you should consider tree spacing and orientation, because these factors can greatly affect the profitability of a planting. Sunlight is the source of energy for tree and fruit growth; therefore, a grove should be designed so that the tree canopies capture sunlight most efficiently. Tree spacing should be based on the expected vigor of the scion/rootstock combination and the expected lifespan of the grove. Tree rows oriented north to south will maximize sunlight interception. However, row orientation may also depend on the row length and the direction of water drainage. A good grove design results in healthier, more productive trees.

Spacing between rows is a question of infrastructure. Rows need to allow enough space for a tractor to pass through without harming the trees when they are mature. Typically, row spacing is 18–22 feet. This allows enough space for an 8-foot-wide tractor to pass between trees with 10- to 14-foot canopy widths. The between-row spacing should be as narrow as your equipment allows. Anything wider than necessary will result in fewer plants per acre and thus fewer boxes of fruit per acre. Within rows, growers typically plant 8–12 ft apart. A spacing of 18 feet between rows and 8 feet within rows allows for 302 trees per acre, whereas a spacing of 22 feet between rows and 12 feet within rows only allows for 165 trees per acre. Within this range, climate, soil, scion variety, influence of rootstock on tree vigor, and expected disease pressure should be considered. Although there are few studies comparing planting densities with currently planted varieties in Florida, these studies have indicated that higher-density plantings achieve higher yields in the first 6 years of a planting under HLB pressure. In general, groves planted at higher density provide earlier returns than groves planted at lower densities, though they yield less on a per-tree basis at maturity and may require more pruning. Because the expected life span of a tree is considerably shorter under the present endemic conditions of HLB, in combination with reduced yields of infected trees over time, maximizing yield during the early production years is essential.

Pest History

It is best to avoid sites with a history of *Diaprepes* root weevil or phytophthora. If this is not possible, take measures to minimize the effects of this pest-disease complex. Generally, phytophthora problems are intensified in poorly drained soils. Therefore, improving drainage will reduce disease pressure (see “Soil Moisture,” below). If the selected site has a history of phytophthora or *Diaprepes* root weevil, choosing the proper rootstock is essential. Several suitable rootstock options are available; see the *Florida Citrus Rootstock Selection Guide* for more information.

Soil Fertility

One of the major fertility challenges in Florida citrus soils is high pH. Adjustment of the pH to the optimal range of 5.8–6.5 is recommended, because at a higher pH, availability of some nutrients is limited. However, soils that have high pH will tend to be high for a long time. Therefore, if the pH of the planting begins high, you should consider planting with one of the few rootstocks that tolerate high pH.

Florida citrus soils often require adjustment prior to planting. Our soils often have high pH accompanied by low nutrient-holding capacity. Preplanting applications of acidifying fertilizers, such as ammonium sulfate, can help lower the soil pH. Additionally, acid injection systems to acidify irrigation water should be considered. For more information, see chapter 13, "Irrigation Management of Citrus Trees," and chapter 14, "Nutrition Management for Citrus Trees."

In addition to pH adjustment, preplant practices that increase or preserve soil organic matter can improve soil fertility during establishment. These practices include the planting of cover crops and using minimal tillage to prepare the ground for planting, if additional shaping such as bedding is not required. Although costly, additions of composted materials increase soil fertility and therefore tree growth and productivity of newly planted trees, because they help maintain a balanced pH and improve nutrient-holding capacity. For further information about cover crops, SARE offers a free, well-documented cover crop manual for download.

Soil Moisture

Excessive soil moisture can be more damaging to citrus trees than drought. More than 3 days of root zone flooding will cause severe damage to the roots, followed by tree decline and possible death of trees. Sites in the southern and coastal areas of the state referred to as flatwoods are poorly drained and therefore more prone to flooding than other parts of the state. To improve drainage in poorly drained areas, trees are usually planted on double-row raised beds. The crown of raised beds should be 3–4 feet above the bottom of the furrow. Drainage systems consist of water furrows, ditches, tile drains if needed, and a perimeter ditch to remove excess water. The drainage system in the flatwoods should be designed to remove approximately 4 inches of water per day. Drainage is usually adequate in the sandy soils of the central Florida ridge, and these groves usually do not require bedding or additional drainage measures.

Because of seasonal prolonged periods without adequate rainfall, in combination with the predominantly sandy soils in Florida’s citrus production areas, installation of an irrigation system is required prior to planting. Microirrigation, including low-volume emitters such as drippers or microsprinklers, is preferred over other systems because it is more cost-effective and water-use efficient than traditional sprinkler systems. Microirrigation systems are easily automated, operate at lower pressures, and hence use less energy. Microsprinkler systems can be engineered to offer some degree of cold protection by installing one emitter per tree and using additional “spaghetti” tubing to hang the emitter in the lower canopy when there is a threat of a freeze. Compared to overhead irrigation, microirrigation also reduces incidence of diseases that thrive in a moist environment by not wetting the canopy.

The goal of designing an irrigation system is to apply the water uniformly across the grove, improve water-use efficiency, and minimize water losses to evaporation, runoff, or drainage below the root zone. Uniform application means that each tree receives the same amount of water. Water-use efficiency means that the plants receive just enough water to grow optimally. This will also minimize nutrient leaching. When designing an irrigation system to optimize water-use efficiency, emitter type and strategies to schedule and monitor irrigation need to be considered. For details, see chapter 13, "Irrigation Management of Citrus Trees."

Nutrient management should also be considered when selecting an irrigation system. Injection systems can allow you to acidify the soil through acid injection or to fertilize through the irrigation system (“fertigation”). There are other options to reduce soil pH, including acid-forming fertilizers and elemental sulfur. However, for sites with high soil and water pH, an injection system may result in a rapid drop in pH. Injection systems should be installed before planting.

Water Supply

When planning for an adequate water supply, well capacity and permits for any additional wells need to be considered. Well capacity should be calculated for the maximum volume needed, whether for cold protection or for irrigation. In the dry season, calculations need to include the estimated volume of water lost to total daily evapotranspiration of the crop per acre. For cold protection, calculations need to include the maximum volume needed to ensure the crop remains above freezing temperature. See chapter 13, "Irrigation Management of Citrus Trees," and chapter 19, "Citrus Cold Protection," for how to calculate these values. Conduct these calculations before designing the irrigation system to avoid a situation where the system cannot deliver the amount of water needed to keep trees alive and productive.

Variety Selection

Both scion and rootstock selection should consider soil type, expected disease pressure, and desired planting density. Choosing the rootstock that is best adapted to the conditions of the soil in the selected site is essential for maximum productivity; the rootstock will influence tree size, fruit quality, and yield. If you intend to have a high-density planting, small-to-mid-size-inducing rootstocks should be preferred over more vigorous rootstocks. Small-to-mid-size-inducing rootstocks should also be preferred if fruit quality is of concern. Similarly, vigorous scion varieties such as Sugar Belle® are not well suited to high-density planting. Vigorous varieties will generally require more pruning, especially when planted at a higher density. For more information, see chapter 11, "Rootstock and Scion Selection."

Planting

Sourcing High-Quality Trees

High-quality nursery trees are essential for maximum productivity. Citrus growers should purchase only from certified nurseries to obtain healthy, uniform, and true-to-type trees. Healthy trees should have good foliage and a well-developed root system. Roots should not be pot-bound. Trees should be of good vigor with a mature woody stem (larger than ⅜ inch in diameter) to ensure survival and rapid growth after planting. Trees with mature flush are preferred over trees with tender new flush because the new flush may compete with roots for available resources. A good sign of tree health is how long the leaves have remained on the tree; the lower in the canopy the leaves have held, the more likely the plant has not had a debilitating stress while in the nursery.

The traditional method of rootstock propagation is by seed. Other ways of propagating rootstocks are by cuttings or tissue culture. These propagation methods are important when the demand for popular rootstocks is higher than the seed supply. Some of the newer rootstocks also need to be propagated by cuttings or tissue culture because they do not produce true-to-type plants when grown from seeds. For more information on rootstock propagation see UF/IFAS publication HS1309, "Citrus Propagation," and chapter 6 of the *Citrus Nursery Production Guide*.

Tissue culture and cutting-propagated rootstocks lack the typical taproot system of seed-propagated rootstocks. Instead, they have an adventitious-type root system with multiple smaller-diameter roots arising from the base of the stem. There have been concerns that the different root systems of non-seed-propagated rootstocks could render the grafted tree inferior in growth and survival. However, field trials at different commercial production sites have found no major differences in growth among trees on rootstocks propagated by seed, cutting, or tissue culture. Furthermore, excavation studies demonstrated that any initial differences in root architecture disappear during the early years of field growth. This is because the taproot of seed-propagated rootstocks ceases to grow after field planting and is replaced by lateral roots, which anchor the tree in the ground. Most of the root system in Florida citrus is limited to the upper 2 feet of the soil regardless of the propagation method. For more information on rootstock propagation, see chapter 6 of the *Citrus Nursery Production Guide*.

Planting Day

Young citrus trees can be planted during most times of the year. However, in regions where there is potential for freezing temperatures, planting should be delayed until spring. Ideally, trees should be planted on the same day they are received. Under no circumstances should the roots be allowed to dry out. To minimize root desiccation and damage, trees should be kept shaded and moist until they are planted. Trees should be removed from the container, and roots should be inspected. If circling roots are not removed, they will continue circling and restrict growth and therefore productivity of the tree. In some cases, root girdling can occur, resulting in stunted trees. Thus, pot-bound roots should be removed or untangled prior to planting. If roots are moderately pot-bound, use a clean and sharp knife to make several vertical slashes about one inch deep through the root ball to encourage new root growth. These slashes will also allow the roots to interface more closely with the soil in the planting hole. If planting severely pot-bound plants cannot be avoided, it is advisable to cut off the outer ½ inch of the root ball. Alternatively, some of the outer roots may be exposed by pulling them so they protrude from the root ball and extend into the soil in which the tree is planted. If roots are left in a pot-bound state, trees will not grow quickly, and growth may be hampered for the life of the trees. Trees with irregular root systems should not be planted, because this indicates other problems, such as phytophthora. For more information, refer to chapter 16, "Root Health Management."

Other Details to Consider at Planting

Plastic tree tags from nurseries may girdle a tree if they remain on the trunk and become buried in the soil during planting. Remove tree tags or ensure they remain aboveground, where they will usually deteriorate over time and not girdle the tree. Tree damage can also occur from metal tree stakes. Close contact of stakes with the tree trunk can lead to injury and pathogen infection and therefore restrict tree growth.

Caring for Young Trees

Because of Florida's sandy soils, high temperatures, and frequent rainfall, young tree care requires regular fertilization, insect and disease management, and weed control. The primary objective during the first few years is rapid development of the tree canopy. Young trees are more sensitive and more attractive to pests than mature trees due to high levels of vegetative growth. Monitoring insect pests and diseases in new plantings is essential, and adequate control is imperative. Weed management is especially important in newly established groves to reduce competition and ensure rapid tree growth. Application rates of crop protection chemicals need to be adjusted based on the size of the trees. Proper irrigation and nutrition are also critical factors to ensure the rapid growth of young trees. Minor selective pruning (especially of water sprouts) can be beneficial during the first two years to develop good canopy architecture. The goal of such pruning should be to develop a canopy that allows light penetration into the center of the canopy.

Weed Control

Weeds compete with young citrus trees for water, nutrients, soil-applied pesticides, and sunlight, and they should be controlled both before planting and during the early years of growth. If herbicides with residual activity are used prior to planting, they should be applied at least 30 days in advance of planting to avoid negative impacts on the young trees. Herbicides should always be applied at recommended rates, which are lower for young trees. Not all herbicides are suitable for young trees; be sure to read labels carefully for restrictions. To minimize herbicide contact to young trees, using tree wraps is advisable. When using wraps, be sure to monitor the space between trunk and wrap for ants or other pests that may damage the tree. For more information, refer to chapter 42, "Weeds."

Suckering

Rootstock sprouts, called “suckers,” should be removed during the growing season before the sprouts become large and compete with the scion shoots. Young trees require regular sprout removal. Tree wraps usually reduce the need for removal.

Irrigation and Drainage

Because of their smaller root systems, young citrus trees require frequent but moderate irrigation for survival and proper growth. Irrigation systems should be in place before planting. Trees should be monitored frequently to be certain that they are receiving sufficient but not excessive amounts of water. For more information, refer to chapter 13, "Irrigation Management of Citrus Trees."

Fertilization

Regular fertilization of young trees is imperative to promote vigorous vegetative growth that rapidly produces a canopy with high fruit-bearing capacity. Applying fertilizer in several small doses is more efficient than applying fertilizer in a few large doses because it ensures constant nutrient availability and reduces losses due to leaching. Frequent application of water-soluble fertilizers with irrigation water (fertigation) or controlled-release fertilizers can greatly increase nutrient-use efficiency. The needed quantities of water and fertilizers increase each year as the trees grow and should be based on tree size and canopy density. Great care must be taken to ensure that proper rates of fertilizer materials are dispensed to prevent nutritional deficiencies or toxicities. It is not recommended to place granular fertilizer in the planting hole, because direct contact with the roots may burn them and cause root deformations. For more information, refer to chapter 14, "Nutrition Management of Citrus Trees."

Pest Control

Because young trees flush more frequently than mature trees, they are more attractive and sensitive to pests. Therefore, special care is needed to control Asian citrus psyllids and leafminers to reduce leaf damage, the severity of citrus canker, and the incidence of HLB. Maintaining young trees free of citrus canker and HLB is of utmost importance, because trees that become infected during the early years will never become productive. Relying solely on foliar-applied contact insecticides for young trees is not a good strategy.

Non-insecticidal approaches may also be beneficial. These include kaolin particle films and individual protective covers (IPCs). Particle films are sprayable materials that reduce psyllid populations and can enhance growth. IPCs are fine-meshed pest exclusion nets that cover individual trees, preventing psyllid colonization and reducing the incidence of citrus canker. Kaolin particle films may be used in conjunction with insecticides. IPCS, on the other hand, are not always compatible with insecticide applications, but they are very effective at preventing infection with HLB. They also provide a better environment for growth, as IPCs provide mild shade and keep some air moisture trapped in the canopy. For more information on the management of citrus psyllids and leafminers, refer to the pest management sections in this guide. Under the current HLB-endemic conditions in Florida, trees are very likely to become infected, but any practice that prevents or delays infection will improve productivity and increase economic returns in the long term.

Web Addresses for Links

Citrus Nursery Production Guide, chapter 6: https://edis.ifas.ufl.edu/hs1329

UF/IFAS publication HS1309, "Citrus Propagation": https://edis.ifas.ufl.edu/publication/HS1309

Florida Citrus Rootstock Selection Guide: https://ask.ifas.ufl.edu/publication/HS1260

SARE, *Managing Cover Crops Profitably*, 3rd Edition: https://www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition

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2026–2029 Florida Citrus Production Guide: Irrigation Management of Citrus Trees[1]

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The chapter on irrigation management of citrus is largely taken from guidelines on trees prior to citrus greening, provided in chapter 9 of Nutrition of Florida Citrus Trees. A section has been added to cover recent findings on water use of trees affected by citrus greening and the impact this has on irrigation management considerations.

Water Supply

Water is a limiting factor in Florida citrus production during the majority of the year because of the low water-holding capacity of our sandy soils and the nonuniform distribution of rainfall. In Florida, most rainfall occurs from June through September, but rainfall is usually scarce from February to May. The latter period coincides with the critical stages of leaf expansion, flowering, fruit set, fruit enlargement, and the onset of natural fruit drop in late-maturing varieties, and additional irrigation is necessary to reduce the negative effects of water stress. Adequate irrigation management is key to optimize water use and increase crop yield. Diurnal fluctuations of water use need to be considered because they result in variation in fruit retention and percent juice content. Several weather-, soil-, and plant-based methods are available for irrigation management. The most-used methods rely on weather stations to calculate evapotranspiration (ET), which is the combination of water lost by plant transpiration and removal of water from soils and wet surfaces by evaporation, and soil moisture (SM), which indicates the water availability status of the soil for plant uptake.

Allowable Soil Water Depletion

As soil dries out, water becomes increasingly difficult for trees to uptake, which can eventually cause water stress. Tree health and yield will suffer if the soil is allowed to become too dry. Before huanglongbing (HLB) was found in Florida in 2005, it was recommended that maximum soil water depletion should not exceed 25% to 33% of available water from February to June to provide adequate water for flowering, fruit set, and vegetative growth. Once the rainy season starts, recommendations stated that maximum depletion could be increased to 50% to 66%. This additional allowable depletion increases the capacity of the soil to hold rainfall without leaching nutrients or any soil-applied chemicals. The same depletion in the fall and winter months will save water without reduction in yield. The soil water depletion of the available soil water is calculated as the difference between moisture contents at field capacity and permanent wilting point. Field capacity is the water content at which the initial rapid gravity drainage ceases or becomes negligible, considered as 10 centibar for sandy soils. The permanent wilting point is considered the soil water content at 15 bar (or 1500 centibar; a higher number means drier soil condition). Under Florida conditions, field capacity is assumed to be in the range of 8% to 12%, and wilting point is assumed to be 2% to 3%. Research has shown that water uptake by healthy citrus trees declines as the soil dries, resulting in less than half as much water being taken up at an available water content of about 50%. Recent research has further indicated that distributing irrigation across the week with more frequency and less volume increases water use efficiency and improves water uptake by HLB-affected trees, thus improving yield. For example, if 3 hours/week of water are required, irrigation should be distributed in daily 30-minute applications for five days.

Irrigation Scheduling

Current UF/IFAS citrus irrigation recommendations estimate citrus tree water requirements for mature trees based on data collected prior to the introduction of HLB into Florida. Citrus trees affected by HLB are known to lose substantial foliage and root mass depending on disease severity, thus negatively influencing water and nutrient uptake.

The commonly used methods of irrigation management include water budgeting, soil water measurement, and smartphone apps. These irrigation scheduling methods will be discussed in the following sections.

Water Budgeting

Experience or the calendar method can provide a reasonably good irrigation schedule, but they are not accurate enough to maximize water-use efficiency and prevent nutrient leaching. The calendar method of irrigation scheduling requires the user to obtain daily evapotranspiration (ET) from weather data sources such as the Florida Automated Weather Network (FAWN), accessible at https://fawn.ifas.ufl.edu. The daily ET is then multiplied by a crop coefficient (K_c) based on the time of year (Figure 1) to determine daily estimated water loss. This amount is then subtracted from the estimated soil moisture from the previous day. Reference ET and convenient irrigation scheduling management tools for all Florida citrus production regions can be found on the FAWN website mentioned above.

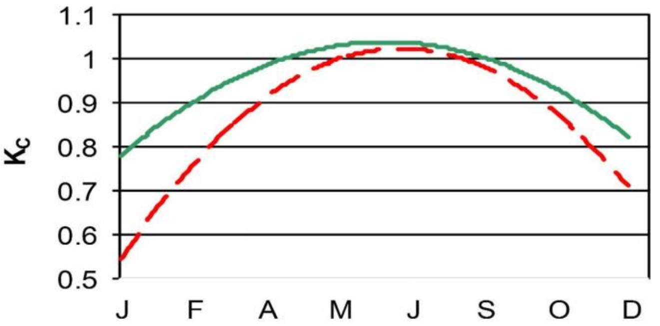

Figure 1. Estimated crop coefficient, or K_c, for mature (solid green line) and young (dashed red line) trees not affected by huanglongbing.
Credit: UF/IFAS

Soil Water Measurement

The use of soil moisture sensors (Figure 2) improves accuracy in determining irrigation timing and amount because they quantitatively measure changes in soil water status. These sensors may be fixed in one location, portable, or handheld. They may measure soil water at one depth or at multiple depths, in the case of soil moisture probes. General categories include time-domain reflectometry (TDR) and time-domain transmissivity (TDT) probes and frequency domain reflectometry (FDR) capacitance probes.

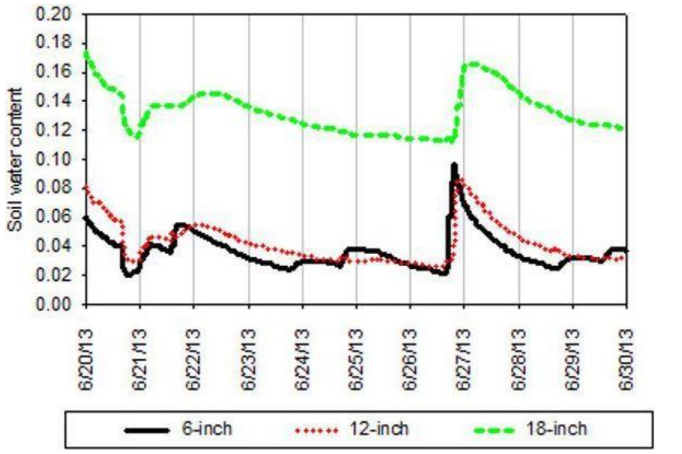

Figure 2. Continuous monitoring of soil moisture at 6-, 12-, and 18-inch depths in the soil by a multilevel capacitance probe installed in the root zone of a mature citrus tree.
Credit: UF/IFAS

Considerations when using soil moisture sensors to schedule irrigation include the following:

- Knowing the soil water-holding capacity (or soil type) and tree root zone depth.
- Placing sensors where the majority of roots are located (typically in the top 12 inches), such as at the dripline of the tree, in an area inside of the microsprinkler or dripper wet pattern and no more than 1 foot from the canopy area.
- Using multiple sensors, both across the grove and with depth, to fully characterize the tree root zone. At least two sensors should be installed in the top 12 inches of soil.
- Basing irrigation on the soil depth containing the greatest root density.
- Managing root zone soil moisture between field capacity and the maximum allowable water depletion (one-fourth to two-thirds depletion, depending on the time of year).

Considerations for soil moisture sensor installation and management can be found in UF/IFAS publication AE551, "Common Questions When Using Soil Moisture Sensors for Citrus and Other Fruit Trees."

Mobile Apps

Mobile smart devices (e.g., smartphones, tablets) are convenient and easy to use, making them ideal for disseminating information on a regular basis with real-time data. That is why UF/IFAS developed the Citrus SmartIrrigation app, which is free and available to download in the App Store and Play Store at no cost. The app can also be used directly from the FAWN website. A quick video tutorial for installation and use is available at https://www.youtube.com/watch?v=8st9riCtyAE. Similarly, FAWN developed an app for the iPhone and

Android platforms, provided as a cost share from the Florida Department of Agriculture and Consumer Services, which allows users to view data from grower-owned weather stations on their smartphones in much the same way that the data can be viewed on the FAWN webpage. By using the app instead of a set time-based schedule for irrigation, users achieve accurate irrigation. The irrigation scheduling app has the potential to reduce water and fertilizer use, resulting in reduced irrigation and fertilizer costs and possibly reduced nutrient leaching.

Figure 3. Information required to schedule irrigation using the Citrus SmartIrrigation app.
Credit: UF/IFAS

Irrigation Strategies to Improve Nutrient Uptake and Reduce Leaching

Developing an irrigation strategy to reduce nutrient leaching has the objective of not applying more water than the root zone can hold. Considering the low water-holding capacity of citrus grove soils, this objective is very challenging even for the most experienced and diligent irrigation managers. The major questions to be answered in this procedure are:

- How much water can be held across the root zone?
- What is the maximum irrigation system run time before leaching occurs?

Assumptions are:

- Root depth for HLB-affected trees has been reduced to about 1 foot on both the ridge and flatwoods.
- Diurnal demand for water varies during the day as temperature and relative humidity fluctuate.

Example

We have a central ridge citrus grove with the following characteristics:

- Tree spacing — 10 ft in-row × 20 ft between rows = 218 trees/acre.
- Tree canopy diameter — 15 ft.
- Root zone depth — 1 ft.
- One 16 GPH microsprinkler per tree with a 16-ft diameter wetted pattern.
- The citrus root zone is continuous from tree to tree, existing both inside and outside of the wetted pattern.
- The irrigated system wets approximately 60% of the total root zone (Figure 4A).
- Nutrient leaching risk in this grove is higher within the wetted pattern due to potential overirrigation, plus the fact that most fertilizers are applied to that zone (Figure 4B). Irrigation managers can control this risk by controlling irrigation using soil moisture sensors or the Citrus SmartIrrigation app.

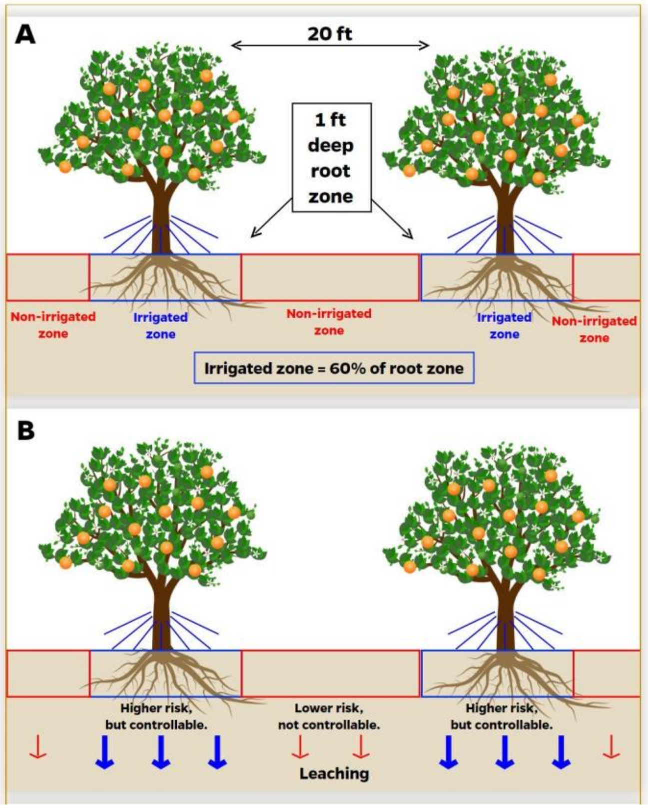

Figure 4. Irrigated and nonirrigated zones in a citrus grove have different leaching potentials that depend on irrigation scheduling and fertilizer placement.
Credit: UF/IFAS

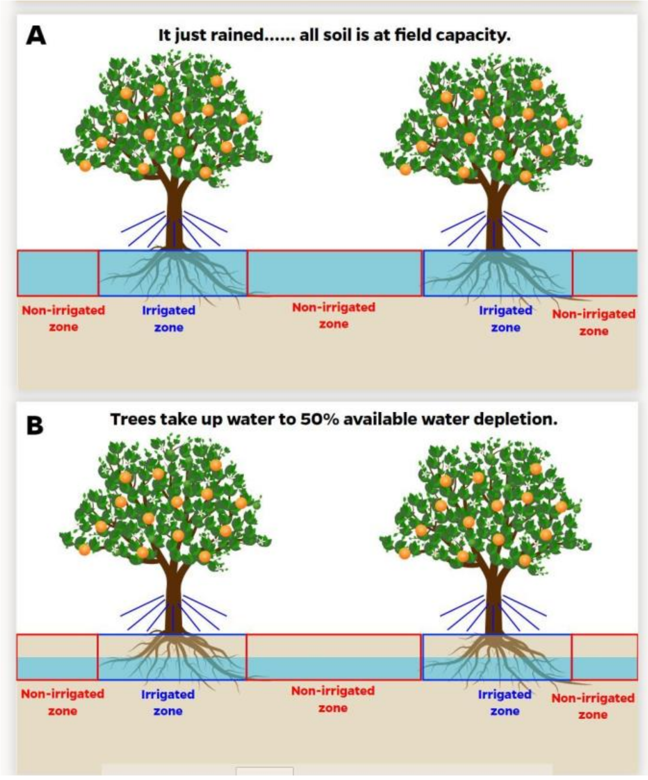

Figure 5. (A) The citrus grove at field capacity soil water content (time = 0). (B) The citrus grove several days later, after half of the available water has been removed from the root zone. Note that water extraction has occurred from both the irrigated and nonirrigated zones.
Credit: UF/IFAS

This example starts with the entire grove at field capacity moisture content following a heavy rain (Figure 5A). The citrus trees begin to remove water from the soil in response to the atmospheric ET demand. After several days have passed (depending on time of year), the water content in the root zone decreases to 50% of available water capacity (Figure 5B).

At this point, the grove manager turns on the irrigation system and operates it long enough to return the soil in the wetted pattern back to field capacity (Figure 6A). From this point until the next significant rainfall, the manager can only influence the soil water content in the irrigated zone. The water content in the nonirrigated zone rapidly decreases to the point where little to no soil water can be extracted by the trees.

If the grove manager operates the irrigation system too long and applies more water than the soil can hold, water will move beneath citrus tree roots. If water-soluble nutrients like nitrate or potassium are present in the irrigated zone during the irrigation period, a portion will leach (Figure 6B).

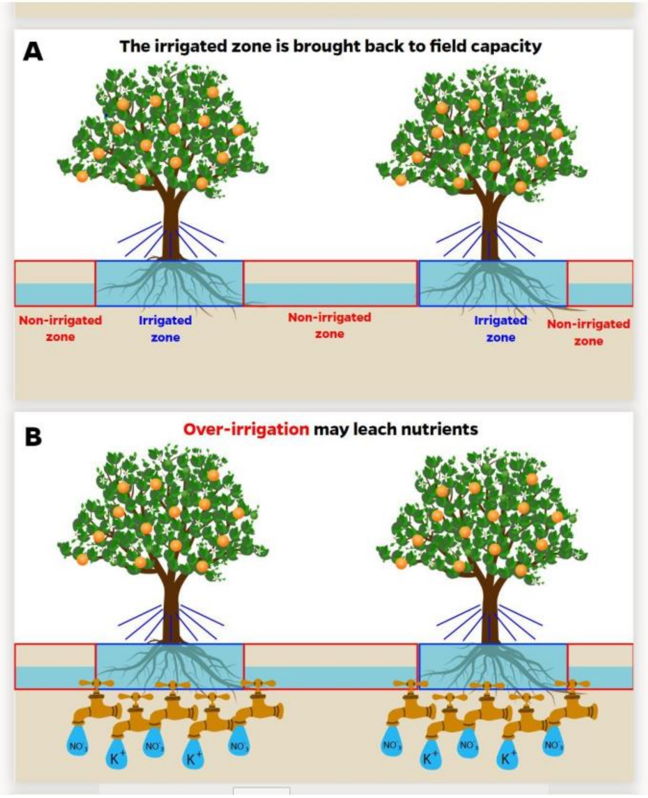

Figure 6. (A) The citrus grove after irrigation returns the wetted zone to field capacity. Note that the nonirrigated zone contains very little available water. (B) Excessive irrigation leaches mobile nutrients like nitrate or potassium.
Credit: UF/IFAS

Central Ridge Soils

How much water can the root zone hold?

- Central Ridge soils — 0.3 to 0.7 in/ft

What is the maximum system run time before leaching occurs?

Calculations are shown below (Table 1) based on daily irrigation schedule.

Calculations — Summer High Water Depletion Schedule

- Volume of water the root zone can hold: 0.6 in/ft × 1 ft deep root zone = 0.6 inches
- Volume of water to refill at maximum depletion: 0.6 in × 10% = 0.06 inches
- Volume of water this represents per tree space: 0.06 in/tree × 1 ft/12 in × (20 ft × 10 ft) × 7.5 gal/ft^3 × 60% coverage = 4.3 gal/tree
- Maximum system run time: 4.3 gal ÷ 16 gal/hr emitter flow rate = 0.27 hr
- Adjust for system irrigation efficiency of 90%: 0.27 hr ÷ 0.9 = 0.3 hr

Therefore, the irrigation system should never be run longer than about 0.3 hours (18 minutes) for any single cycle, provided that the available soil water is at least 10% depleted when the irrigation begins.

Flatwoods Soils

How much water can the root zone hold?

- Flatwoods soils — 0.3 to 1.2 in/ft

What is the maximum system run time before leaching occurs?

Calculations are shown below (Table 2) based on daily irrigation schedule.

Calculations — Summer High Water Depletion Schedule

1. Volume of water the root zone can hold: 0.6 in/ft × 1 ft deep root zone = 0.6 inches
2. Volume of water to refill at maximum depletion: 0.6 in × 30% = 0.18 inches
3. Volume of water this represents per tree space: 0.18 in/tree × 1 ft/12 in × (20 ft x 10 ft) × 7.5 gal/ft^3 × 60% coverage = 9 gal/tree
4. Maximum system run time: 9 gal ÷ 16 gal/hr emitter flow rate = 0.56 hr
5. Adjust for system irrigation efficiency of 90%: 0.56 hr ÷ 0.9 = 0.62 hr

Therefore, the irrigation system should never be run longer than about 0.6 hours (36 minutes) for any single cycle provided that the available soil water is at least 30% depleted when the irrigation begins.

Irrigation Management Considerations for HLB-Affected Trees

With HLB, irrigation scheduling is becoming more important than ever, because water stress can negatively affect tree growth and crop production.

Other benefits of proper irrigation scheduling include reduced loss of nutrients through leaching due to excess water applications and reduced pollution of groundwater or surface waters. Three studies were conducted in Florida from 2011 to 2015 with the objective of determining (1) the effectiveness of ET-based irrigation scheduling on reduced water use in citrus, (2) irrigation requirements of HLB-affected citrus trees compared with healthy trees, and (3) the effect of irrigation scheduling on productivity of citrus trees affected with HLB.

Results from the first field study indicate water use with soil moisture sensors and ET-based models reduced average monthly water use by approximately 14% of the conventional irrigation practice without reducing yields (see Notes section).

Results from a second study under greenhouse conditions indicated that healthy trees consumed approximately 25% more water than HLB-affected trees (Figure 5). Reduced water uptake by HLB-affected trees resulted in significantly greater soil water content. The relationship between leaf area and water uptake indicated that diseased trees with lower canopy density and corresponding lower leaf area index take up less water and consequently fewer nutrients from the soil. The elevated soil water content may partially explain higher rates of root infection with *Phytophthora* spp. observed in some HLB-affected trees.

The third experiment was conducted in three commercial groves on Ridge and flatwoods soils. Irrigation schedules consisted of current UF/IFAS ET-based recommendations, daily irrigation, and an intermediate schedule, all using the same amount of water on an annual basis. The UF/IFAS schedule was determined weekly using the Citrus Irrigation Scheduler found at the Florida Automated Weather Network (FAWN) website and resulted in irrigation schedules ranging from daily in May to every 10–14 days in the winter months from November to February. Daily irrigation schedules were determined by dividing the UF/IFAS irrigation duration by the number of days between irrigations. “Intermediate” irrigation was half the UF/IFAS interval for half the time. Daily irrigation increased tree water uptake and soil water content compared with Intermediate and UF/IFAS schedules. Daily and intermediate irrigation increased canopy density as measured by leaf area index compared with the UF/IFAS schedule. Fruit drop per square foot under canopy area was lower for daily irrigation schedules in the second year of the study, but yields were similar among all irrigation schedules.

This shows that for HLB-affected trees, **irrigation frequency needs to be increased and amounts of irrigation water decreased to minimize water stress from drought or excess water**, while ensuring optimal water availability in the root zone at all times. In addition, irrigation should be done early in the morning, preferably before 9 a.m., to optimize water uptake. Growers should seek to maintain soil moisture in the root zone (top 12 inches for both ridge and flatwoods soils) using soil moisture sensors or irrigation apps. The SmartIrrigation app provides the option of daily irrigation schedules. As noted above, HLB-affected trees with lower canopies use less water than do healthy trees. Therefore, if the irrigation scheduling app is used, the irrigation time should be reduced by 10% to 20%. For example, if the app suggests an irrigation time of 1 hour, this time could be reduced by 6 to 12 minutes for HLB-affected trees.

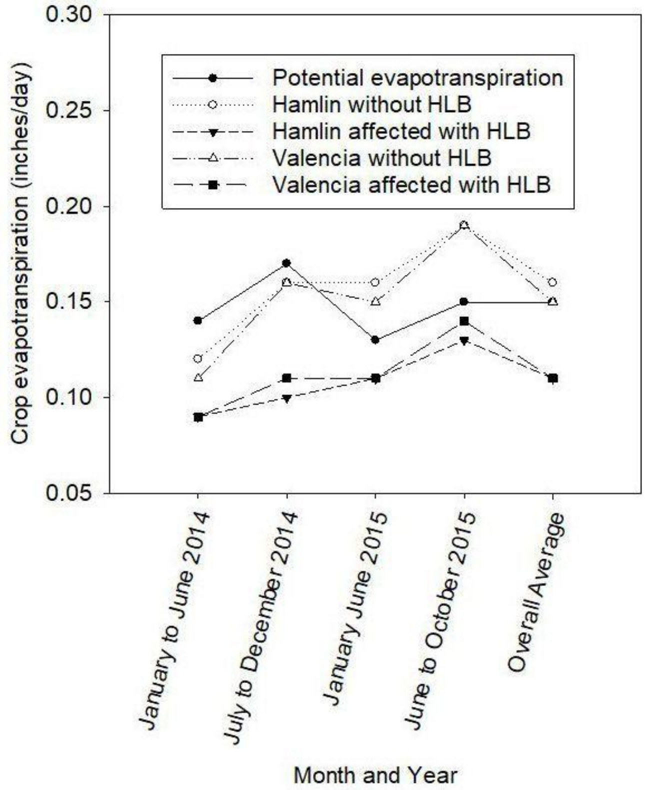

Figure 7. Water use of HLB-affected trees in southwest Florida under greenhouse conditions.
Credit: UF/IFAS

Notes

Figures 4 to 7 were illustrations included in UF/IFAS publication SL253, chapter 9. The illustrations of water content changes in the citrus tree root zone (Figures 5 to 6) do not represent the actual water extraction pattern. The blue shading shows (1) approximately where water extraction occurs beneath the canopy, and (2) the relative soil water content with respect to available soil water-holding capacity.

Conventional irrigation practice for Florida citrus refers to use of microsprinkler irrigation based on replacing the citrus seasonal tree water requirements using Florida Automated Weather Network data.

Web Addresses for Links

Citrus Irrigation Scheduler:
https://fawn.ifas.ufl.edu/tools/irrigation/citrus/scheduler/

UF/IFAS publication AE551, "Common Questions When Using Soil Moisture Sensors for Citrus and Other Fruit Trees": https://edis.ifas.ufl.edu/publication/ae551

Nutrition of Florida Citrus Trees, chapter 9:
https://edis.ifas.ufl.edu/publication/SS676

Table 1. Run time.

Information Needed	In This Example
Soil water-holding capacity	0.6 in/ft
Maximum allowable depletion	10%
Root zone depth	1 ft
Surface area wetted by microsprinklers	60%
Microsprinkler flow rate	16 gal/hr
Tree spacing	10 ft × 20 ft

Table 2. Run time.

Information Needed	In This Example
Soil water-holding capacity	0.6 in/ft
Maximum allowable depletion	30%
Root zone depth	1 ft
Surface area wetted by microsprinklers	60%
Microsprinkler flow rate	16 gal/hr
Tree spacing	10 ft × 20 ft

[1] This document is CPG12, one of a series of the Department of Agronomy, UF/IFAS Extension. Original publication date January 2019. Revised annually. Most recent revision August 2026. Visit the Ask IFAS website at https://ask.ifas.ufl.edu for the currently supported version of this publication.

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2026–2029 Florida Citrus Production Guide: Nutrition Management for Citrus Trees[1]

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The following description of citrus fertilizer uptake, soil and leaf testing, and nutrient recommendations was taken from UF/IFAS publication SL253, *Nutrition of Florida Citrus Trees*, 3rd Edition, edited by Kelly T. Morgan and Davie M. Kadyampakeni.

Fertilizer, Nutrition Uptake, and Yield Response

This section describes the typical citrus yield increase with added fertilizers. The increase in yield with increased fertilizer rates is called the yield response curve. The shape of this curve is similar for a range of crops and conditions (Figure 1).

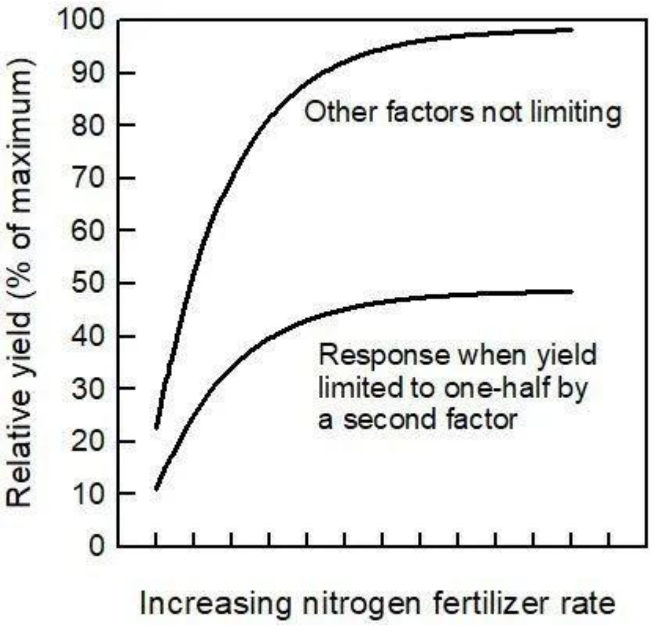

Figure 1. Generic response of healthy citrus yield to N fertilizer rate.
Credit: UF/IFAS

Fertilizer nitrogen (N) is used in this example, but the nature of the response curve is similar for other nutrients. At very low N rates, there is a large increase in yield with each added unit of N. As yield increases, each additional unit of N results in a smaller increase in yield. This smaller response to increasing the fertilizer amount is also referred to as the law of diminishing returns. The two response curves in Figure 1 compare the effect of N rate for two situations: one where the amount of fertilizer nutrients in the soil limits or reduces yield, and another where the yield is limited to one-half by low concentrations of a second fertilizer nutrient. The shapes of the curves are similar, and the rate of N where the slope levels off is only slightly higher for the more productive grove.

The amount of nutrient the crop removes varies from a fraction of a lb/acre for some of the micronutrients to as much as 100 lb/acre of N or K from a high-producing grove. The following numbers were determined for healthy trees prior to HLB entering the state. Micronutrient requirements for HLB-affected citrus trees have been studied, and changes in recommendations for these nutrients are being considered. Research on other nutrients is ongoing and will be provided as studies are completed. For oranges, approximately 0.12 lb N/box is removed with the harvest. Therefore, crop removal ranges from 12 lb N/acre for a 100 box/acre yield to around 100 lb N/acre for a grove producing 800 boxes/acre. Using this same rate of N removal would suggest that groves with reduced yields would be in the range of 24 to 36 lb N/acre. This number is too low for HLB-affected trees, and the rate of removal for HLB-affected trees is being determined.

Nutrient uptake from applied fertilizers is not 100% efficient — that is, not all the fertilizer applied is taken up by the tree, so more nutrients must be applied than the minimum required by the tree. N use efficiency, expressed as lb N removed by the crop divided by lb N applied, ranges from 0.2 to 0.4 in groves with low to moderate yield. For healthy citrus trees, N efficiencies around 0.5 have been observed in groves with a good production record. Application of 200 lb N/acre supplies sufficient N for an 800 box/acre orange yield when N use efficiency is 0.5.

Effect of HLB on Nutrient Management

Nutrient uptake efficiency of HLB-affected trees may be at the low range of nitrogen (N) use efficiency because of root loss (up to 80% depending on HLB severity). Therefore, an HLB-affected orange grove picking 300 boxes per acre and requiring 12 lb of N per 100 boxes would need only 120 lb of N based on lower uptake efficiency of 30%. The UF/IFAS annual recommended range of N applications is 120 to 160 lb per acre for grapefruit and 125 to 240 lb per acre for mature sweet orange trees based on average fruit yield from healthy trees. Lower yields of HLB-affected trees would indicate that current rates should be 120 to 150 lb per acre for oranges. However, recent research has indicated that N requirement for HLB-affected trees should be in the range of 160 to 220 lb per acre because of reduced N use efficiency from root density reductions. Rates of N for grapefruit should be 120 to 160 lb of N per acre per year. Similar amounts of potassium (K) to those for nitrogen would also be required. These experimental results also indicate that frequent multiple applications of these nutrients are preferred instead of fewer applications as recommended for healthy citrus trees prior to HLB.

Leaf Nutrient Analysis

Leaf analysis is a useful tool to detect problems and adjust fertilizer programs for citrus trees because leaf nutrient concentrations are the most accurate indicators of sufficient nutrition of fruit crops. Leaves reflect nutrients taken up from the soil and redistributed throughout the plant, so the deficiency or excess of an element in the soil is often reflected in the leaf analysis. Nutrient deficiency or excess will cause citrus trees to grow poorly and produce lower yields and/or fruit quality. Determining potential nutritional problems should be a routine citrus-growing practice. Quantifying nutrients in trees or soils with leaf and soil analysis eliminates guesswork in adjusting a fertilizer program.

Leaf analysis should include N, phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), manganese (Mn), zinc (Zn), copper (Cu), iron (Fe), and boron (B). Chlorine (Cl) concentration is sufficient under most field conditions, but Cl may become excessive where soil or irrigation water is saline. Similarly, molybdenum (Mo) deficiency or toxicity is rare. The goal in tissue analysis is to adjust fertilization programs such that nutritional problems and their costly consequences from higher costs and lower yields are prevented.

Leaf analysis integrates all the factors that might influence nutrient availability and uptake. It shows the relationship of nutrients to each other. For example, potassium deficiency may result from a lack of K in the soil or from excessive Ca, Mg, or sodium (Na). Similarly, adding N when K is low may result in K deficiency because the increased growth requires more K.

Tissue Analysis

- Determines if the soil is sufficiently supplying the essential nutrients.
- Confirms nutritional deficiencies, toxicities, or imbalances.
- Identifies “hidden” toxicities and deficiencies when visible symptoms do not appear.
- Evaluates the effectiveness of fertilizer programs.
- Provides a way to compare several fertilizer treatments.
- Determines the availability of elements not tested for by other methods.
- Helps in determining interactions between nutrients.

Steps in Leaf Analysis

Citrus trees affected by HLB are typically low to optimum for many nutrients, but sampling guidelines should be followed precisely to ensure that analytical results are meaningful.

Procedures for proper sampling, preparation, and analysis of leaves have been standardized to achieve meaningful comparisons and interpretations. If done correctly, the reliability of the chemical analysis, data interpretation, fertilization recommendations, and adjustment of fertilizer programs will be sound. Therefore, considerable care should be taken from the time leaves are selected for sampling to the time they are received at the laboratory for analysis.

Leaf Sample Timing

- Leaf samples must be taken at the correct time of year because nutrient concentrations within leaves continuously change. As leaves age from spring through fall, N, P, and K concentrations decrease while Ca and Mg increase. However, leaf mineral concentrations are relatively stable from four to six months after emergence in the spring.
- The best time to collect spring flush leaves of this age is July and August. If leaves are sampled later in the season, summer leaf growth can easily be confused with spring growth.

Leaf Sampling Technique

- A sampled citrus grove block or management unit should be no larger than 20 acres. The sampler should ensure that the leaves taken represent the sampled block.
- Each leaf sample should consist of about 100 leaves taken from nonfruiting twigs of 15 to 20 uniform trees of the same variety and rootstock and under the same fertilizer program.

- Use clean paper bags to store the sample. Label them with an identification number that can be referenced when the analytical results are received.
- Avoid immature leaves due to their rapidly changing composition.
- Do not sample abnormal-appearing trees, trees at the edge of the block, or trees at the end of rows, because they may be coated with soil particles and dust or have other problems.
- Do not include diseased, insect-damaged, or dead leaves in a sample.
- Select only one leaf from a shoot and remove it with its petiole (leaf stem).
- Leaves should be washed with soapy water and rinsed with distilled water within 24 hours of sampling.

Analysis and Interpretation

- The laboratory determines the total concentration of each nutrient in the leaf sample. Because total concentration is determined, there should be no difference in leaf analysis results between different laboratories.
- The laboratory usually interprets each result as deficient, low, optimum, high, or excessive, but the citrus grower can also interpret the results using UF/IFAS leaf analysis standards (Table 1). These standards are based on long-term field observations and experiments conducted in different countries with different citrus varieties, rootstocks, and management practices and are used to gauge citrus tree nutrition throughout the world.
- The goal in nutrition management is to maintain leaf nutrient concentrations within the optimum range every year. If the interpretation for a particular nutrient is not optimum, various strategies can be used to address the situation (Table 2).

Soil Nutrient Analysis

Soil analysis measures organic matter content, pH, and extractable nutrients, which are useful in formulating and improving a fertilization program. Soil analysis is particularly useful when conducted for several consecutive years so that trends can be observed.

Similar to leaf analysis, methods to determine the organic matter and soil pH are universal, so results should not differ between laboratories. However, soil nutrient extraction procedures vary from lab to lab. Several accepted chemical procedures exist that remove different amounts of nutrients from the soil because they vary in strength. To draw useful information from soil tests, consistency in the use of a single extraction procedure from year to year is important to avoid confusion when interpreting the amount of nutrients extracted.

A soil extraction procedure does not measure the total amount of nutrients present, nor does it measure the quantity actually available to citrus trees. A perfect extractant would remove nutrients from the soil in amounts that are exactly correlated with the amount available to the plant. Therefore, the utility of a soil testing procedure is how well the extractable values correlate with the amount of nutrients a plant can take up. The process of relating these two quantities is called calibration.

A soil test is only useful if it is calibrated with plant response. Calibration means that as a soil-test value increases, nutrient availability to plants increases in a predictable way (Figure 2). Low soil-test values imply that a crop will respond to fertilization with the particular nutrient. High soil-test values indicate the soil can supply all the plant needs, so no fertilization is required (Figure 3). Caution should be taken on some high soil-test values, such as Ca and P, where all extractable nutrients might not necessarily be available for plant uptake, and supplemental fertilizer might be required.

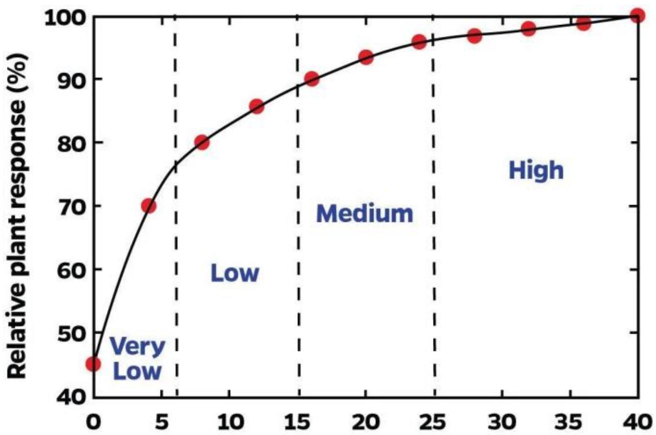

Figure 2. Ideal soil test calibration curve.
Credit: UF/IFAS

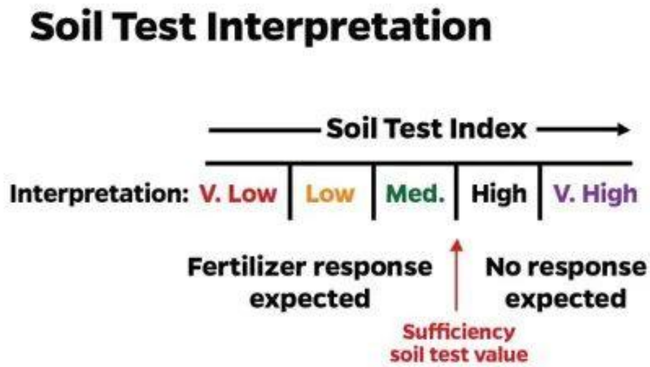

Figure 3. Soil test interpretation categories and their relationship to expected fertilizer response. The probability of response to added fertilizer decreases as soil test index increases.
Credit: UF/IFAS

In Florida, soil testing for mobile, readily leached elements such as N and K has no value. In addition to organic matter and pH, soil testing is important for P, Mg, Ca, and Cu. The UF/IFAS soil-test interpretations for P, K, and Mg using Mehlich-3 extraction were established from experiments conducted for many years (Table 3).

The single most useful soil test in a citrus grove is for pH. Soil pH greatly influences nutrient availability. Some nutrient deficiencies can be avoided by maintaining soil pH between 5.5 and 6.5. Deficiencies or excesses (toxicities) are more likely when the pH is outside this range.

In some cases, soil tests can determine the best way to correct a deficiency identified by leaf analysis. For example, Mg deficiency may result from low soil pH or excessively high soil Ca. Dolomitic lime applications are advised if the pH is too low, but magnesium sulfate is preferred if soil Ca is very high and the soil pH is in the desirable range. If soil Ca is excessive and soil pH is relatively high, then foliar application of magnesium nitrate is recommended. Many citrus soils have become elevated in pH because irrigation water is high in Ca and carbonates from limestone aquifers. In this case, irrigation water acidification or application of soil-acidifying fertilizers is recommended. Soil-acidifying fertilizers are those formulations containing ammonium N sources or sulfur. The use of organic acid can also be considered because the organic acid can help in lowering the soil pH as well as conditioning the soil and improving nutrient uptake. Recent studies have shown that organic acids such as humic and fulvic acid can improve the growth and yield of citrus trees.

Steps in Soil Sampling

Standard procedures for sampling, preparing, and analyzing soil should be followed for meaningful interpretations of the test results and accurate recommendations.

Soil Sample Timing

- In Florida, if soil samples are collected once per year, the best time is at the end of the summer rainy season and prior to fall fertilization (September and October).
- Annual soil samples should be taken at the same time as leaf samples to save time and reduce cost.

Soil Sampling Technique

- The accuracy of soil-test interpretations depends on how well the soil sample represents the grove block or management unit sampled.
- Each soil sample should consist of one soil core taken about 8 inches deep at the dripline of 15 to 20 trees within the area wetted by the irrigation system in the zone of maximum root activity.
- Areas sampled should correspond to the grove blocks where leaf samples were taken. They should contain similar soil types with trees of roughly uniform size and vigor.
- Thoroughly mix the cores in a nonmetal bucket to form a composite sample. Take a subsample from this mixture and place it into a labeled paper bag.

Preparation for Analysis

- Soil samples should be dried in the oven before shipping to the laboratory for analysis.

Analysis and Interpretation

- The basic soil analysis package run by most agricultural laboratories includes soil pH and extractable P, K, Ca, and Mg. Organic matter is sometimes also part of the package, or it may be a separate analysis. Extractable Cu is normally determined upon request.
- The laboratory interprets each soil test result as very low, low, medium, high, or very high and may also provide fertilizer recommendations accordingly. A citrus grower should independently interpret the numerical results according to UF/IFAS guidelines based on the Mehlich-3 extractant used (Table 3).
- The interpretations should be used to make decisions regarding soil pH control or fertilizer application (Table 4).

Recommended Fertilizer Rates and Timing

Young Trees (1 to 3 Years after Planting)

Nitrogen

Recommended rates of N for the first three years a citrus tree is in a grove can be found in Table 5. A constant supply of N throughout the growing season is essential to achieve maximum tree growth and early fruit yield. It is recommended to apply controlled-release fertilizer or frequent fertigation (Table 5).

Phosphorus

If soil testing justifies P fertilizer application, test the soil again the following year and compare with Table 3 to determine if P fertilization can be decreased or omitted. A leaf tissue-testing program for P should begin at this time, comparing the results with the standards in Table 1.

Potassium

Apply K fertilizer at a K_2O rate equal to 1.25 times the N rate.

Calcium

If the soil pH is in the optimum range of 5.5 to 6.5, there is no need to apply Ca. If soil pH is below 5.5, the soil should be limed to pH 6.5, which will supply needed Ca. If soil pH is above 6.5, the soil will contain abundant Ca. At pH close to 8, Ca will form precipitates.

Nutrient Management

Applying fertilizer in several small doses increases fertilizer efficiency by maintaining more constant nutrient availability throughout the growing season and by reducing leaching if unexpected rain occurs (Table 4). A minimum of four to six applications of dry fertilizer is recommended. If fertigating, splitting fertigation into 10 to 30 applications per year is common and desirable. The cost of liquid injection during irrigation is relatively small, particularly if the injection can be automated. Two or three applications of controlled-release fertilizer are satisfactory for HLB-affected trees because nutrients are protected from leaching rains. Controlled-release formulations may be applied preplant, incorporated after planting, or broadcast to ensure uniform distribution of nutrients throughout the enlarging root zone of young trees.

Bearing Trees (4+ Years in Grove)

Nutrient management for bearing trees requires many of the same considerations important for nonbearing trees. Applications of dry soluble fertilizer (3–6) or fertigation (10–30) are suggested to supply a near-constant soil nutrient concentration for HLB-affected trees. Nitrogen continues to be the most important element for tree growth, fruit yield, and fruit quality, but others also have substantial effects on production and fruit quality. Removal of elements by harvesting the crop becomes significant but accounts for only part of the fertilizer requirement.

Nitrogen

Recommended N fertilizer rates (Table 6) provide enough N for canopy expansion towards containment size while producing maximum economic yields of high-quality fruit. The chosen N rate will depend on soil characteristics, yield potential, and tree needs as indicated by leaf analysis interpretation (Table 1).

- For grapefruit, the recommended annual N rate is 120 to 160 lb/acre.
- For oranges and other varieties, the recommended annual N rate is 120 to 200 lb/acre.

Mature Bearing Trees (8+ Years in Grove)

Once trees reach containment size, further canopy growth is not desired, so nutrition inputs can be stabilized. Nitrogen fertilizer management should focus on replacing N exported with the harvested crop plus that needed to maintain tree vegetative growth. The guidelines for annual N fertilizer rates account for the needs of both vegetative growth and crop removal (Table 6).

- For grapefruit, the recommended annual N rate is 120 to 160 lb/acre. The chosen N rate will depend on soil characteristics, desired fresh-fruit quality characteristics, yield potential, and tree needs as indicated by leaf analysis interpretation (Table 1).
- For oranges, the annual N rate should fall within the range of 125 to 240 lb/acre. The recommended rate for a specific grove depends on either expected yield potential (for 8- to 11-year-old trees) or 4-year running average production history (for trees 12 years and older) expressed as either fruit yield or soluble solids production. When basing N fertilization on expected yield potential, the rate should be chosen considering (1) how well the young, bearing trees have produced and (2) leaf tissue analysis. If leaf N is maintained in the optimum range, additional fertilizer likely will not produce additional fruit and may reduce quality.

Leaching Rain Rule: If more than 3 inches of rainfall accumulates within a 72-hour period after an N fertilizer application, "replacement" fertilizer may be applied within one week up to one-half of the N rate used in the preceding application (not to exceed 30 lb/acre).

Phosphorus

Determine the need for P fertilization using leaf tissue and soil test results.

- Sample leaves and soil.
- Compare the analytical results with the interpretations provided in Tables 1 and 2.
- Follow the P fertilization guidelines in Table 7.

Potassium

Apply K fertilizer at a K_2O rate equal to 1.25 times the N rate. If leaf K is consistently below optimum, increase the K_2O rate by 25%, especially if the grove soil is calcareous.

Calcium

The optimum soil pH range is 5.5 to 6.5. If soil pH is below 5.5, the soil should be limed to pH 6.5, which will supply needed Ca. If soil pH is above 6.5, the soil will contain abundant Ca. Recent research on HLB-affected citrus trees indicates that leaf Ca is typically deficient; therefore, UF/IFAS changed its recommendation for Ca to 40 lb per acre per year.

Timing of Fertilizer Applications

In Florida, citrus trees should always be fertilized with split doses because there are numerous season-related nutrient requirements to satisfy growth, yield, fruit quality, and BMPs, which would be difficult to achieve with a single fertilizer application.

- The active growing season of perennial citrus trees spans six to nine months, and sandy soils have insufficient nutrient storage capacity to sustain a whole season of growth from a single application of fertilizer.
- Citrus trees have peak times for nutrient demand in the late winter and spring, and moderate to low nutrient demand in the summer, fall, and winter.
- The summer rainy season is the period of greatest risk for leaching nutrients from the soil profile.
- Split fertilizer applications provide some insurance against disastrous results from any single application error or the effects of natural disasters such as hurricanes.

Peak demand for nutrients by bearing citrus trees is during the period from bloom to the end of fruit growth phase 1 (cell division). In Florida, the physiological fruit drop during May/June marks the end of the cell division stage. The timing of the main bloom may vary by variety and year but typically occurs in March. During the weeks leading up to bloom, the trees must be primed with sufficient nutrients to be ready for the explosion of new growth. The nutrient priming can be achieved either through a fall fertilizer application during late September/October of the previous year, or with a prebloom fertilizer application in late winter (February). The disadvantage of a fall fertilizer application (after October) is that during the fruit maturation phase in the fall and winter, persistent high levels of nutrients (especially N) can inhibit fruit color break and suppress Brix levels at the intended harvest time. Incomplete color break and low Brix can reduce pack-out for fresh fruit, while delays in harvesting intended to improve fruit quality can increase the risk of preharvest fruit drop in HLB-endemic groves. Fall or winter fertilizer applications can also make psyllid control more difficult and increase the susceptibility of trees to freeze injury.

Split applications of dry soluble fertilizer are often made in equal increments for convenience (e.g., three splits of 33.3%, or four splits of 25%). Some fertilizer application equipment may not be able to calibrate correctly for very small fertilizer doses, and excessively numerous splits would be costly to apply, which is why typically three to four equal splits of dry fertilizers are recommended for Florida citrus. When the fertilizer is applied by fertigation, growers have much more flexibility for customizing the number and size of split applications. Figure 4A shows the incorrect method for applying three splits of fertilizer in a linear fashion using equal time increments, which mismatches with the peak nonlinear demand for nutrients by citrus in the spring. In situation 4A, the trees would likely encounter nutrient deficits during April. A better method for splitting three doses of fertilizer is shown in Figure 4B, where two of the three fertilizer increments are strategically timed during the period of peak nutrient demand (bloom to the end of fruit growth phase 1). Similarly, the suggested strategy for applying four equal splits of fertilizer is shown in Figure 4C.

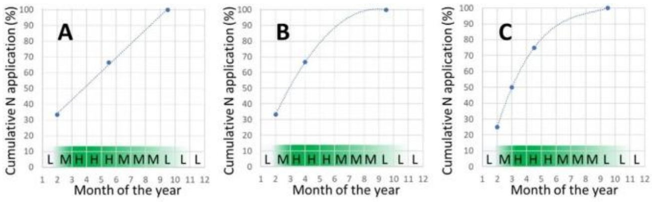

Figure 4. Linear trend of nitrogen supplied by three equal allocations (33.3%) of fertilizer and equal time increments during the growing season (A; not recommended) versus nonlinear supply of nitrogen from three unequally timed 33.3% increments (B) and four unequally timed 25% increments (C). Approximate nitrogen requirements for citrus by calendar month are depicted as increasing green color and Low (L), Moderate (M), and High (H) labels.

Some trial and error with the timing of fertilizer splits may be required to obtain the best results, especially when targeting optimum color development for fresh fruit. In fresh-fruit production, knowledge of the expected harvest time (early-, mid-, or late-season varieties) is important to help determine the timing of the last fertilizer split for the growing season. For early varieties, the last split application of fertilizer N should be in early to midsummer, rather than late summer to early fall for the mid- to late-season varieties. Be aware that fertilizer applications made during the summer carry a higher risk of leaching events due to the higher probability of rain during the summer season in Florida. Leaf sampling will also provide guidance for fresh-fruit growers to target leaf tissue N in the high end of the optimal range (2.7%) during the bloom, fruit set, cell division, and cell enlargement stages, and in the low end of the optimal range (2.5%) or the low range (2.2% to 2.4%) during the fruit maturation stage in the fall and winter (see Table 1).

The optimum timing of K fertilizer splits is slightly different from that for N. In general, less K than N is required in the bloom and fruit set period, while more K than N is required in the cell division, cell enlargement, and maturation stages. This is particularly important for fresh-fruit production because adequate K at the right time is needed for proper fruit sizing. Examples of fertilizers that could be used to provide a suitable N:K_2O ratio in the fertilizer blend at the correct times are (1) 15:3:11 applied prebloom, (2) 9:3:18 at the cell division stage, and (3) 12.5:3:18 at the cell enlargement stage.

Effect of Huanglongbing on Micronutrient Requirements

Leaf chlorosis develops as a result of infection with *Candidatus* Liberibacter asiaticus (*C*Las), including interveinal chlorosis of young leaves, similar in symptomology to Mn and Zn deficiencies that develop early in the growing season. Leaf chlorosis is followed by blotchy mottling of older leaves, which develops later in the growing season. Symptoms similar to those of nutrient deficiency develop in HLB-affected trees, including K, P, Mg, Ca, Mn, Zn, and Fe. HLB causes feeder roots to decline within a few months after infection and before foliar symptoms develop. Feeder roots are responsible for the bulk of nutrient uptake, and their decline likely explains the deficiency symptoms that develop in the canopy. Research has demonstrated that HLB symptoms can be reduced by foliar or ground applications of secondary macronutrients and micronutrients, especially Ca, Mg, Mn, and Zn. These responses have promoted the development and use of enhanced foliar nutritional programs in Florida. The efficacy of these programs has been a topic of considerable discussion and debate. Fertilization programs have varied considerably among growers and have consisted of various rates and application schedules of essential macro- and micronutrients.

Foliar nutrition applications are not likely to lead to past production levels in the short term. Research* has found that maintaining leaf concentration of essential nutrients increased canopy volume and occasionally yield. Application of the current UF/IFAS foliar recommendations (Table 8) three times per year following flushes in March, May, and September was found to maintain leaf concentrations in the optimum range with improved canopy density and yield. For example, the previous UF/IFAS recommendation for Mn and Zn was 5 lb metallic per acre per year. In 2022, UF/IFAS recommendations for Mn and Zn for HLB-affected citrus trees were changed to three applications for a total of 15 lb metallic per acre per year.

*Morgan, K. T., R. E. Rouse, and R. C. Ebel. 2016. "Foliar Applications of Essential Nutrients on Growth and Yield of 'Valencia' Sweet Orange Infected with Huanglongbing." *HortScience* 51(12): 1482–1493. https://doi.org/10.21273/HORTSCI11026-16

Table 1. Guidelines for interpretation of leaf analysis based on 4- to 6-month-old spring-flush leaves from nonfruiting twigs of healthy trees.

Element	Unit of Measure	Deficient	Low	Optimum	High	Excess
N	%	< 2.2	2.2–2.4	2.5–2.7	2.8–3.0	> 3.0
P	%	< 0.09	0.09–0.11	0.12–0.16	0.17–0.30	> 0.30
K	%	< 0.7	0.7–1.1	1.2–1.7	1.8–2.4	> 2.4
Ca	%	< 1.5	1.5–2.9	3.0–4.9	5.0–7.0	> 7.0
Mg	%	< 0.20	0.20–0.29	0.30–0.49	0.50–0.70	> 0.70
Cl	%	---	---	< 0.2	0.20–0.70	> 0.70[1]
Na	%	---	---	---	0.15–0.25	> 0.25
Mn	mg/kg or ppm[2]	< 18	18–24	25–100	101–300	> 300
Zn	mg/kg or ppm	< 18	18–24	25–100	101–300	> 300
Cu	mg/kg or ppm	< 3	3–4	5–16	17–20	> 20
Fe	mg/kg or ppm	< 35	35–59	60–120	121–200	> 200
B	mg/kg or ppm	< 20	20–35	36–100	101–200	> 200
Mo	mg/kg or ppm	< 0.05	0.06–0.09	0.10–2.0	2.0–5.0	> 5.0

[1] Leaf burn and defoliation can occur at Cl concentration > 1.0%.

[2] ppm = parts per million.

Table 2. Adjusting a citrus fertilization program based on leaf tissue analysis.

Nutrient	What if it is less than optimum in the leaf? Options:	What if it is greater than optimum in the leaf? Options:
N	Check yield. Check tree health. Review water management. Review N fertilizer rate.	Check soil organic matter. Review N fertilizer rate.
P	Apply P fertilizer (see chapter 8 of UF/IFAS publication SL253).	Do nothing.
K	Increase K fertilizer rate (see chapter 8 of UF/IFAS publication SL253). Apply foliar K fertilizer.	Decrease K fertilizer rate.
Ca	Apply 40 lb per acre per year.	Do nothing.
Mg	Apply 40 lb per acre per year.	Do nothing.
Micronutrients	Check soil pH. Apply foliar micronutrients for immediate uptake. Include micronutrients in soil-applied fertilizer.	Check for spray residue on tested leaves. Do nothing.

Table 3. Interpretation of soil analysis data for citrus using the Mehlich-3 extractant.

Nutrient	Soil Test Interpretation (mg/kg [ppm][1])				
	Very Low	Low	Medium	High	Very High
P	< 11	11–16	17–29	30–56	> 56
Mg[2]	---	< 25	25–33	> 33	---

Nutrient	Soil Test Interpretation (mg/kg [ppm][1])				
	Very Low	Low	Medium	High	Very High
Ca[2]	---	---	200[3]	> 200	---

[1] parts per million (ppm) × 2 = lb/acre.

[2] A Ca-to-Mg ratio greater than 10 may induce Mg deficiency.

[3] The UF/IFAS Extension Soil Testing Laboratory does not interpret extractable Ca. Work with Florida citrus trees suggests that a Mehlich-1 soil test Ca of 250 mg/kg or greater is sufficient.

Table 4. Adjusting a citrus fertilization program based on soil analysis.

Property or Nutrient	What if it is below the sufficiency value in the soil? Options:	What if it is above the sufficiency value in the soil? Options:
Soil pH[1]	Lime to pH 5.5–6.5; pH in this range can avoid nutrient deficiencies.	Do nothing. Use acid-forming N fertilizer. Apply elemental sulfur. Change rootstocks.
Organic matter[2]	Do nothing (live with it). Apply organic material.	Do nothing.
P	Check leaf P status. Apply P fertilizer if leaf P is below optimum (see chapter 8 of UF/IFAS publication SL253 for further details).	Do nothing.
K	Apply K fertilizer.	Lower K fertilizer rate.
Ca	If soil pH is < 5.3, apply lime. Apply gypsum.	Do nothing. Check leaf K and Mg status.
Mg	If soil pH is < 5.3, apply dolomite. Check leaf Mg status.	Do nothing.
Cu	Do nothing.	Lime to pH 6.5.

[1] The sufficiency value for soil pH is 6.0.

[2] There is no established sufficiency value for soil organic matter.

Table 5. Recommended N rates and minimum number of applications for nonbearing citrus trees (1–3 years old).

Year in Grove	lb N/tree/year (range)	Lower Limit of Annual Application Frequency	
		Controlled-Release Fertilizer	Fertigation
1	0.15–0.30	1–4	10–20
2	0.30–0.60	1–4	10–20
3	0.45–0.90	1–4	10–20

Table 6. Recommended N rates and minimum number of applications for bearing citrus trees.

Year in Grove	lb N/acre/year (range)			Lower Limit of Annual Application Frequency		
	Oranges	Grapefruit	Other Varieties	Controlled-Release Fertilizer	Dry Soluble Fertilizer	Fertigation
4–7	125–200	120–160	120–200	1	3–4	10

Year in Grove	lb N/acre/year (range)			Lower Limit of Annual Application Frequency		
	Oranges	Grapefruit	Other Varieties	Controlled-Release Fertilizer	Dry Soluble Fertilizer	Fertigation
8+	125 to 240 Yield-based	120–160	120–300	1	3–4	10

Table 7. Recommendations for P fertilization of bearing citrus trees based on leaf tissue and soil tests.

If leaf tissue P is…	…and soil test P is…	…the recommendation for P fertilization is:
Excessive High	Very High High Medium Low Very Low	Do not apply P fertilizer to the soil for 12 months following leaf and soil sampling, then sample again and reevaluate.
Optimum	Very High High Medium	Do not apply P fertilizer to the soil for 12 months following leaf and soil sampling, then sample again and reevaluate.
Optimum	Low Very Low	Apply 8 lb P_2O_5/acre for every 100 boxes/acre of fruit produced during the current year. Sample leaves and soil again in 12 months and reevaluate.
Low	Low Very Low	Apply 12 lb P_2O_5/acre for every 100 boxes/acre of fruit produced during the current year. Sample leaves and soil again in 12 months and reevaluate.
Deficient	Low Very Low	Apply 16 lb P_2O_5/acre for every 100 boxes/acre of fruit produced during the current year. Sample leaves and soil again in 12 months and reevaluate.

Table 8. Recommended methods, timing, and rates for micronutrient application to citrus groves.

		Mn	Zn	Cu	B	Fe
Method	Foliar	Yes	Yes	Yes	Yes	No
	Soil	Yes[1]	No	Yes	Yes	Yes
Timing	Foliar	When spring flush leaves reach full expansion				
	Soil	Any time as needed				
Rates (applied in a combination of foliar and soil applications)Pound (lb) metallic equivalent/acre	Foliar	15	15	5	1	See below[2]
	Soil	20	25			

[1] Soil applications of Mn are not recommended on calcareous soils.

[2] Acid soil: Fe-EDTA, 20 grams/tree; Calcareous soil: Fe-EDDHA, 50 grams/tree.

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2026–2029 Florida Citrus Production Guide: Fertilizer Application Methods[1]

Mongi Zekri, Arnold W. Schumann, Tripti Vashisth, Davie M. Kadyampakeni, Kelly T. Morgan, Brian Boman, Muhammad A. Shahid, and Thomas A. Obreza[2]

Fertilization is an important aspect of growing citrus commercially. Citrus tree growth, health, fruit production, and fruit quality are closely affected by plant nutrition. As important as it is to include all the mineral nutrients in proper balance in a fertilizer program, choosing the right method of delivery is equally important. Many fertilizer sources and formulations are available for commercial citrus production. There are also different methods of applying fertilizers. Applying the right fertilizer type, at the right rate, at the right time, at the right location (within the root zone) is very important to improving nutrient uptake efficiency. Some fertilization methods are better suited for a particular setting; therefore, it is suggested to consider all the fertilization options before deciding to invest in one program. Often a combination of delivery methods in fertilization programs works best for commercial citrus groves to ensure a tree receives all the nutrients in the right form and at the right time.

Granular and Controlled-Release Fertilizers

Most commonly used commercial fertilizers are water-soluble, meaning they are readily available to plants when properly applied. Soluble fertilizers are applied to the soil dry in granular form, liquid through fertigation, or foliarly. When applied in granular form to the soil, soluble fertilizers release nutrients relatively quickly, assuming the soil water content is at the appropriate level. Applying too much readily soluble fertilizer to crops at once can result in plant toxicity. In addition, heavy rainfall or irrigation can result in leaching of the nutrients. Therefore, it is suggested to split the soluble fertilizer into smaller doses.

Over many decades, the fertilizer industry has developed controlled-release fertilizers (CRFs). The Association of American Plant Food Control Officials defines CRFs as fertilizers that contain a plant nutrient in a form in which the plant uptake is delayed after application, or that provide a longer duration of nutrient availability compared with quick-release fertilizers. CRFs have become more popular in recent years. CRFs are often called slow-release fertilizers (SRFs) or timed-release fertilizers. However, the terms CRF and SRF should not be used interchangeably. The main difference between CRFs and SRFs is that in CRFs, the factors affecting the rate, pattern, and duration of release are well known and controllable, whereas in SRFs, they are not well controlled. CRFs were initially developed for their horticultural benefits, but they have also attracted attention in the best management practices (BMPs) and citrus greening era. CRFs have advantages in:

- inducing more growth and yield due to a continuous supply of nutrients
- reducing rates and frequency of fertilizer applications
- saving substantial labor and time
- reduced environmental impact

CRFs are typically coated or encapsulated with inorganic or organic materials that control the rate, pattern, and duration of plant nutrient release. Soil moisture, temperature, and microbes have the greatest influence on nutrient release. CRFs have different N-P-K blends and may or may not include micronutrients. They can have different durations of release, expressed as months, which determine how long the CRF will persist.

Citrus fertilization research conducted in Florida within the past 30 years showed that tree growth and fruit yield where part or all of the fertilization program included CRF are similar or greater than growth and yield resulting from an all-conventional water-soluble N fertilization program. CRFs are more efficient, have low plant-toxicity hazard, and have less leaching and volatilization potential than conventional soluble fertilizers. The improved efficiency of fertilizer use saves energy and reduces environmental pollution.

Applying Dry Fertilizers

Dry-solid fertilizer spreaders should apply materials directly over the root zone. When applying fertilizers to young trees, managers should take advantage of manual or electronic spreader adaptations that deliver fertilizer rates accurately to small tree root zones while leaving out the area between trees where roots are not present. For economical and efficient fruit production, it is essential that spreaders be calibrated to apply accurate and appropriate amounts of fertilizers.

Fertigation

Microirrigation is an important component of citrus production systems. For citrus trees, microirrigation is more desirable than other irrigation methods for three main reasons: water conservation, fertilizer management efficiency, and freeze protection. Microirrigation combined with fertigation (applying of small amounts of soluble fertilizer directly to the root zone through irrigation systems) provides precise timing and application of water and fertilizer nutrients in citrus production. Fertilizer can be prescription-applied in small doses and at particular times when those nutrients are needed. This capability helps growers increase fertilizer efficiency and reduce nutrient leaching by excess rainfall or overirrigation, and it should result in reduced fertilizer rates for citrus production. The two most common nutrients applied to citrus through fertigation are nitrogen and potassium.

Florida state law requires that backflow prevention equipment be installed and maintained on irrigation systems that have fertilizer injection capability. The function of the backflow prevention device is to prevent contamination of ground or surface water by the applied chemicals. Therefore, before injecting fertilizer into any irrigation system, make sure all required backflow prevention devices are in place and working properly.

The time required for water to travel from the injection point to the farthest emitter is generally 20 to 30 minutes for most microirrigation systems. Therefore, a minimum injection time of 30 minutes is recommended. After fertigation, continue to run water for 30 minutes to completely flush the fertilizer from irrigation system lines and emitters to minimize clogging potential. Keep in mind that excessive flushing time beyond 30 minutes can leach the recently applied plant nutrients below the root zone.

Fertilizer Solubility

Before injecting fertilizer solutions, a "jar test" should be conducted to determine compatibility of liquids and clogging potential of the solution within irrigation system components. A sample of the fertilizer solution should be mixed with irrigation water in a jar (at the same dilution rate used in the irrigation system) to determine if any precipitate or milkiness occurs within one to two hours. If cloudiness does occur, there is a chance that injection of the chemical will cause line or emitter plugging.

When urea, ammonium nitrate, calcium nitrate, or potassium nitrate is dissolved, heat is absorbed from the water and a very cold solution results. Consequently, it may not be possible to dissolve as much fertilizer as needed to achieve the desired concentration. It is often necessary to let the mixture stand for several hours and warm to a temperature that will allow all the mixture to dissolve.

Fertigation — Summary

- Fertilizer is precisely placed in the wetted zone area where feeder roots are extensive due to water availability.
- Increased fertilizer application frequency can improve plant nutrient-uptake efficiency and reduce leaching.
- Application cost is much lower than that of dry or foliar fertilizer application.
- Through fertigation, comparable or better yields and quality can be produced with less fertilizer.
- Microirrigation systems must be properly maintained to apply water and fertilizer uniformly.

Foliar Fertilization

Foliar fertilizer application is certainly not a new concept to the citrus industry. For over five decades, foliar fertilization of citrus has been recommended to correct zinc, manganese, boron, copper, and magnesium deficiencies. It is now common knowledge in agriculture that properly nourished crops may better tolerate insect pests and diseases.

Field research has shown that supplemental foliar feeding can increase yield by 10%–25% compared with conventional soil fertilization. However, foliar fertilization should not be considered a substitute for a sound soil-applied nutritional program, but a supplement to that soil program. Foliar applications are often used in situations to help trees through short but critical periods of nutrient demand, such as vegetative growth, bud differentiation, fruit set, and fruit growth. Foliar application of nutrients is of great importance when the root system is unable to keep up with crop demand or when the soil has a history of problems that inhibit normal nutrient uptake. Foliar nutrition is proven to be useful under prolonged periods of wet conditions, drought conditions, calcareous soil, cold weather, or any other condition that decreases the tree's ability to take up nutrients when there is a demand. Foliar feeding may be effectively utilized when a nutritional deficiency is diagnosed. Foliar application is absolutely the quickest method of getting the most nutrients into plants. However, if the deficiency can be observed on the tree, the crop has already lost some potential yield.

While foliar feeding has many advantages, it can burn leaves when applied at high rates under certain environmental conditions. It is therefore important to foliar feed within established guidelines. A number of plant, soil, and environmental conditions can increase the chances of causing foliar burn to foliar fertilizer application. Applications when the weather is hot (above 80°F) should be avoided. This means that during warm seasons, applications should be made in the morning or evening when the temperature is right, wind is minimal, and the stomates on citrus leaves are open, allowing leaves to efficiently exchange water and air. Highly concentrated sprays have the potential to cause leaf burn or drop.

Nutrient absorption is increased when spray coverage reaches the undersides of the leaves where the stomates are located. Favorable results from foliar feeding are most likely to occur when the total leaf area is large. Foliar applications of micronutrients, with the exception of iron, are more effective and efficient when the spring, summer, and fall new-flush leaves are almost fully expanded. Another important factor when applying nutrients foliarly is to ensure that the pH of the spray solution is between 5.5 and 6.5. This is particularly important in areas where water quality is poor. To enhance uptake and thus the effectiveness of any foliar application, nitrogen should be added to the solution. Urea may be the most suitable nitrogen source for foliar applications due to its low salt index and high solubility in comparison with other nitrogen sources. However, the urea utilized in foliar sprays should be low in biuret content (0.2% or less) to avoid leaf burn. Be careful about possible chemical interactions among foliar fertilizers. Some materials are incompatible and should not be mixed together. They may create precipitates that tie up and make some nutrients unavailable or clog spray nozzles. Many product labels warn of such incompatibilities.

Overall, foliar nutrition is a very important and effective way of addressing diagnosed problems with specific deficiencies observed within the grove, as well as a best management strategy for supplying micronutrients, with the exception of iron. The concept that foliar sprays should be applied only after the appearance of a deficiency is not advisable because reductions in yield and quality usually precede the appearance of visual symptoms. In addition to soil-applied fertilizers, foliar sprays of nutrients should be used with the objective of maintaining citrus trees' health at an optimal level.

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2026–2029 Florida Citrus Production Guide: Root Health Management[1]

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Developing and maintaining a healthy root system is important for the establishment and long-term productivity of trees. Roots take up nutrients and water from the soil to transport them to the tree canopy (i.e., the leaves and fruit). The root system also acts as an anchor for the tree, which is important during high wind conditions, such as thunderstorms and tropical systems. At the same time, the leaves provide carbohydrates to grow and maintain a functional root system. In a healthy tree, the carbohydrate supply is balanced between new leaves, fruit, and roots. When root health is compromised, the root system has reduced nutrient and water uptake capacity, which can subsequently affect growth of new leaves and fruit.

Root health can be compromised by pests, pathogens, and environmental (abiotic) factors. Citrus root pests include *Diaprepes* root weevils, burrowing nematodes, sting nematodes, and others. Historically, the most damaging root pathogens in citrus have been *Phytophthora* spp. that cause root, crown, and foot rot. The most common detrimental environmental factors for roots in Florida citrus are soil pH, salinity, and flooding. An increase in soil pH above 7.0 results in precipitation of phosphorus, calcium, magnesium, and other plant nutrients, reducing the concentration of nutrients in solution available for uptake by the roots. A reduction of soil pH below 5.5 results in rapid leaching of nutrients such as calcium and magnesium from the soil and mobilization of toxic levels of micronutrients such as copper. Extended waterlogging (oxygen deprivation) and salinity can cause root decline and death. Site-specific decisions made while preparing to plant will reduce the risk and impact of these biotic and abiotic causes of root health decline. Management of root health problems depends on cultural practices and, when necessary, chemical management tools.

The root system has two main types of roots, structural and fibrous (feeder), which serve different essential functions for the tree. The structural roots provide the anchoring scaffold of the root system and act as the major transport corridors for nutrients, water, and carbohydrates. The fibrous roots form the interface with the soil where water and nutrients are absorbed, and they provide extra grip, or friction, to assist anchoring of the tree. Both kinds of roots are important for root and tree health and are affected differently by pests, pathogens, environmental factors, and any interactions of the three. Structural roots often extend outward to the edge of the wetted zone or canopy and then continue down and outward beyond the canopy. Fibrous roots only grow in high-density clusters from structural roots where water and nutrients are most abundant. In irrigated trees, the fibrous roots are concentrated in the wetted zone of the irrigation system. For example, microsprinkler irrigation concentrates 80% of the fibrous roots in the top 10 inches of the wetted zone under the canopy. Root systems are important to understand because root health management should be focused on these areas of high fibrous-root density.

Introduction of *Candidatus* Liberibacter asiaticus (*C*Las), the cause of huanglongbing (HLB), into Florida greatly complicates citrus root health management. *C*Las infection causes severe damage to fibrous roots, which exacerbates the effects of the other root pests and pathogens and can reduce the efficacy of treatments. Root health management has become more challenging and more important because most citrus trees in Florida are now affected by HLB.

Huanglongbing and Root Health

HLB severely affects root health, causing 30%–50% root loss early in disease development and greater than 70% root loss once canopy decline begins (sectored leaf drop and dieback). This root loss results from a shortened lifespan of 1.5–4 months for fibrous roots compared to 9–12 months for healthy roots. The shortened lifespan is accompanied by increased root growth, leading to an imbalance in carbohydrate demand in the tree and reducing the total uptake capacity of the root system. Structural roots also die back from HLB, with ~20% dieback within the wetted zone as canopy decline begins, continuing inward toward the trunk. Currently, there is no proven management option for prevention of HLB-associated root loss. Treatments that stimulate root growth are **not** recommended, because they may increase the root-canopy imbalance. Instead, growers should focus on altering soil applications to adapt to the limited uptake capacity and, when economically feasible, attempt to prevent further damage to the existing roots to maintain or improve root longevity. This includes irrigation and fertilization in small and frequent doses to balance the water and nutrient supply with uptake capacity and adjustment of soil pH between 6.5 and 5.8 to avoid additional stress on the root system.

Managing Root Health

A healthy root system improves productivity of trees and improves their tolerance of major stresses, such as freezes, drought, and high winds. Starting a grove with a healthy root system allows for rapid tree establishment and growth. Maintaining a healthy root system in existing groves lengthens the productive life of the trees.

Root Health in New Plantings

The best way to manage root health is to prevent problems from starting. This requires careful consideration and planning before ordering trees and planting a new grove. The largest contributors to root health that will affect pests, pathogens, and the tree itself are the soil and water at the site. The most cost-effective way to manage root health is proper field preparation for planting and choosing rootstocks based on site-specific knowledge of the soil and irrigation water. Flooding and water table problems that affect root health can be managed with land preparation, including drainage and bedding (see chapter 12, "Grove Planning and Establishment").

Many of the soil, pest, and pathogen problems can also be addressed by choosing the best-adapted rootstock. To select a rootstock, you need to know the site history, such as existing nematode problems or previous infestations of *Diaprepes*. It may also be important to know what has been done in the past to modify soil pH. If recent efforts were made to change the soil pH with liming or sulfur, it is likely that the soil will slowly shift back to its native pH. To avoid the perennial expense of adjusting the pH in your grove, select a rootstock with the appropriate pH tolerance. Rootstock selection can be difficult because there is limited knowledge about soil preference and pest and pathogen resistance for some rootstocks (especially newly released rootstocks). To help in the selection process, a summary of what is known for commercially available rootstocks can be found in chapter 11, "Rootstock and Scion Selection," and the *Florida Citrus Rootstock Selection Guide*. Some locations may have multiple pests, pathogens, and environmental problems. In these cases, a rootstock that addresses all the problems may not be available. It is important to consider which problems are the most severe at the site and which can be most easily and economically managed by land preparation or on a regular long-term basis. In situations where multiple problems cannot be addressed by proper rootstock selection, alternative crops should be investigated.

Once an appropriate site and rootstock have been selected, it is also critical to have healthy root establishment. When planting trees, you should inspect the root balls for signs of phytophthora damage, a pot-bound root system, or dry potting medium. Phytophthora damage will slow or prevent root establishment, immediately stunting trees. Dry potting media will inhibit water penetration after planting, leading to tree stunting or death. Pot-bound root systems can lead to intertwined structural roots that can cause tree stunting and decline a few years after planting as the structural roots begin to girdle each other. For more details, see chapter 12, "Grove Planning and Establishment."

Root Health for Existing Groves

Root health problems in existing groves must be managed and require site-specific management. The first step is to identify the problems present in the grove. Take soil samples for pH and nutrient analysis as well as phytophthora and nematode counts. Determine the pH, salinity, and bicarbonate content of irrigation water. Bicarbonates are leached from limestone in the aquifer and act as a buffer, raising the pH of the water and irrigated soil. Groves should be scouted for the presence of *Diaprepes* root weevil. If *Diaprepes* root weevils are known to be a problem, see chapter 26, "Citrus Root Weevils." Once the root health problems are identified, develop a decision-making process to determine which problems are the most severe and should be managed first. For example, if *Phytophthora* spp. are at damaging levels on roots, but there are also problems with soil pH and *Diaprepes*, addressing soil pH or *Diaprepes* may effectively reduce phytophthora populations in a grove's soil because these factors interact with phytophthora to make it worse than it would otherwise be. Therefore, pH or *Diaprepes* should be treated first, and phytophthora counts should be reassessed to determine if chemical applications for *Phytophthora* spp. are still needed. HLB-induced root damage also interacts with *Phytophthora* spp. by increasing the exudation of sugars from roots. This sugar exudation attracts *Phytophthora* zoospores, increasing infection. HLB also reduces the efficacy of fungicides (phosphite, fosetyl-Al, fluopicolide, and mefenoxam) for control of *Phytophthora* spp. Timing is essential to maintain efficacy of phytophthora management applications. Propagule counts should be monitored carefully for developing problems, so late summer or fall root flushes (root flushes follow leaf flushes) can be protected. For more information, see chapter 30, "Phytophthora Foot Rot, Crown Rot, and Root Rot."

Soil pH and bicarbonates in irrigation water have gained attention because HLB has reduced the tolerance for pH incompatibilities on rootstocks mismatched with grove soil, such as Swingle on high-pH soils. In many cases, especially in the flatwoods, management of pH and bicarbonates resulted in increased root density of trees with HLB. For reasons yet to be determined, groves on ridge soils do not respond as well to pH and bicarbonate management. Soil pH or high-bicarbonate irrigation water can be treated with ground-applied sulfur or by acidifying irrigation water with injections of sulfuric or N-phuric acid. For Swingle rootstocks, the ideal pH range is 5.5 to 6.5. Recent field experiments have determined that maintaining soil pH in the 5.5 to 6.5 range increases nutrient uptake and root density. It is important to test the pH before and after treatment because over-acidification could lead to the release of toxic amounts of copper and other metals and depletion of essential nutrients, such as calcium and magnesium, from the soil. Extra care also needs to be taken to avoid over-acidification when using sulfur. Sulfur acidification is dependent on the microbial breakdown of elemental sulfur and can take a year or more before soil pH drops. The soil pH is very likely to drop below the optimum range if other acidification methods are used before the sulfur takes effect.

Depending on the results of soil tests for nutrients such as calcium, supplemental application may be necessary to replenish what was lost from leaching and to prevent copper toxicity to roots. When pH management is necessary, sources of calcium that do not counteract pH management should be chosen; for example, applying gypsum ($CaSO_4 \cdot 2H_2O$) instead of lime can add calcium without increasing the soil pH.

Managing Soil Health for Root Health

Cultural practices to manage the quality, or health, of soils may also improve root growth and health. One of the key components of healthy soils is soil organic matter, which is critical for maintaining or increasing microbial activity. There is increasing evidence that greater soil microbial activity can improve root growth through reduction of disease incidence and influence on nutrient availability. While Florida citrus soils generally have low soil organic matter content, cultural practices such as planting cover crops and/or applying compost can increase soil organic matter. Recent field trials have measured significant increases in soil organic matter and changes in microbial functions when cover crops are planted year-round in Florida citrus groves. Cover crops can be planted either only in the row middles or trunk to trunk. Because citrus roots extend into the row middles, benefits of cover crops may still apply even if they are only planted in the row middles. The increased biomass provided by cover crops contributes to soil organic matter through decomposition. Legume cover crops may also provide additional nitrogen. More details on cover crops can be found in UF/IFAS publication SL534, "Cover Crops for Florida Citrus: Practical Considerations and Their Impact on Soil Microbes." Together, these changes can enhance microbial abundance and activity and impact root growth.

Web Address for Link

Florida Citrus Rootstock Selection Guide:
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2026–2029 Florida Citrus Production Guide: Canopy Management[1]

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Tree canopy and bearing volume are two important factors in fruit production and fruit quality. Generally, trees with larger canopy and bearing volumes produce more fruit than smaller-canopy trees. Canopy management is an important aspect of citrus production in Florida to avoid problems associated with overcrowding and excessively tall trees, improve light interception, enhance pesticide distribution within the canopy, and facilitate equipment operation within the grove. Proper control of vegetative growth is essential for the maintenance of healthy, productive citrus trees. The effect of insufficient light is frequently observed in mature citrus groves that are not managed regularly. Shading reduces yield and foliage on the lower parts of the trees. Sunlight not only influences flowering and fruit set but also enhances fruit quality and color development. Increased sunlight penetration within the tree canopy might also allow foliage to dry more quickly after a rain shower and could help reduce establishment of fungal pathogens. Therefore, adjustments must be made to the tree canopy to maximize sunlight interception.

Pruning is one of the oldest horticultural practices that changes the form and growth of a tree. The pruning process (1) adjusts tree shape and the ratio of the framework to the fruit-bearing shell of the canopy, (2) alters the shoot/root ratio, and (3) changes the carbohydrate (food storage) status of the tree. Pruning healthy, mature citrus trees can reduce yields in proportion to the amount of foliage removed and can delay fruiting of young, nonbearing trees. Pruning should therefore be limited to that required for future canopy bearing-surface development and to conduct efficient cultural and harvesting operations (Figure 1). Under Florida weather conditions, citrus trees often produce vigorous vegetative growth, which can result in overcrowding and shading. Therefore, canopy management is very important. In general, tree response to pruning depends on several factors, including variety, rootstock, tree age, growing conditions, time of pruning, and production practices. There is no fixed set of rules, and therefore each situation should be critically analyzed before any severe canopy management decisions. Growers are encouraged to gain a clear understanding of the basic principles regarding pruning, to take advantage of research results, and to consult knowledgeable colleagues and custom operators for their observations and recommendations.

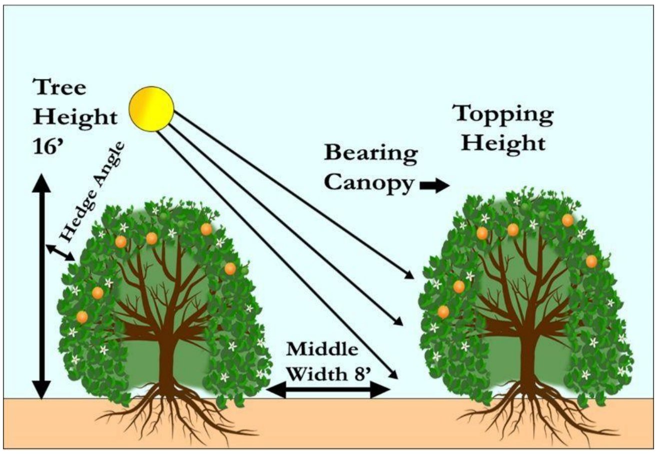

Figure 1. Topping height, middle width, and solar angle influence the amount of sunlight that gets to the lower canopy.
Credit: UF/IFAS (adapted from UF/IFAS publication HS1026)

What to Do before Pruning

The correct use of equipment tools is very important before pruning. There are several pruning tools available like loppers, scissors, saw pruners, hedge shears, and trimmers. Keep the tools sharp and in good working condition and remember to disinfect the tools before and after use every time to prevent the spread of disease among trees. Sterilize your pruning tool when moving from one plant to another one. It is better to sanitize with alcohol, 5% bleach, or disinfectant instead of heating.

When and How to Prune

Time is very important for pruning, and it varies with the type of scion and rootstock. Prune at the time that best complements plant growth, characteristics, flowering, or any other objective you desire to achieve. Early spring is the best time for pruning in most fruit-bearing trees, including citrus. Pruning in citrus too early may stimulate new growth, but if a late freeze event occurs, it can cause serious damage. Always prune back to or just above the branch or bud growing point.

Basic Pruning Cuts

Thinning out and heading back are the main types of pruning cuts (Figure 2). Thinning out is a selective pruning method that involves the removal of complete branches down to the main trunk and is often done with handheld equipment. It encourages longer growth of the remaining terminals and can result in a more open tree, which allows more sunlight to penetrate deeper into the tree canopy. Thinning out is commonly seen in peaches and plums to maximize light penetration into the inner canopy for better fruit set and growth. This type of pruning is generally considered too labor intensive and costly, and therefore it is not commonly practiced in the Florida citrus industry. Heading back removes the terminal portion of a shoot or branch, removing apical dominance and stimulating lateral bud breaks (Figure 2). As a result of heading back, trees are more branched and compact. Mechanical hedging and topping are the main forms of mass heading back used in Florida for mature trees.

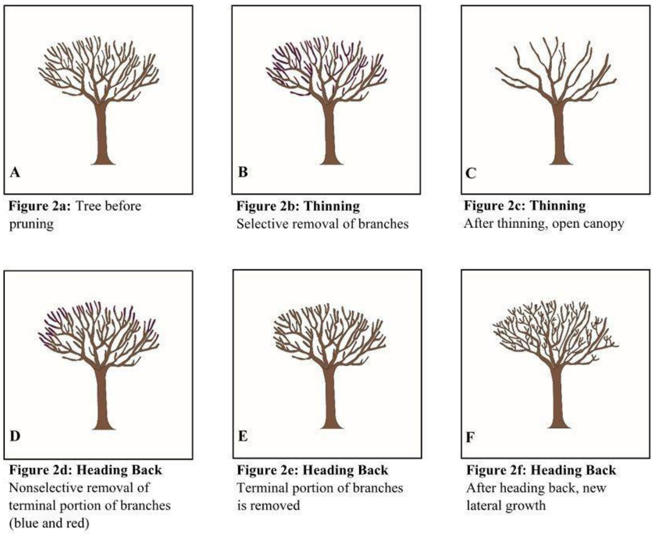

Figure 2. The two types of pruning cuts. a: Tree before pruning; b–c: Thinning, selective removal of branches to open up the canopy; d–f: Heading back, nonselective removal of terminal portion of branches resulting in more lateral branching.
Credit: Tracy Bryant, UF/IFAS Communications

Canopy Management for Young Trees

Severe pruning and training of young, nonbearing trees tend to delay fruit production and should be avoided. Most trees usually need no pruning for the first few years in the grove except for removal of sprouts on the trunk. Larger sprouts should be cut off flush with the trunk to avoid dominance over a weaker tree. Sprouting on the trunks of young, nonbearing trees can be greatly reduced by using a commercial sprout inhibitor (refer to chapter 18, "Plant Growth Regulators"). While protective wraps around the trunk will reduce sprouting, careful monitoring and observation are required to avoid insect and disease problems under the wraps.

Canopy Management for Mature Trees

When mature trees begin to overcrowd, growing tall and into the row middles, canopy management becomes essential to maintain tree size and improve light penetration. Hedging and topping are very common cultural grove-management practices in Florida (Figure 3).

Hedging and Topping

Hedging consists of cutting back the sides of trees to prevent or alleviate crowding. Hedging produces numerous cut wood surfaces along the side of the tree canopy from which new sprouts arise, eventually developing into a wall of new foliage. Middles (alleys) between tree rows should be sufficiently wide to accommodate grove equipment and provide adequate light access to the sides of the trees. Middles are usually hedged to a width of 7 to 8 ft, but will vary depending on original grove design, scion variety, rootstock, and equipment used in all production practices.

Hedging should be completed before canopy crowding becomes a problem. As a general rule, pruning of branches greater than 0.13 to 0.25 inch (1/8 to 1/4 inch) in diameter should be avoided. Developing a proactive pruning program should assist managers in removing the right-sized branches. Removal of a significant portion of the tree will result in excessive vegetative growth and a drastic reduction in subsequent yield. Hedging is usually done at an angle, with the boom tilted inward toward the treetops so that the hedged row middles are wider at the top than at the bottom. This angled hedging allows more light to reach the lower skirts of the tree. Commonly used hedging angles vary from 10 to 15 degrees from vertical.

Topping should be done before trees have become excessively tall and should be an integral part of a tree-size maintenance program. Long intervals between toppings increase the cost of the operation due to heavy cutting and more brush disposal.

Furthermore, excessively tall trees are more difficult and expensive to harvest and spray. Topping trees will improve fruit quality and increase fruit size while reducing management and harvesting costs. Some common topping heights are 12 to 14 ft at the shoulder and 16 to 17 ft at the peak. Generally, topping heights should be two times the row-middle width.

Lower heights are sometimes used for training trees, increasing fruit size, or rejuvenating declining trees, or after flooding events that damaged the root system. Taller trees are sometimes maintained when they are vigorous and widely spaced. Trees in the flatwoods areas are generally topped lower than those on the ridge because the more limited root systems will usually not support as much top growth. Topping should be started before extensive cutting is required. If heavy cutting is required, the initial cuts should be low enough to avoid cutting excess wood in subsequent topping operations. Retopping is generally done just above the old cut.

After severe hedging or topping, heavy nitrogen applications will produce vigorous vegetative regrowth at the expense of fruit production. Therefore, nitrogen applications should be adjusted to the severity of hedging or topping. Reducing or omitting a nitrogen application before and possibly after heavy hedging will reduce both costs and excessive vegetative regrowth. Light maintenance hedging should not affect fertilizer requirements or application.

Large crops tend to deplete carbohydrates and result in reduced fruit yield and increased vegetative growth the following year. Pruning after a heavy crop additionally stimulates vegetative growth and reduces fruit yield the following year. Pruning after a light crop and before an expected heavy crop is recommended because it can help reduce alternate bearing, which can be a significant problem in Pineapple orange and Murcott production.

Severe hedging may create problems of brush disposal and stimulate vigorous new vegetative growth, especially when done before a major growth flush. This happens because an undisturbed root system is providing water and nutrients to a reduced canopy area. The larger the wood that is cut, the larger the subsequent shoot growth. Severe pruning reduces fruit set and increases fruit size.

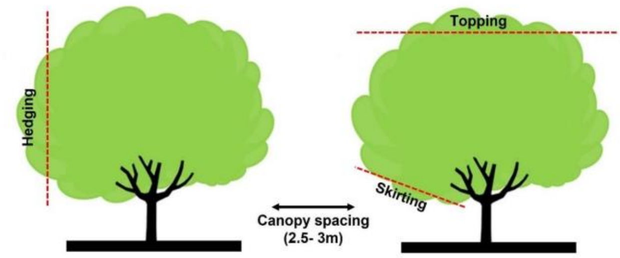

Figure 3. Different ways for canopy management. Demonstration of various pruning types for canopy management such as hedging, topping, and skirting.
Credit: Muhammad A. Shahid, UF/IFAS

Canopy Management Program

The best time of year to hedge or top depends on scion variety, grove location, severity of pruning, and availability of equipment. Because pruning is usually done after removal of the crop, early-maturing varieties are generally hedged before late-maturing varieties. Most growers prefer to hedge before bloom, but trees will get more vegetative regrowth, which may not be desirable. Pruning could begin as early as November prior to harvesting in warmer areas. During this period, pruning operations should only cut minimal foliage and fruit from the trees.

Valencia trees may be hedged in late fall with only minimal crop reduction when the hedging process removes only a small amount of vegetative growth. In cases where excessive growth is to be removed, the trees are usually harvested before hedging is conducted. Light maintenance pruning can be done throughout the summer and until early fall with little or no loss in fruit yield. Moderate to severe pruning should not continue into the winter in freeze-prone areas, because trees with tender regrowth are susceptible to cold injury.

Tree Skirting

Skirting is a pruning practice to raise tree skirts. Without skirting, the movement of herbicide booms, fertilization (in wetted zones), and mechanical harvesting equipment is impeded. Fruit and limbs near the ground are often damaged by the passage of such equipment and by herbicide spray and fertilizer contact. Skirting allows uniform distribution of granular fertilizers and improved water coverage of microsprinkler irrigation systems under tree canopies. The practice facilitates the inspection of microirrigation systems and reduces the incidence of phytophthora foot rot and brown rot because it also allows good air circulation.

Canopy Management and Huanglongbing

Because Florida groves have become heavily affected with huanglongbing (HLB) and the psyllid population has been on continuous increase, selecting the best time for hedging and topping is becoming more complicated. New growth flushes promoted by hedging and topping in late spring, summer, and early fall can increase the population of leafminers and psyllids and aggravate the spread of HLB. HLB-affected trees often undergo severe root loss; therefore, these trees can be hedged and topped to help balance the shoot-to-root ratio to improve tree performance and extend tree longevity. However, buckhorn pruning or severe pruning of HLB-affected trees is not recommended. Such practices have been found to not be economically viable; a significant reduction in yield should be expected in years one and two following severe/buckhorn pruning. Severe pruning can also result in reduction in root density for up to three years.

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2026–2029 Florida Citrus Production Guide: Plant Growth Regulators[1]

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Plant growth regulators (PGRs) are a tool used to manipulate vegetative and reproductive growth, flowering, and fruit growth and development. PGRs have been successfully used in agriculture for decades to amend plant growth characteristics to maximize yield and thus grower profit. Foliar-applied PGRs are routinely used in various fruit crops for flower and fruit thinning; improving fruit set, growth, and development; controlling vegetative growth; and reducing fruit drop. Citrus is no exception to the use of PGRs, which can provide significant economic advantages to citrus growers when used appropriately. According to the Florida state legislature, PGRs are defined as “any substance or mixture of substances intended, through physiological action, for accelerating or retarding the rate of growth or maturation or for otherwise altering the behavior of ornamental or crop plants or the produce thereof, but not including substances intended as plant nutrients, trace elements, nutritional chemicals, plant inoculants, or soil amendments.”

Most PGRs are plant hormones, naturally occurring plant compounds. A plant hormone is a chemical signal produced in one part of the plant, due to some internal and external stimuli, and then transported through vascular bundles to another part, where it triggers a response. Hormones regulate plant responses to various biotic and abiotic stimuli. PGRs are synthetic analogs of naturally occurring plant hormones (PGRs and hormones are used interchangeably throughout this chapter). There are five classic groups of PGRs: auxins, gibberellins, cytokinins, abscisic acid, and ethylene (Table 1).

In addition to the five classic PGRs, other groups of biochemicals are now also recognized as PGRs. They include jasmonates, salicylic acid, strigolactones, melatonin, and brassinosteroids. Each group of PGRs has unique attributes and is involved in a number of different physiological processes.

It is very important to keep in mind that PGRs do not work in isolation. Plant response and efficacy of materials often depend on several factors, such as the concentrations of the materials, levels of other plant hormones, plant health, nutritional and water status, time of year, and climate. For example, the influence of gibberellins on citrus flowering, fruit set, seedlessness, color development, and preharvest fruit drop varies with many of these factors.

Auxins

Auxins were among the first plant hormones identified. Auxins are known to be involved in plant-cell elongation, apical dominance, inhibition of lateral bud growth, promotion of rooting, suppression of abscission, inhibition of flowering, and seed dormancy. A well-known auxin is indoleacetic acid (IAA), which is produced in actively growing shoot tips and developing fruit.

Synthetic auxin analogs like 2,4-dichlorophenoxyacetic acid (2, 4-D) and naphthalene acetic acid (NAA) are extensively used in fruit crop production. 2,4-D is commonly used in agriculture as an herbicide. It is also used to control preharvest fruit drop and to increase fruit size, particularly in oranges, grapefruit, mandarin, and mandarin hybrids. The efficiency of 2,4-D in reducing preharvest fruit drop increases when used with oil sprays. The timing of 2,4-D application to reduce preharvest fruit drop should be carefully assessed to minimize undesirable effects on flowering and harvest timing.

NAA is used to inhibit the undesirable growth of suckers on tree trunks. As discussed earlier, NAA can inhibit lateral branching; therefore, its application to trunks keeps lateral buds in a dormant state. NAA can also promote fruit abscission and can therefore be used to thin excessive fruit and increase the size of the remaining fruit. Environmental conditions can greatly influence uptake and activity of NAA. High temperatures and delayed drying of spray solution due to high humidity both contribute to greater thinning action. Best results are likely to occur when applied between 75°F and 85°F. Because uptake continues for several hours after the spray dries, heavy rain within six hours of application may significantly reduce NAA action.

Gibberellins

Gibberellins, abbreviated as GA for gibberellic acid, have many effects on plants but primarily stimulate elongation growth. Spraying a plant with GA will usually cause the plant to grow larger than normal. GA also influences plant developmental processes like seed germination, dormancy, flowering, fruit set, and leaf and fruit senescence.

In citrus, GA is often used to delay fruit senescence. GA delays changes in rind color, and application will result in fruit with green rinds and delayed coloring. This will have a negative effect when selling fruit early in the season for the fresh-fruit market. However, this effect is desirable for late-harvested fruit because it results in fruit that are paler in color than the deeper-colored fruit from untreated trees. GA also affects flowering in citrus. GA application can reduce the number of flowers and therefore fruit yield. It is important to carefully assess timing of GA applications to avoid yield losses. Depending on the application time, GA can reduce preharvest fruit drop and improve fruit set in some citrus varieties.

Cytokinins

Cytokinins derived their name from cytokinesis (cell division) because of their role in stimulating plant cells to divide. In addition to being involved in cell division, cytokinins were shown to have important effects on many physiological and developmental processes, including activity of apical meristems, shoot growth, inhibition of apical dominance, leaf growth, breaking of bud dormancy, and xylem and phloem development. Cytokinins also play an important role in the interaction of plants with both biotic and abiotic factors, including plant pathogens, drought and salinity, and mineral nutrition.

Abscisic Acid

Despite its name, abscisic acid (ABA) does not initiate abscission (drop). ABA is synthesized in the chloroplast of the leaves, especially when plants are under stress, and diffuses in all directions through the vascular bundles. ABA promotes dormancy, inhibits bud growth, and promotes senescence. It also plays a major role in abiotic stress tolerance. During water stress, ABA levels increase in leaves, which leads to the closing of stomata, thereby reducing water loss due to transpiration. ABA is costly to synthesize; therefore, its use in agriculture is limited.

Ethylene

Ethylene, a gaseous hormone, is well known for its role in promoting fruit ripening. In addition, it plays a major role in leaf, flower, and fruit abscission. Ethylene also affects cell growth, shape, expansion, and differentiation. Plants under biotic or abiotic stresses produce high levels of ethylene, which triggers an array of responses. For example, when leaves are damaged or infected with pathogens, high levels of ethylene are produced to promote abscission of those leaves. In citrus, ethylene is commonly used in postharvest to degreen oranges, tangerines, lemons, and grapefruit, making them more attractive to consumers. Ethylene treatment of mature but poorly colored fruit enhances the peel color and increases the marketability of fruit.

New Classes of Plant Hormones

Brassinosteroids

Brassinosteroids (BR) play a pivotal role in a wide range of developmental processes in plants, such as cell division, cell differentiation, cell expansion, germination, leaf abscission, and stress response. BR can increase the freezing tolerance of plants by alternating the metabolism of plants. BR, when applied exogenously, can enhance biotic and abiotic stress tolerance and help to maintain good health of the plants. Because of their involvement in many different physiological processes, application of BRs might be of interest in crop production. Successful use of BR in agriculture depends on the production of cost-effective, stable synthetic analogs of BR.

Strigolactones

This class of hormones was first discovered in the secretions of plants from the root. This group of plant hormones is known for inhibiting shoot growth and branching, stimulating root-hair growth, and regulating the root architecture. Strigolactones (SLs) also promote a symbiotic interaction with mycorrhizal fungi and facilitate phosphate uptake from the soil. They also help in seed germination. Under nutrient deficiencies, particularly phosphorus deficiency, SLs are produced to attract symbionts to regulate shoot and root architecture.

Jasmonates

This group of plant hormones is involved in plant defense responses. Herbivory, wounding, and pathogen attacks trigger the production of these hormones, which results in the regulation of plant-defense-related genes to fight the infection. Experimental evidence suggests that the exogenous application of jasmonic acid, one of the compounds from the jasmonates group, regulates the stress responses in plants under different abiotic stresses. For example, the exogenous applications of jasmonic acid increase the cold tolerance of fruits like citrus and bananas. In addition, jasmonic acid also functions synergistically and antagonistically with other phytohormones, such as abscisic acid, ethylene, salicylic acid, and so forth, to enhance resiliency to different climatic stresses.

Salicylic Acid

Salicylic acid (SA) plays a role in plant growth and development processes, photosynthesis, and transpiration. SA is well known for mediating plants' defense response against pathogens. Its role in increasing plant resistance to pathogens is inducing the production of pathogenesis-related proteins. It is involved in the systemic acquired resistance (SAR) response, in which a pathogenic attack on one part of the plant induces resistance in the affected area as well as in other parts of the plant.

Melatonin

Melatonin is a class of indole compounds that are derived from the metabolism of tryptophan amino acid in plants. It is found in almost all types of plants, but it is produced more in aromatic plants. It is involved in regulation of many processes in plants, including seed germination, root growth and development, circadian rhythm, leaf senescence, and fruit ripening. During abiotic stresses like cold, drought, and salinity, this hormone is distributed in leaves, stems, and fruits to enhance stress tolerance. During water deficiency, it helps in root development and increases photosynthetic efficiency.

Use of PGRs for Huanglongbing-Affected Trees

Different plant growth regulators (PGRs) can be applied at specific times of the year to achieve targeted outcomes in citrus trees affected by huanglongbing (HLB).

Fruit Drop

Trees affected by huanglongbing (HLB) often suffer from extensive preharvest fruit drop. Considering the ability of PGRs such as 2,4-D and GA to reduce preharvest fruit drop, PGRs are considered good candidates to mitigate HLB-associated fruit drop. However, results from field trials with HLB-affected trees suggest that single applications of 2,4-D and GA (alone) are not effective in reducing fruit drop. Nonetheless, recent findings from multiyear field trials suggest that 2,4-D (Citrus Fix, 3.2 oz/acre) along with GA (ProGibb LV Plus, 10 oz/acre), as a combination application, can reduce fruit drop significantly in HLB-affected 'Valencia' sweet oranges when applied in the November–December period.

Tree Productivity and Canopy Improvements

A multiyear field trial with multiple GA applications in fall (September–January) at 20 grams a.i. along with surfactant has shown improvement in yields of HLB-affected trees, a reduction in preharvest fruit drop, and an improvement in canopy density. In light of this current study and previous field trials, it is recommended that multiple GA applications in fall can be beneficial for HLB-affected sweet orange trees. For early sweet orange varieties, such as Hamlin, the sprays should start in August and end by November. GA applications are likely to keep fruit green. Therefore, an interval of at least two months should separate the last application and harvest.

Flowering

If excessive flowering, prolonged flowering, or off-season flowering is identified as a problem in HLB-affected trees, GA applications in the fall (September–January) can be made at 10–20 grams a.i., 100–120 gal per acre without negatively affecting yield. Fall GA applications reduce flowering in the following season. However, GA can also cause delay in color break of the existing crop; therefore, for early-season varieties of sweet orange, mandarins, and grapefruit, applying GA after the fruit is harvested would be ideal. GA applications in 'Valencia' during fall may improve fruit size of the existing crop as well as next season's crop due to reduced flowering. Do not apply GA later than January because late applications can suppress flowering significantly, resulting in low yields.

General Consideration for Use of PGRs in Citrus Groves in Florida

Because PGRs function by directly influencing plant metabolism, plant response can vary considerably, depending on the variety and plant stress level. Therefore, it is recommended that growers become familiar with PGR effects before application. Preliminary trials in a small field plot should be conducted before using on a large acreage of trees. Most PGRs work best when used with an adjuvant (surfactant, sticker, or spreader). PGRs are regulated as pesticides and therefore, label instructions need to be followed. *The label is the law.* The table in booklet 2 summarizes some of the PGRs that are known to be effective in Florida citrus production.

The following are things to consider when applying PGRs:

- Concentration of active ingredient
- Spray volume
- Method of application
- Time of day
- Season
- Compatibility with other chemicals in the tank mix
- Type of adjuvant
- Weather condition (humid, dry, sunny, cloudy, windy)
- Tree health (canopy density)

Table 1. Major plant growth regulator classes, associated function(s), and practical uses in agriculture.

Class	Associated Function(s)	Practical Uses
Auxins	Shoot elongation	Fruitlet thinning; increased rooting and flower formation; sprout inhibitor
Gibberellins	Stimulate cell division and elongation	Increase shoot length, fruit size, and fruit set
Cytokinins	Stimulate cell division	Prolong storage life of flowers and vegetables and stimulate bud initiation and root growth
Ethylene	Ripening, abscission, and senescence	Induces ripening and loosens fruit
Abscisic acid	Seed maturation, dormancy	Regulates plant stress
Jasmonates	Plant defense	Wound response
Salicylic acid	Systemic acquired resistance (SAR)	Defense against pathogenic invaders
Brassinosteroids	Developmental processes	Regulate germination and other developmental processes
Strigolactones	Suppress branching and promote rhizosphere interaction	Suppress branching, promote secondary growth, and promote root hair growth

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2026–2029 Florida Citrus Production Guide: Citrus Cold Protection[1]

Tripti Vashisth and Chris Oswalt[2]

No other single factor has affected the historical distribution of Florida citrus more than freezing temperatures. Since the introduction of citrus by the Spanish in the 1500s, freezing temperatures have dictated where the citrus production areas in Florida are located.

Early citrus production in Florida relied on principles of passive cold protection practices to mitigate the effects of freezing temperatures. Passive principles of cold protection are decisions made prior to planting the citrus trees. Site selection, horticultural selections, and cultural practices are considered passive methods. These practices are those that do not require the grower to actively participate in cold protection of citrus during a freeze event.

Passive Methods of Cold Protection

Traditionally, site selection decisions that would result in a higher level of protection from cold would include planting on higher-elevation ground to better facilitate cold-air drainage; selecting areas on the south and southwest sides of lakes or large bodies of water, because they are warmer during freeze events; and planting in close proximity to natural windbreaks to reduce wind speeds, helping retain natural heat stored in the grove. Geographically, areas farther south along the Florida peninsula are warmer than locations in north Florida. Soil texture can also affect minimum temperatures and citrus freeze damage in a given grove. For example, white-colored sand-sink soils are significantly colder on a given freeze night than other soil types.

Horticultural selection of citrus rootstocks and varieties can influence the susceptibility of trees to freeze damage. Citrus rootstock selection can often result in success or failure of a citrus grove in a particular geographical location. Generally, the more vigorous the rootstock, the more susceptible the tree will be to freeze damage. Rough lemon, Volkamer lemon, and Carrizo citrange are vigorous rootstocks and are more sensitive to freezing temperatures. Cleopatra mandarin and Swingle citrumelo are considered slower growing and therefore more cold tolerant. During the freezes of the 1980s, it was not unusual for rough lemon groves to be killed while groves on sour orange grown beside them would recover from the same damage. That said, when the minimum temperatures reach a critical threshold for long enough, no rootstock is resistant to freeze damage, as was observed in 1980s freeze in north and central Florida. The selection of citrus varieties used in a particular grove location should be influenced by the probability of freezing temperatures. Mandarin or tangerine trees are considered more cold tolerant than orange trees, and orange trees are considered more cold tolerant than grapefruit trees. The time of fruit maturity can also have an effect on the profitability of a particular grove, depending on the probability of freezing temperatures. Early-maturing varieties that can be harvested before freezing temperatures may result in growers making a profit in areas where later-maturing varieties would receive fruit damage. The crop load on trees during the winter can influence cold tolerance. Pineapple oranges and Murcott tangerines with excessive crop loads (“on” years) have been shown to be more susceptible to freeze damage.

Cultural practices can also provide some degree of cold protection. Practices such as increasing soil moisture during the day prior to the freeze can increase the thermal conductivity of the soil, allowing for this stored heat to be released overnight. In addition, during the winter, tree water status should be maintained at levels that reduce fruit drop and prevent water stress without stimulating vegetative growth. Citrus trees under drought stress are also more susceptible to freeze damage. Row-middle management in the form of low-growing turf or clean row-middle management (by discing or by trunk-to-trunk herbicide application) can increase the solar interception of the soil and allow the storing of heat during the day. Tall-growing weeds in row middles reduce the soil solar interception and may create cold-air dams that impede the drainage of cold air from a grove. The nutritional status of the citrus tree can also affect its susceptibility to freeze damage. No single nutritional element will affect the cold hardiness of citrus trees, although excessive nutrition and nutritional deficiencies can lead to an increase in freeze susceptibility.

Active Methods of Cold Protection

Passive cultural practices can only provide a certain level of protection. Active cultural practices are used by growers during a freeze to reduce the freeze damage to citrus trees. During the 1900s, several of these active cold-protection practices were used by growers to reduce freeze damage to citrus trees. These practices included heating, wind machines, low-volume irrigation, and tree wraps for young citrus trees.

Heating a citrus grove involves the use of grove heaters burning fossil fuel to prevent temperatures from reaching a critical temperature. Heating is very effective in protecting trees and fruit from freeze damage. Years ago, this was one of the more common methods to protect citrus trees and fruit. Depending on the grove, usually 35 to 40 heaters per acre were used. These heaters would burn about 1 gal of fuel oil per hour. This type of system is quite labor-intensive and expensive due to the initial cost annually associated with setting out and picking up the heaters at the end of the winter. Refueling and lighting heaters before and during freeze events and the need for in-field refueling during a freeze add to these costs. Moreover, there were also environmental concerns, such as fuel spills in and around the heaters. These problems, along with fuel costs and the fuel shortage of the 1970s, have resulted in the disuse of grove heaters in Florida citrus.

Wind machines are used extensively in "cold pockets," depressed areas of elevation in the "ridge" production region where dense cold air drains on radiation freeze nights. One wind machine will protect about 10 grove acres if ideally located. Wind machines need the development of a strong temperature-inversion reversal at the height of the machine (about 30 feet above the ground) in order to be effective. Temperature inversions develop only during radiation-type freeze events. Cold air at the surface cools and displaces warmer air to levels above the ground where the warmer air is mixed by the wind machine, increasing grove temperature to an average of the volume of air mixed. The development of inversions can be monitored with the Florida Automated Weather Network (FAWN) tower locations by looking at the difference between 2-foot and 30-foot temperatures. FAWN data can be accessed at https://fawn.ifas.ufl.edu.

Low-volume microsprinkler irrigation is the most widely used method in the Florida citrus industry to protect citrus trees from freezing temperatures. Early attempts in 1962 to use overhead irrigation for freeze protection resulted in widespread damage to trees due to insufficient volumes of water being applied. This resulted in growers being reluctant to use irrigation for cold protection until the early to mid-1980s. Widespread use of microsprinklers in the early 1980s allowed growers to apply sufficient volumes of water directly under and on the lower portions of citrus trees, resulting in protection of these trees from freeze damage.

Irrigation used for freeze protection is based on a few simple principles. First, the sensible heat of water that is released when water hits the tree is beneficial. This sensible heat is due in large part to the actual temperature of well water (about 68°F). There may also be some additional benefit if irrigation can cause the development of fog in the grove, which in turn will reduce the rate of temperature fall during the night (this is highly dependent on the dew point temperature). Secondly, the process of water turning to ice (called the latent heat of fusion) releases additional heat to the grove microclimate. The formation of ice also helps in insulating plant tissues above critical temperatures. Current recommendations call for application rates of 2000 gal per acre per hour to protect trees from freezing temperatures.

During radiation freezes, water applied under the canopy of citrus trees modifies the tree microclimate, resulting in limited protection of the tree and fruit from freeze damage. This modification of the tree microclimate decreases with height above the irrigation source. Generally, irrigation under mature trees will provide little protection of fruit on the exterior canopy of the tree, but it may limit damage to fruit located closer to the microsprinkler.

During advective freezes, mature trees may not typically benefit from irrigation, but this would be highly dependent on evaporative cooling and the amount of irrigation heat removed from the grove due to increased wind speeds. Microsprinklers can provide excellent protection of young citrus trees from such freeze damage. Microsprinklers should be located on the north or northwest sides of the tree no further away than 2 to 3 feet. This will allow winds during an advective freeze to blow water at the tree. The type and pattern of emitter used are critical. Emitters should be the fan type, with either a 90° or 180° pattern applying a uniform distribution of water at the tree. This condition should provide for excellent protection of young citrus trees. Another version of this system would involve elevating 360° fan-type microsprinklers on PVC stakes, 24 to 36 inches in length, in the center (2 to 4 inches from the trunk) of young trees. The emitter tubing should be wrapped around the PVC stake to keep ice formation from pulling down the elevated emitter. This system has been shown to provide additional protection to greater heights in young citrus trees.

Before making a decision on using irrigation for cold protection, a grower must understand some of the potential issues. Low-volume irrigation works as long as the heat added to the grove (sensible heat and the heat of fusion) is greater than what is lost. Heat losses from a grove when using irrigation will generally come from evaporative cooling. This process occurs when the dew point is low and evaporation of water exceeds that of ice formation. It takes 7.5 gal of water freezing to equal the heat lost in 1 gal of water evaporating. This demonstrates the importance of knowing the effects of dew point and wind speed on the effectiveness of low-volume irrigation. Another consideration is the power source of the irrigation system. Growers using electricity to power their irrigation systems should exercise caution. In past freezes, rolling power outages during peak demand have resulted in damage to citrus groves due to inadequate irrigation caused by ice plugging up emitters. Growers in this situation need to evaluate contingency plans for backup power sources. Growers also need to determine a critical temperature start time of microirrigation for cold protection. The start time needs to be prior to any formation of ice in the irrigation tubing; otherwise, the freeze protection could be compromised.

Tree wraps are used to protect the trunk and bud union of young citrus trees recently planted in the grove. The effectiveness of tree wraps is directly related to the insulating properties of the wrap used. Tree wraps are designed to reduce the rate of temperature fall around the trunk of young citrus trees. This reduction in the rate of temperature drop allows for critical temperatures to be reached after sunrise, past the time of minimum temperature. A number of tree wraps are available on the market today. Research has shown that poor insulating wraps can cause temperatures under the wrap to be lower than air temperature. Care should be used when determining if the chosen tree wrap will provide adequate protection of the tree trunk. Tree wraps with good insulating properties have been demonstrated to be quite effective, yet most growers have tended to rely solely on irrigation for freeze protection in the past 20 years. Young citrus trees are more susceptible to freezing temperatures than mature trees. Wraps could be an attractive alternative to entire-grove irrigation when protection is needed for only young trees.

To summarize, there are several citrus cold-protection practices or decisions growers can make to ensure the success of a grove in surviving freezing temperatures. Some of these would be done prior to planting, but additional practices can be deployed in an established grove.

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2026–2029 Florida Citrus Production Guide: Citrus under Protective Screen (CUPS) Production Systems[1]

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Citrus can be grown under protective screen structures for fresh-fruit production to exclude the Asian citrus psyllid (ACP, *Diaphorina citri*) — which is the vector of the causal pathogen of huanglongbing (HLB), or citrus greening disease — and thereby produce disease-free, healthy fruit. The benefits of eliminating HLB are immediate and include rapid, normal tree growth, higher yields of premium-quality fruit, negligible fruit drop, and uncomplicated fertilizer and irrigation requirements. Because CUPS is a relatively new citrus production system with new challenges, current guidelines are undergoing constant refinement by adoption of new research findings.

The CUPS significantly increases the cost of establishing a citrus grove due to the high cost of screen-house construction (on average, $1 per square foot). We evaluated the potential of six high-density polyethylene (HDPE) screens, ranging in mesh size from 17 to 50, to exclude ACP from citrus grown in CUPS production systems. We concluded that screens with rectangular openings need to limit the short side of the openings to no more than 384.3 µm with an SD of 36.9 µm (= no less than 40 mesh) to prevent psyllid from passing through the screen. The long side of the openings can be at least 833 µm, but the efficacy of screens exceeding this value should be tested before using.

The recommended 40- to 50-mesh screen may need replacement every 7 to 10 years, depending on exposure to tropical storm winds; replacements come at a lower cost than the entire structure. High-quality construction, including setting support poles in concrete, can help minimize potential wind-related damage in the future. When constructing new CUPS screen houses, it is essential to consider the size and shape of the structure, as these factors can significantly impact the economies of scale and also the functionality of a CUPS. A larger, more square-shaped facility can reduce the cost per acre, making it a more economical option. For example, a single 38-acre CUPS structure can cost $35,297 per acre, while four smaller square CUPS of 9.5 acres each can cost $36,841 per acre. However, this 4.2% increase in cost can be offset by the benefits of better management of pests and diseases, isolated storm damage, quarantined pest invasions, and preventing cross-pollination. In general, per-acre cost decreases with larger structures because the perimeter of a screen house grows only linearly with width and length, while the area grows quadratically. Thus, the cost for the framing, roof, and enclosure per acre falls as the structure becomes larger. A square (1:1 length-to-width) plan reduces the ratio of perimeter to area. For the same acres, a 10 × 10 acre (100 ac) square has a smaller perimeter than a 20 × 5 acre rectangle, lowering framing and cable costs. The "sweet spot" for commercial viability is around 10 acres; beyond that the marginal benefit diminishes but the cost advantage per acre remains.

Pests, such as mites, thrips, citrus leafminer (CLM), scales, and mealybugs may selectively enter through the permeable screen, while some of the larger pest predators are excluded. Most of these pests are significantly reduced compared to their populations outside, such as with CLM, and their infestations may be localized and easy to manage when detected early. However, the environment in the CUPS may better suit some pests, such as the citrus rust mite and the citrus red mite, to develop high populations. Although parasitoids of several pests, including scales, mealybugs, and CLM, and small predators such as predatory mites were regularly detected in the CUPS, they were not detected enough to provide full control of target pests. Greasy spot and other fungal diseases may also thrive in the more humid conditions of the screen-house environment. These nonlethal but economically important pests and diseases must be adequately controlled with integrated pest management approaches customized for CUPS to avoid loss of fruit quality and yield.

It is important to monitor CUPS on a regular basis for pests and diseases and to implement control measures, either by manually removing infested foliage or spraying treatments at an early stage of pest incursion to avoid dealing with high populations and spread. Yellow sticky traps for ACP and pheromone traps for male CLM are effective in detecting adults of these pests. However, visual examination of shoots is also required to check for larval infestations of CLM, thrips, scales, and mealybugs in the tree canopies. A magnifying lens is important in the detection of pest mites, thrips, and small predators such as predatory mites. The tap sampling method conducted in the tree canopies is useful in dislodging pests such as ACP, thrips, citrus red mites, and predatory mites onto a laminated sampling sheet where they are counted.

The ACP was successfully excluded long-term by the UF/IFAS screen-house structures for as long as there was no damage to the screen. Only one adult psyllid was found on a yellow sticky trap in the UF/IFAS Citrus Research and Education Center (UF/IFAS CREC) CUPS during nearly six years of weekly scouting and monitoring, and only one tree tested positive for HLB out of about 1,000 trees at that time. During the summer of 2020, a localized ACP outbreak occurred in the UF/IFAS CREC CUPS, following the period in March 2020 when the screen was completely replaced. The psyllids were controlled with comprehensive repeated insecticide sprays, and to date (9 years), HLB incidence is about 0.5%. The ACP was also detected at very low levels in the CUPS located at the UF/IFAS Indian River Research and Education Center (UF/IFAS IRREC) — mainly adults in the yellow sticky traps and some shoot infestation with immatures. Most of those infestations resulted from the damage to CUPS caused by Hurricane Irma and were cleared immediately through manual removal of infested shoots, followed by maintenance sprays of insecticides, which also helped lower the populations of other pests detected in the CUPS. No HLB incidence has been confirmed in the four CUPS structures at UF/IFAS IRREC. Several species of predatory mites and parasitoids as well as their potential prey, such as mites, CLM, scales, and mealybugs, were observed in the CUPS. For ACP and other pests, the most vulnerable entry point of a screen house is through the doors from the movement of personnel and equipment, so standard decontamination procedures should be followed. In particular, citrus leaves and other grove debris that adhere to personnel or equipment should be carefully removed before personnel enter a CUPS facility, because grove debris could carry live ACP eggs, nymphs, or adults that can be dropped in the screen house and cause an infestation. Double-door or foyer entrances (Figure 1) are the minimum requirement for preventing ACP entry into CUPS, and the trees should be regularly inspected for ACP and signs of their feeding damage on leaves.

Figure 1. Steel roll-up door with a second plastic strip door inside the UF/IFAS CREC CUPS.
Credit: Arnold W. Schumann, UF/IFAS

The expected economic benefit from adopting CUPS and excluding the Asian citrus psyllid (ACP) to prevent HLB infection is increased yield and quality of fruit, which in turn are expected to contribute to increased sustainability and profitability of citrus production. We evaluated the profitability of CUPS assuming the investment is for fresh Ray Ruby grapefruit. The main source of data is the experimental CUPS at the UF/IFAS CREC in Lake Alfred, Florida, for which production and input data is available for years 1 through 7 out of a 10-year horizon. For the years for which data was not yet available, the annual cash flows were estimated using sensible yield, packout rates, and prices assumptions and projections. We found that, when the grower insures the CUPS structure against hurricanes at a cost of $2,200 per acre, the Internal Rate of Return (IRR) ranges from 9.21% to 13.10% as the cost of the structure decreases from $1.03 per square foot to $0.69 per square foot. This implies that the investment in CUPS is profitable when the cost of capital is less than the obtained IRR. The profitability of the investment in CUPS is driven not only by the increased yield per acre and high packout rates resulting from ACP exclusion but also by the significant increase in the prices of fresh fruit in the last few seasons. From 2016/17 to 2020/21, grapefruit production in Florida decreased from 7.8 to 4.1 million boxes, which represents a 53% decline. From years 3 to 7 of the CUPS investment, the price per box of a size 32 fresh grapefruit increased from $36.74 to $52, which represents a 42% increase.

Early-maturing fresh-fruit varieties have additional advantages over late-maturing varieties because their fruits have to be protected from pests and diseases for less time. Thus, the risk of freeze damage to fruit is reduced, and routine pruning operations, including mechanical hedging and topping, can be conveniently conducted in the time between the end of harvest and the following bloom.

Trees can be grown in the ground and also in pots inside the CUPS (Figure 2), although pots are not recommended. In-ground trees developed a fuller canopy more quickly than potted trees, although fruit yields were similar within the first three years. Juice quality, however, can be better (i.e., higher Brix and acidity) for potted than in-ground trees. Results after seven years of growing citrus trees in pots of various sizes and designs at the UF/IFAS CREC CUPS showed that after about five years of high productivity, the trees became root-bound, causing lower vigor, diminished fruit size, and lower yields. Trees were successfully transplanted into the ground, where they recovered within one year and were producing 855 boxes/acre in year 7.5 (Figure 3). We currently recommend that citrus grown in CUPS should only be planted in the ground to ensure long-term sustainable production.

Figure 2. High-density (871 trees per acre) 'Ray Ruby' grapefruit trees in pots, yielding 380 boxes/acre in year 2, at the UF/IFAS CREC CUPS.
Credit: Arnold W. Schumann, UF/IFAS

Figure 3. High-density (871 trees per acre) 'Ray Ruby' grapefruit trees in the ground, yielding 855 boxes/acre in year 7.5, at the UF/IFAS CREC CUPS.
Credit: Arnold W. Schumann, UF/IFAS

The fruit yields in CUPS should also be produced as early as possible to achieve the desired early return on investment. Several different cultural methods for accelerating growth and optimizing early yields are being studied in the CUPS facilities at the UF/IFAS CREC, UF/IFAS IRREC, and UF/IFAS SWFREC. These include intensive hydroponics with daily or hourly delivery of all essential nutrients by drip fertigation to the trees; higher planting densities (871 and 1,361 trees per acre); selecting heat-tolerant, self-pollinating, seedless, precocious varieties without strong alternate-bearing habits; dwarfing rootstocks for limiting tree size when trees are grown in the ground; growing trees in containers to limit tree sizes with any rootstock; and canopy, irrigation, and fertilization management.

The CUPS is increasingly being adopted by growers in Florida, with over 2,000 planted acres in 2026. As most CUPS growers are now entering their first producing years, with others reaching that stage in the next couple of years, they are encountering challenges regarding fruit quality and yield. Among these challenges are, depending on the variety selected, variable yield over the years and lack of adequate peel color. These are not uncommon problems in the varieties grown under CUPS, but as a new system with unique conditions, it requires new approaches to solve them. One main advantage of CUPS is that trees are HLB-free and the level of stress can be controlled. For this reason, classical techniques of grove management may be adopted. Ways to improve cultural management procedures include deficit irrigation, manual pruning, and gibberellic acid treatments, as well as photoselective screens, reduced late-season nitrogen fertilization, and brassinosteroid treatments to achieve better fruit color. For both Sugar Belle® and Tango mandarins, deficit irrigation (i.e., watering both trees in the ground and in pots once every 15 days to field capacity for 2 months, December and January) can be adopted to increase yield. Our data shows a 30% fruit yield increase for both varieties, whereas gibberellic acid treatment (10 ppm spray) at petal fall of Sugar Belle® grown in the absence of cross-pollination increased fruit set by 2.5-fold. Similarly, deficit irrigation and brassinosteroid treatments at the beginning of peel color change can be implemented to promote both internal and external fruit maturation: our data show higher Brix after deficit irrigation and both higher Brix and significant advance in peel coloration after brassinosteroid treatments in Tango mandarins. In an experiment with Honey Murcott where preharvest fruit peel color during December was correlated with leaf tissue N, the leaf N concentrations in the optimum range (2.5% to 2.7%) were associated with greener peel colors, while leaf N concentrations in the lower ranges (2.2% to 2.4%) were associated with redder peel colors. Corresponding fruit Brix measurements followed a similar trend whereby lower leaf tissue N during the fruit maturation stage favored higher Brix. These treatments to improve fruit quality still need to be refined to find the most favorable window of treatment efficacy. More information about fertilizer splitting and timing to improve yields and fruit quality is available in chapter 14, "Nutrition Management for Citrus Trees."

In 2025, CUPSchat (https://citrusdiagnosis.ifas.ufl.edu/CUPSchat/) was created as a modern artificial intelligence tool designed to provide instant answers and reports from over a decade of CUPS knowledge. It pools information from over 100 documents and can be continuously updated with new information. CUPSchat can collate and interpolate information, including data collected over time in different documents, making it an invaluable resource for growers, Extension agents, and researchers. Its purpose is to assist users in finding accurate and reliable information on CUPS, and its functions include answering questions, providing data, and offering guidance on best practices.

In conclusion, CUPS is a relatively new citrus production system for growing HLB-free fresh fruit. It works by near-total exclusion of the ACP vector. This solution to HLB may seem simple but in reality is more complex, relying on novel integrated approaches for optimizing all management practices, including pest and disease management, planting densities, variety and rootstock selection, irrigation and fertilization, hedging and topping, harvesting, and marketing. Noteworthy additional advantages of CUPS are that trees remain free of citrus canker, citrus leafminer is easier to control, and trees and fruit are protected during hurricanes.

Figure 4. The UF/IFAS CREC CUPS facility near Lake Alfred, Florida.
Credit: Arnold W. Schumann, UF/IFAS

Figure 5. Sugar Belle® in the UF/IFAS CREC CUPS facility near Lake Alfred, Florida.
Credit: Arnold W. Schumann, UF/IFAS

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2026–2029 Florida Citrus Production Guide: Asian Citrus Psyllid[1]

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Psyllid Feeding Damage and Pathogen Transmission

The Asian citrus psyllid (ACP), *Diaphorina citri* Kuwayama, was first detected in Florida in 1998, and it has since become the key pest of citrus due to its role as vector of the pathogen that causes citrus greening disease, also known as huanglongbing (HLB) detected in 2005. The HLB pathogen, *Candidatus* Liberibacter asiaticus (*C*Las), is transmitted and spread by adult ACP but acquired primarily by nymphs. ACP are sucking insects, related to aphids, that obtain most of their nutrition from phloem sap, which they access by feeding on leaves. Young flush is required by the female to mature eggs, for egg laying, and by nymphs for development. Developing leaf buds and feather-stage flush are preferred for egg laying. Feeding on young shoots results in twisting and distortion of the leaves due to toxins present in saliva that are injected during ingestion. *C*Las can be transmitted from an infected adult to the next generation of nymphs through the intermediary of the flush, enabling both the tree and the next generation of ACP to become infected within as little as a month. However, infected trees do not show characteristic HLB symptoms of leaf mottling, dieback, and fruit drop until the root system becomes at least partially dysfunctional.

Factors Affecting Psyllid Populations

Once young leaves have expanded and are no longer suitable for egg laying, adult psyllids may either feed on mature leaves of the same tree or leave in search of other host plants. ACP is only able to reproduce on citrus or citrus relatives like orange jasmine (*Murraya paniculata*), although other plants may be used for adult survival. Target plants may be citrus trees within the same grove (particularly young resets, which flush more often) or trees in neighboring groves. Therefore, psyllid management practices in one grove affect future psyllid populations in nearby surrounding citrus groves. Temperature is also closely linked to the abundance of psyllids in the field. Ideal temperatures for maximum egg production are between 77°F–86°F. Above 93°F, lifespan decreases to less than 30 days, with a corresponding decrease in fecundity. Egg laying below 60°F slows to under two per day, and development time increases to two months. ACP populations in Florida are consistently lower during the midsummer months and in winter compared to late spring and even early fall due to both temperature and flush availability.

Psyllid Management

ACP control slows spread of HLB and is critical for young trees, which are most susceptible to HLB and most attractive to ACP due to frequent flushing. However, effective management is also required on mature infected trees to reduce reinoculation of the pathogen and allow the tree to produce healthy flush. Thus, vector control is a critical component of HLB management. The goal of psyllid management programs in commercial citrus groves is to reduce psyllid populations to the lowest levels possible and to remain economically viable.

Chemical Control

Use of insecticides to control ACP is a major component of HLB management strategies in Florida and elsewhere. Management programs should optimize benefits while minimizing cost of pest control, risk of pest resistance to insecticides, and negative impacts of insecticides on beneficial insects and mites useful for control of ACP and other pests. The information provided in this chapter is intended to aid in the development of site-specific psyllid management. Products recommended in this chapter for psyllid suppression have been demonstrated in field trials conducted by UF/IFAS to be effective for reducing ACP populations. However, *most of these products will have negative effects on natural enemies of insect and mite pests.* Therefore, *new pest problems may develop as a result of increased insecticide use for psyllid suppression*. However, the problems posed by these other potential pests are generally less serious than the threat posed by ACP as the vector of the HLB causal pathogen.

Noninsecticidal Control

Exclusion mesh, in the form of CUPS (see chapter 20) or Individual Protective Covers (IPCs), can prevent psyllid access to trees, thereby reducing the likelihood of *C*Las infection. Implementation of either tool comes with other challenges including cost and management of other arthropods and pathogens. However, exclusion mesh is currently the only tool that can fully prevent ACP infestation in citrus, and that has been proven to nearly eliminate HLB infection when trees are covered with the protective structures.

Nonbearing Trees

Young trees are most susceptible to infection with *C*Las. The multiple flushes they produce throughout the year place them at greater risk of disease infection, compared to mature trees, because adult psyllids are attracted to new flush. Even without HLB, young trees in the field need to be protected for about four years from psyllids and leafminers to grow optimally. Soil-applied systemic insecticides have historically provided the longest-lasting control of psyllids with the least impact on beneficial insects. Currently, three neonicotinoid (all group 4A mode of action) insecticides (imidacloprid, thiamethoxam, and clothianidin) and one group 28 insecticide (cyantraniliprole) are available for soil application to control ACP on young nonbearing trees. Because of the cost of the group 28 product, most use is presently restricted to 4A products. Depending on formulation, systemic insecticides are best applied to the soil, which is far more effective on young trees than foliar sprays.

Most soil applications of systemic insecticides are applied as drenches. For reset trees, this is the only application method. However, injection is effective and efficient once roots have established around emitters in solid blocks on drip irrigation. Soil drenches are best applied using an applicator metered to deliver 8–10 oz of formulated drench solution per tree. Drench applications should be applied directly at the soil-rootstock interface. Use restrictions limit the number of applications that can be made in a growing season. Imidacloprid applications are limited to no more than 0.5 lb a.i./acre per growing season, regardless of application method. This equates to 14 fl oz/acre for 4.6F formulations, 16 fl oz/acre for 4F formulations, or 32 fl oz/acre for 2F formulations. Thiamethoxam applications are limited to no more than 0.172 lb a.i./acre (or 3.67 oz Platinum 75 SG/acre) per growing season. Clothianidin (Belay 50 WDG) is currently labeled for use on nonbearing trees only and is limited to 0.4 lb a.i./acre (or 12.8 fl oz Belay 50 WDG/acre) per growing season. However, the Florida Department of Agriculture and Consumer Services (FDACS) has issued a Section 18 Emergency Exemption for Belay 2.13 Insecticide (EPA Reg. No. 59639-150) permitting two applications at a rate of 12 fl oz/acre each to bearing citrus trees. Applicators must have the 24c SLN label for Belay insecticide and the letter issued by the Commissioner (FDACS) present when making applications of Belay insecticide to bearing citrus.

Due to restrictions on the amount of neonicotinoid insecticide products that can be used per growing season, the number of allowed applications in solid plantings of trees 5–9 feet in height is greatly limited. It is also important to note that imidacloprid, thiamethoxam, and clothianidin share the same mode of action and are therefore not considered alternatives for rotation to prevent resistance. Foliar sprays of products with modes of action other than the ones used in drenches should be used between soil-drench applications to provide additional control of ACP and to help minimize pest selection for insecticide resistance development.

Bearing Trees

Foliar sprays of broad-spectrum insecticides targeting adults are most effective when used prior to the presence of new flush. Once psyllids begin reproducing on new flush, it becomes increasingly difficult to gain control of rapidly increasing populations. Management programs should begin by targeting overwintering adult psyllids with insecticidal sprays when the trees are not producing flush. Elimination of overwintering ACP adults greatly reduces populations in the following spring flushes and is recommended regardless of adult population size. Targeting adult ACP with broad-spectrum insecticides (organophosphates, group 1B, or pyrethroids, group 3A; see Table 1) early in the year may provide sufficient suppression of psyllid populations to reduce the need for psyllid sprays during bloom, when pollinators are present and most pesticides cannot be applied. Additional sprays of insecticides for psyllids should be made when observing an increase in adult populations in a grove. A threshold of one adult per 10 tap samples during the growing season has been shown to provide an economically viable level of suppression in mature trees with high incidence of HLB and fruit destined for the process market. Rotating modes of action throughout the year is important to reduce pest selection for insecticide resistance and conserve critically needed products.

Bee Caution

Citrus growers should be aware that most insecticides recommended for psyllid control have restrictions on the pesticide label due to the impact these products may have on pollinators. Planning to control psyllids prior to the presence of bloom will help reduce the need to apply pesticides during the bloom period. Check the pesticide label for restrictions on application of a product when trees are in bloom. Currently, there are 4 products in addition to horticultural mineral oil that are considered effective with minimal effects on pollinators when used as directed. Products listed in Table 2 are recommended for psyllid control during the period when citrus is in bloom.

Biological Control

While a single female psyllid may lay up to 800 eggs in the laboratory, studies in Florida have shown that over 90% of the resulting nymphs never make it to adulthood in the field, even in the absence of insecticides. Most are consumed by predaceous insects such as ladybeetles and spiders. The parasitic wasp *Tamarixia radiata* has become established in parts of Florida and contributes some mortality. Additionally, there are many pests, such as mites, leafminers, scales, mealybugs, whiteflies, and so forth, that are currently suppressed or maintained at low levels in Florida citrus either by biological control or the additional sprays now being used to control psyllids. Excessive sprays could result in resurgence of these pests. Foliar insecticide applications to mature trees during the growing season are best made with selective insecticides to minimize impact on natural enemies that help control psyllids and other pests.

Other Management Considerations

Management practices used within a grove can affect psyllid populations, especially those practices that promote new flush such as hedging, topping, and fertilization. Trees should always be sprayed with a broad-spectrum insecticide prior to or just after hedging and topping and before flush develops. Management strategies that reduce or limit the duration of flush may help to keep psyllid populations at low levels and reduce the need for additional pesticide applications. Alternate host plants, such as orange jasmine (*Murraya paniculata*) and box orange (*Severinia buxifolia*), near the grove can serve as sources of psyllids for infestation. When possible, these plants should be removed from areas surrounding commercial citrus groves.

Recommended chemical controls for Asian citrus psyllid are in the second booklet of the *Florida Citrus Production Guide*.

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2026–2029 Florida Citrus Production Guide: Citrus Leafminer[1]

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Citrus Leafminer Biology

Citrus leafminer (CLM) adults, *Phyllocnistis citrella,* are tiny moths that hide within the canopy during the day, emerging at dusk and at night to lay eggs individually on young, expanding leaf flushes. The egg first appears as a tiny dew drop, usually alongside the midvein on the underside of the unexpanded leaf. The larva emerges directly into the leaf tissue, feeding and mining first along the midvein, then back and forth as it makes its way to the leaf margin, where pupation occurs.

Leafminer populations decline to their lowest levels during the winter due to cool temperatures and the lack of flush for larval development. Populations build rapidly on the spring flush, although their presence is not apparent until late spring while the amount of new flush decreases. Throughout the ensuing warm season, leafminer populations vary with the flushing cycles, and subsequent flushes are often severely damaged.

The spring and summer period of high leafminer damage coincides with the rainy season, when citrus canker spread is most likely. CLM greatly exacerbates the severity of citrus canker caused by *Xanthomonas citri* subsp. *citri* (see chapter 29 of this guide, "Citrus Canker"). CLM is not a vector of the disease, although tunnels resulting from its feeding and mining are especially susceptible to infection, and infected tunnels produce many times more inoculum than in the absence of leafminer. Control of leafminer should be optimized where infection by canker is high, especially in young trees and susceptible varieties such as grapefruit and, to a lesser extent, early oranges.

Leafminer Sampling Method

Sampling is important to monitor CLM populations over time and to determine the timing to apply insecticides or pheromone-based disruption treatments. CLM generally exhibits two population peaks following the flush cycle, in spring and in fall, although the exact timing can vary from year to year. Pheromone-baited traps typically capture CLM adults about one month before peak infestation, providing an early indication that helps growers choose the optimal timing for insecticide applications. Because serpentine larval mines appear on the underside of new leaves only after larvae have already caused damage, action taken at that stage is often too late to be effective.

It is critical to have a sampling method in place to assess CLM populations before mines start to show up in the grove and to implement an effective control. Control methods such as drenching systemic neonicotinoids or diamide insecticides require one to two weeks after application to be translocated into leaf tissue and reduce larval populations. Similarly, pheromone disruption should be deployed when adults mate in the citrus grove, but it has no effect on eggs and larvae already present in the flush.

The best tools for monitoring CLM are delta traps equipped with a sticky liner on the bottom and baited with a lure that emits CLM sex pheromones. The trap should be placed on a branch at shoulder height. When CLM capture begins to increase, this indicates the optimal time to release a pheromone dispenser or to drench trees with systemic insecticides. It is recommended to deploy one trap per 3 to 5 acres. Trap captures are influenced by the pheromone release rate. Therefore, be sure to replace the lure every six to eight weeks to maintain maximum efficacy.

Leafminer Management

Nonbearing Trees

Leafminers are effectively controlled in young trees using systemic insecticides applied to control the Asian citrus psyllid (ACP). Soil applications of neonicotinoids or diamides should be made about two weeks prior to leaf expansion to allow time for the pesticide to move from the roots to the canopy. Applications of neonicotinoids in summer should be timed to avoid rain events within 24 hours, which would cause leaching of the product away from the root zone. The appearance of leafminers in the young flush of these trees is an indication that residual effects have worn off and reappearance of ACP is soon to follow. Foliar applications of products effective against CLM target larvae and, at best, provide no more than three weeks of protection. Therefore, timing is important, and sprays directed against CLM should be applied when the flush is about halfway extended to kill the maximum number of larvae.

Bearing Trees

Healthy trees with leafminer-damaged leaves are more likely to become sites for new canker infection if disease inoculum is already present nearby. The only products currently available for leafminer control on large trees are for use as foliar sprays. While several products are effective against this pest, achieving good control using foliar sprays is difficult due to the unsynchronized flush typically encountered during summer and fall. However, because leafminers affect only developing leaves, coverage of peripheral leaves in the canopy should be adequate to achieve suppression with foliar pesticides. Foliar sprays are directed against the larvae and should be timed to coincide with the appearance of the first visible leaf mines, which occur immediately following the feather leaf stage, or about 13 days after budbreak. At this time, insecticide applications will provide protection for most of the leaves in the new flush.

Historically, natural enemies present in Florida respond to leafminer infestations, causing up to 90% mortality of larvae and pupae. These natural enemies include the introduced parasitoid *Ageniaspis citricola*, which has established throughout most of Florida and has been responsible for up to 30% of this mortality, mostly later in the year. Several indigenous species of parasitoids such as *Pnigalio minio* also contribute to leafminer suppression.

Recommended chemical controls can be found in the second booklet of the *Florida Citrus Production Guide*.

AS ALWAYS, READ THE CURRENT LABEL OF ANY PESTICIDE TO BE USED.

Some product labels specify rates per acre, while others specify rates per volume delivered (e.g., per 100 gal). Refer to the label for details on how the product should be mixed for desired targets.

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2026–2029 Florida Citrus Production Guide: Rust Mites, Spider Mites, and Other Phytophagous Mites[1]

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Mites from four plant-feeding families commonly colonize citrus. These include (1) two citrus rust mite species in the family Eriophyidae: citrus rust mite, *Phyllocoptruta oleivora,* and the pink citrus rust mite, *Aculops pelekassi*; (2) three species of spider mites in the family Tetranychidae: Texas citrus mite, *Eutetranychus banksi*, citrus red mite, *Panonychus citri*, and the six-spotted mite, *Eotetranychus sexmaculatus*; (3) one species in the family Tarsonemidae: broad mite, *Polyphagotarsonemus latus*; and (4) three species of false spider mites in the family Tenuipalpidae: *Brevipalpus californicus*, *B. obovatus*, and *B. phoenicis*. The three species in Tenuipalpidae are associated with the spread of a disease called leprosis. This disease no longer occurs in Florida, but increasing risk of reestablishment in Florida exists with its recent spread in Latin America. Currently, rust mites, spider mites, and broad mites are common and cause economic damage to commercially grown citrus in the state.

Citrus Rust Mites

The citrus rust mite (CRM) and the pink citrus rust mite (PCRM) are found on all citrus varieties throughout Florida. Although they can coexist on the same leaf or fruit, the CRM is usually the prevalent species. PCRM generally develops to greater damaging populations early in the season (April–May). Both rust mites are important pests of fruit grown for the fresh market. On some specialty varieties, damage may be particularly severe on stems and foliage, causing leaf injury and possible abscission. Fruit damage is the main concern with other varieties. Both mites feed on green stems, leaves, and fruit, with the PCRM being potentially more destructive.

CRM and PCRM are particularly small, and a 10x magnification lens is needed for observation. Each of the two species goes through four developmental stages during their life cycle: egg, first instar (larva), second instar (nymph), and adult. Egg deposition begins within 2 days after the female reaches sexual maturity and continues throughout her life. The female lays one to two spherical transparent eggs (CRM) or transparent flattened eggs (PCRM) per day and as many as 30 during her lifetime. Egg hatch occurs within approximately 3 days at 81°F. Newly hatched larvae resemble the adult, changing in color from clear to lemon yellow (CRM) or pink (PCRM) after molting to the nymphal stage. After about 2 days at 81°F, molting occurs. The first nymphal stage resembles the larval stage and requires about 2 days to molt to an adult at the above temperature. CRM adults have an elongated, wedge-shaped body about three times longer (0.15 mm) than wide. PCRM are narrower, smaller, and rounded. CRM is usually straw to yellow in color, and PCRM is usually pink, but color is not always an effective or accurate means of separating the two rust mites. Males and females have an average life span of 6 and 14 days, respectively, at 81°F. In the field, females can live nearly 30 days in the winter. Rust mites develop from eggs to adults in 6 days at 81°F.

PCRM populations can begin to increase in April to early May on new foliage, reaching a peak in mid-June to mid-July, although the time of peak density can vary by several weeks depending on geographical location and weather. PCRM are more abundant in drier weather conditions. CRM population densities increase in May–July, then decline in late August, but can increase again in late October or early November. Mite densities in the fall rarely approach those occurring early in the summer. During the summer, CRM are more abundant on fruit and foliage on the outer margins of the tree canopy. The bottom portion of the north side of the tree canopy is generally preferred and supports the highest mite populations. The least favorable conditions for CRM increase are found in the top portion of the south side of the tree canopy.

Visible characteristics of mite injury differ according to variety and fruit maturity when damage occurred. When rust mite injury occurs on fruit during exponential growth, before fruit maturity (April to September), epidermal cells are destroyed, resulting in smaller fruit. These destroyed epidermal cells fracture as the fruit enlarges, causing a rough form of russeting known as "sharkskin." Damage to mature fruit creates a brown stain but does not destroy epidermal cells or the wax layer, leading to a polished look referred to as "bronzing." Fruit damage by rust mites affects the appearance and reduces grade initially but may also lead to reduced size, increased water loss, and increased drop under severe infestation.

Leaf injury caused by feeding of CRM exhibits many symptoms on the upper or lower leaf epidermis. When injury is severe, the upper cuticle can lose its glossy character, taking on a dull, bronze-like color or patches of yellowish discoloration where wounded epidermal cells have released ethylene. Damage to lower leaf surfaces results in collapse of spongy mesophyll cells, appearing first as yellow patches and later as necrotic spots. With the exception of upper leaf epidermal injury to some specialty varieties, defoliation caused by CRM is rarely severe.

Leaf injury caused by feeding of PCRM is dramatic at mite densities exceeding 200 or more per leaf. Both mature and developing leaves can be affected, resulting in varying degrees of leaf distortion, curling under of leaf margins, crinkling of leaf tissues, and ultimately burn and leaf dieback. PCRM feeds on the lower leaf surfaces following its movement from overwintering sites on buds in the early spring. Later populations move onto fruit, back to leaves as the mites migrate or disperse, and then decline.

The need for chemical treatments to control rust mites is dictated by numerous biological attributes of the mites, horticultural practices, and marketing objectives for the fruit. These key biological factors include (1) inherent ability of mites to quickly increase to injurious densities on fruit and sustain the potential for reproductive increase over time; and (2) small size, which makes it difficult to monitor population densities in the field and detect injurious levels until visible injury has occurred on the fruit. The marketing objective for fruit is particularly important. Cosmetic appearance is a priority for fruit grown for the fresh market. Fruit growth and abscission are not affected until 50% to 75% of the surface has been injured. Thus, there is reduced justification for chemical control of rust mites on fruit grown for processing. Citrus groves producing fruit designated for the fresh market may receive three or four miticides per year, typically during April, June, August, and October. In contrast, groves producing fruit designated for processing receive zero to two treatments per year. Miticides applied for the control of rust mites on fresh-fruit varieties are often combined with compatible fungicides in the spring and summer.

From a horticultural perspective, canopy density has an effect on rust mite populations and their ability to increase over a short period of time. The denser the canopy, the less favorable conditions are for a rapid rust mite increase. Because most registered miticides have no ovicidal activity and short residual activity on fruit and foliage, residual control is generally better if the miticide is applied when rust mite adult and egg population densities are low for fresh-market varieties.

Because external blemishes caused by rust mites, fungal diseases, and wind are less important when fruit are grown for processing, the chemical control strategy for rust mites can be modified significantly. A summer spray is often required for greasy spot control. Use of petroleum oil in place of copper will reduce the likelihood of requiring a subsequent miticide treatment. Further miticide treatment may be unnecessary. However, a second petroleum oil application may be required for greasy spot control on summer flush.

Many scientific methods for sampling or scouting rust mite populations have been described. Of these, three general approaches are in widespread use: (1) determining the percentage of fruit and/or leaves infested with rust mites; (2) using qualitative rating scales; and (3) counting individual adult mites taken from fruit on randomly selected trees. These sampling approaches are similar in that they are designed to avoid bias by randomly selecting different representative areas within a grove for sampling, avoiding border rows, and selecting fruit and/or leaves within a tree randomly.

One sampling method based on rust mite density (rust mites/cm^2) is described.

Processed Fruit

Initiate rust mite monitoring for PCRM in early April on leaves and fruit and continue every two to three weeks throughout the fruit season. CRM will tend to develop later in the spring or summer. Select trees at random and within uniformly distributed areas throughout a 10-to-40-acre block representing a single variety with uniform horticultural practices. Avoid sampling adjacent trees. Fruit should be sampled at random representing the four quadrants of the tree and taken midway in the canopy (between the interior and the exterior). One fruit surface area should be examined midway between the sun and shade areas. The number of rust mites per cm^2 should be recorded and averaged for the 10 acres, represented by 20 trees with four fruit per tree or 80 readings per 10 acres. Six rust mites/cm^2 would be a planning threshold where pesticide intervention may be required within 10 to 14 days. Ten rust mites/cm^2 would be an action threshold where treatment would be required as soon as possible.

Fresh Fruit

Similar to processed fruit, monitor every 10 to 14 days except with an average of 2 rust mites/cm^2 as an action threshold, because damage to fruit peel reduces the quality and rating of fruit for the fresh market.

Spider Mites

Three species of spider mites are potential pests on Florida citrus: Texas citrus mite, citrus red mite, and six-spotted mite. The Texas citrus mite is the predominant species in most groves throughout the state. The citrus red mite is usually second in abundance, but in some grove and nursery operations, it is the predominant species. The Texas citrus and citrus red mites occur on citrus throughout the year and are usually most abundant in groves between March and June. They are found most commonly on the upper leaf surface of recently mature flush, and all stages of the mites orient along the midvein. As populations increase, they move to leaf margins and fruit.

The six-spotted mite is a sporadic pest occurring in colonies on the lower leaf surface and tends to be more abundant following cold winters, especially during December. Localized populations of this mite can be recognized by characteristic yellow blistering on mature leaves between March and May. Populations decline rapidly in June and remain very low through the remainder of the year.

Spider mites feed primarily on mature leaves and differ from rust mites by feeding beneath the epidermal layer of cells. They are capable of removing cellular contents, causing cell destruction and reducing photosynthesis. Mesophyll collapse and leaf drop can result when trees are stressed by high spider mite infestations alone or in combination with sustained dry, windy conditions that may occur in the late fall, winter, or early spring months. When populations of Texas citrus mite or citrus red mites are high, they will also feed on developing fruit. Spider mites prefer dry weather and low relative humidity in the range of 30% to 60% and generally do not pose a sustained problem in the higher-humidity conditions that occur between June and September. Populations of Texas citrus and citrus red mites aggregate among leaves within and between citrus trees.

A sampling method has been developed that provides 25% or less error margins when motile mite densities (i.e., all stages except eggs) are above 2 mites per leaf. The sample unit is a mature leaf immediately behind flush leaves. Table 1 shows the optimum number of sample areas within a 10-acre block of citrus trees when using 1, 5, or 10 trees per area and collecting either 4 or 8 leaves per tree. For example, if you look at 1 tree/acre, then it is necessary to look at over 10 sample areas within a 10-acre block to achieve accuracy. If you examine 5 or 10 trees/area, then only 4 or 5 areas need to be examined. As mite densities increase above 2 mites per leaf, the optimal number of sample areas declines below 5. Table 1 provides examples of different sample sizes at different control thresholds.

When the control threshold is increased from 5 to 10 mites per leaf, there are corresponding reductions in the amount of sampling required within a 1- or 10-acre block. At weekly or biweekly intervals during periods of spider mite activity, collect either one leaf per quadrant (i.e., N, S, E, W) (4 leaves/tree) on each tree per sample area or two leaves per quadrant (8 leaves/tree). Sampling consistency is important because spider mite numbers can increase on one quadrant of a tree. Place leaves from individual trees into labeled paper bags and then into a cold ice chest for examination under a stereomicroscope; *or* examine individual leaves in the field with a stereomicroscope or 10x hand lens. If one motile stage of a Texas citrus or citrus red mite is present on either the upper or lower leaf surface, then the leaf is infested. A good relationship was found between the average number of Texas citrus mites or citrus red mites and the percentage of leaves infested across 10-acre blocks of young orange trees. For example, an average of five motile spider mites per leaf equals 70% to 80% infestation rate. This constitutes a treatment threshold for processing fruit.

Spider mites are suppressed to low densities by several species of predaceous mites, insects, and entomopathogens in some groves. However, when populations averaging 5 to 10 motile spider mites per leaf develop between September and May, it is reasonable to apply a miticide, especially if the trees are stressed. Infestations comprised predominantly of adults, particularly males, are in decline and would not require control. Adult mites are recognized by their large size relative to immatures, and females are distinguished by their round shape and shorter legs compared to males.

Need for controlling spider mites is based on temperature and humidity conditions, spider mite population levels, tree vigor, and time of year. Petroleum oil provides some ovicidal activity against spider mite eggs. None of the other miticides provide ovicidal activity, and their residual activity must be sufficiently long-lasting to kill subsequently emerging larvae.

Broad Mites

Broad mites are an economic problem on citrus grown in green- or shade-house conditions and on lemons and limes grown in the field. Broad mites are whitish in color and very small — about 160 microns in length. They are found on the lower surfaces of young apical leaves where their eggs are deposited. The life cycle is modified with an emerging larval stage lasting about one day and then molting. Pharate females (developing nymphs) are picked up by the males and moved to newly developing flush and young citrus fruit. Mating occurs immediately after the female emerges. Males are very active and live for about one week.

Broad mites are only capable of feeding on very young, tender leaf or fruit tissues. The toxic saliva that is injected by these mites can result in significant damage. New leaf growth that is fed upon becomes distorted and feathered. A delayed terminal dieback can occur on infested citrus seedlings. Subsequent development of damaged buds can result in a rosette and formation of witches' broom. Small fruit become silvered from intense feeding by broad mite with subsequent reduced fruit growth.

Optimal environmental conditions include warm temperatures, high humidity, and low light intensity.

Adults can survive through prolonged exposure to freezing temperatures but are sensitive to temperatures greater than 90°F.

Application of Miticides

Selection of a miticide should be based on the target pests to be controlled, avoidance of risk of phytotoxicity, products that will be tank-mixed, the time of year, treatment-to-harvest interval, and prior use of a product. With the current emphasis on Asian citrus psyllid and citrus leafminer control, it would be wise to choose a miticide that may also have some activity against one of these two pests, such as diflubenzuron (e.g., Micromite 80 WGS) or spirotetramat (e.g., Movento). Separate chapters of this production guide address Asian citrus psyllid and citrus leafminer management. With the exception of petroleum oil, no miticide should be applied more than once per year to avoid development of resistance. Time intervals for application of products to target mites are provided in the second booklet of the *Florida Citrus Production Guide*. Products listed for more than one time interval can be effective in providing mite control during those times, but use is still allowed only once per year. Petroleum oil spray applications can be effectively applied during the postbloom, summer, or fall intervals. Sulfur is included because it has a short treatment-to-harvest interval and provides a highly effective means of cleaning up rust mite infestations prior to harvest when needed. Use of sulfur should be minimized given its toxic effects on several beneficial arthropods.

Recommended chemical controls for mites can be found in the second booklet of the *Florida Citrus Production Guide*.

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2026–2029 Florida Citrus Production Guide: Soft-Bodied Insects Attacking Foliage and Fruit[1]

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This section is focused on sucking insects that affect foliage, twigs, and fruit of citrus in Florida. Insects covered here include scales, mealybugs, whiteflies, and aphids, which can all impact the health of both young and mature trees and their fruit quality. These insects differ from each other in their biology, generation times, and injury to plants, but approaches to monitoring and management are similar. Individual discussions of some groups are provided, and the tables of management options are organized by active ingredient, with the target pests from this chapter in bold text. Information on the Asian citrus psyllid and citrus leafminer can be found in separate chapters of the *Florida Citrus Production Guide*.

Scale Insects

There are two major groups of scale insects: soft scales and armored scales. Soft scales generally become larger in size than armored scales and are somewhat mobile as nymphs. Nymphs and adult female armored scales are completely sessile, and adult males of both are tiny gnat-like insects with a single pair of wings. The cover and body of soft scales are attached, whereas the cover can be removed from armored scales, revealing the round body underneath. Another important distinction is that armored scales produce no honeydew, while soft scales produce copious amounts of honeydew that attract ants and serve as substrate for sooty mold, which often accumulates on foliage below the infestation.

The most important soft-scale species in Florida citrus is the Caribbean black scale (*Saissetia neglecta*), followed by green and brown scales (*Coccus viridis* and *C. hesperidum*, respectively), cottony cushion scale (*Icerya purchasi*), and Florida wax scale (*Ceroplastes floridensis*). Mature females are usually found on scaffold limbs, especially those of young trees. Mobile first instars, or "crawlers," move out toward the outer canopy, and successive nymphal stages gradually migrate inward.

The most important armored scales in Florida are snow scale (*Unaspis citri*), Florida red scale (*Chrysomphalus aonidium*), California red scale (*Aonidiella aurantii*), purple scale (*Lepidosaphes beckii*), Glover's scale (*Lepidosaphes gloveri*), and chaff scale (*Parlatoria pergandii*). Snow scale tends to infest the trunk and scaffold limbs, especially those of grapefruit. The name refers to the male nymphs, which are white, numerous, and indistinguishable from males of the related species, a lesser snow scale, *Pinnaspis strachani*, and fern scale, *P. aspidistrae*. Female snow scales are relatively large, oyster-shaped, and purple in color with a median ridge. Lesser snow scale generally inhabits smaller limbs, and fern scale makes small, round colonies of males on leaves and fruit, with a single female off to the side. Florida red scale and California red scale typically inhabit fruit, leaves, and small limbs, while purple, Glover's, and chaff scale may be found in any part of the canopy.

Historically, pest management of both armored- and soft-scale insects in Florida citrus has been based on highly successful action of native and introduced natural enemies, including predators, especially ladybeetles, parasitic wasps, and fungal pathogens. These relatively specific natural enemies coexist with their hosts in the citrus grove under most conditions and can respond to and suppress pest numbers when they periodically increase in individual groves. Thus, scale insects should not be considered key pests in development of seasonal programs. However, there are conditions under which natural enemies may not function well. It is in these cases that scale insects achieve importance in an overall integrated pest management program. Factors that are most often responsible for increases in scale populations are (1) weather conditions that disrupt biological control; (2) movement of the pest to groves where natural enemies do not occur; and (3) disruption of natural enemies by other practices, particularly repeated use of broad-spectrum insecticides during a period when natural enemies are active and exposed. When these disruptions occur, scale populations can increase sufficiently to damage leaves, fruit, twigs, branches, or trunks. The sessile nature of scale insects promotes high concentrations of scales in limited areas within the grove, and so building populations can go unnoticed for several generations. Generation times for most scale species require more than one month to progress from egg to adult. Thus, populations do not build quickly like some other pest groups, such as mites or aphids.

The first consideration for management should be to determine if the problem is induced by management practices and can be solved by changing those practices. For example, if repeated applications of broad-spectrum pesticides are responsible for scale population increase, then the solution is to stop use of broad-spectrum products and opt for selective materials that can allow natural enemies to recover. If, on the other hand, seasonal fluctuations have brought about population levels of concern, then some intervention with insecticides may be required. The basis for this decision should be population levels of living scales that are deemed sufficient to cause direct damage or produce large quantities of honeydew, which promotes the growth of sooty mold (soft scales only). Scale bodies from previous generations often remain on the plant for several months and may be mistaken for living scales, resulting in the application of pesticides at inappropriate times. For effective suppression, most scale species should be in young nymphal stages (crawlers) at the time of application, because pesticides are not very effective against eggs, large nymphs, or adults. In spring, crawler activity can be monitored using double-sided tape wrapped around a citrus branch and checked weekly. No economic injury levels or thresholds are available for scale insect pests in Florida. Thus, the manager must evaluate each situation, considering the intensity and extent of scale populations and how much damage is likely to result. Generally, the intent of spraying for scale insects is to reduce populations with a single application during the crawler activity period such that no additional sprays are necessary during that season and disruption to biological control is minimized.

Treatment, when warranted, should focus on selection of an appropriate material (see Table 1), but it is equally important that treatment be applied with thorough coverage in mind. Because scale insects are completely or largely immobile, direct contact is essential. Spray volume, ground speed, nozzle choice, and location of the pest populations should all be emphasized to get maximum target coverage. If only a few trees are involved, then spot treatment with a handheld sprayer or other focused application equipment will provide best results. Generally, spray applications designed for contact with pests on the outer canopy are not effective at suppressing scales, especially if the scales are numerous in the interior of the tree. The follow-up to insecticide application for scale insects should involve evaluation of live scale numbers on the appropriate parts of the tree. Dead scales will not be visibly distinguishable from living scales at first. Hatching crawlers will also create the impression that the spray was not effective. Complete elimination of scale insects following an insecticidal spray is neither practical nor necessary and in fact may be counterproductive.

Soft scales are generally not pests needing treatment; however, high populations of scales can be damaging to citrus. Following mild winters and when populations build within specific groves, treatment, where needed, should be based on scouting for crawlers and young nymphs during the generation that develops in April–May. Applications at other times are ineffective.

Citrus snow scale likewise is a local problem requiring occasional treatment in specific groves or portions of groves. Evidence for the need to treat includes high populations of crawlers showing on patches of bark that have been brushed clean during the previous week and the association of visible snow scale populations with bark splitting, particularly on young trees that are rapidly increasing in trunk girth. Spot-treat wood of heavily infested trees to runoff with a handheld sprayer.

Mealybugs

Citrus mealybugs (*Planococcus citri*) are normally under good biological control by a complex of natural enemies in citrus. However, intensive spraying for psyllid control may disrupt their biological control. Mealybugs' waxy covering, sedentary lifestyle, and preference for feeding in concealed locations make them very difficult to kill with insecticides. Only the most toxic materials have appreciable efficacy against mealybugs, but these materials also pose risks to the environment and are likely to disrupt biological control of other pests. Consequently, treatment is warranted only in cases of severe infestations or when the fruit itself is attacked. Systemic materials give superior control while minimizing impacts on beneficials but may not act quickly enough to prevent damage when high populations are established.

Lebbeck mealybug/hibiscus mealybug (*Nipaecoccus viridis*), present in Florida since 2009, was recently reported in citrus, with the first population documented in the late spring of 2019. Like other mealybugs, it prefers to feed in cryptic locations, making it difficult to find until populations are high enough that large amounts of sooty mold develop and damage to fruit, leaves, and branches is visible. Severe infestations can result in twig dieback and even death of young trees. Several predatory insects have been found to consume this species, and with careful spray planning, they can be integral to gaining control of this pest. Early-season control is key to reducing yield loss from Lebbeck mealybug. Systemic materials that can be applied during bloom should be used to prevent population buildup and protect developing fruit. Contact materials can provide near-term population reduction by killing crawlers and young nymphs, but these materials have little efficacy on the reproductive adult. If using contact insecticides, target them toward times when crawlers are abundant, which can be determined by scouting. **These findings for Lebbeck mealybug are preliminary.**

Whiteflies

The most important whiteflies in Florida are citrus whitefly (*Dialeurodes citri*), the cloudy-winged whitefly (*Singhiella* [=*Dialeurodes*] *citrifolii*), the wooly whitefly (*Aleurothrixus floccosus*), and citrus blackfly (*A. woglumi*). These insects are generally present in most groves in very low numbers and are normally under good biological control by various specialist parasitoids and generalist predators, including the entomopathenogenic fungus *Aschersonia alyrodis*, which can provide excellent control of whitefly nymphs. Whiteflies are dependent on new growth for their development and reproduction; consequently, they are active in citrus only during periods of flush. Populations are rarely high enough to warrant treatment unless biological control has been disrupted. Large populations of these insects can deposit considerable volumes of honeydew, leading to sooty mold accumulation. Serious infestations of whiteflies are an indication that management practices should be reviewed.

Aphids

The most common aphids in Florida citrus are the green citrus aphid or Spirea aphid (*Aphis spiraecola*) and the cotton or melon aphid (*A. gossypii*). The green citrus aphid is responsible for curling of young flush due to feeding injury. This aphid and the melon aphid attack many different plant species and migrate into citrus mostly in spring. The brown citrus aphid (*Toxoptera citricida*) is the most important vector of citrus tristeza virus (CTV), which is responsible for quick decline of trees on sour orange rootstock that often die suddenly with fruit still attached. Brown citrus aphid has a narrow host range restricted largely to Rutaceae, particularly citrus, and has now become rare in Florida, possibly due to intense spraying for psyllids. However, melon aphid is also a vector of CTV and is also dark in color, but mottled, distinguishing it morphologically from brown citrus aphid. Aphids are dependent on the availability of newly expanding leaves for their development and reproduction, so these insects may become problematic during periods of new citrus growth, primarily on young trees in spring and fall. Aphids are largely controlled by many generalist natural enemies, such as ladybeetles, hoverflies, and lacewings, that normally maintain their populations and those of other insects found in flush below levels that warrant treatment in producing groves. Excessive honeydew accumulation on leaves will result in the growth of sooty mold fungus that blocks light and reduces photosynthetic activity. However, mature groves sustain little damage and should not need treatment. Treatment is warranted only in young groves (<3 years old) if a large portion (i.e., >50%) of expanding terminals is infested. Surveys for aphids should be conducted early in flushing cycles when most terminals are still in the feather stage. Systemic materials, such as Admire — applied to the soil for young trees or by foliar application for mature trees — will give good control with minimal impact on beneficial species, but the time required for uptake of these materials by the tree restricts their usefulness to preventive, rather than responsive, treatments.

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2026–2029 Florida Citrus Production Guide: Plant Bugs, Chewing Insect Pests, Caribbean Fruit Fly, and Thrips[1]

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The insects listed in this section are generalist feeders for which citrus is not a preferred host. They are therefore only sporadic problems in Florida citrus. While these pests do not require routine treatment in all groves, periodic outbreaks can potentially have dramatic impacts on tree health or productivity. When these insects are detected at a damaging level, treatment is required. Some pests may migrate into citrus from adjacent field or forage crops when these are harvested. Given that the distribution of these insects is rarely uniform, some monitoring effort should be directed toward delineating the boundaries of an infestation prior to any chemical application so that treatment can be limited to affected blocks only. Benefits of "spot" applications, or restricting treatments to affected areas only, are twofold: (1) direct monetary savings realized through reduced labor and material costs, and (2) the preservation of unsprayed refuges for beneficial arthropods, which ensures rapid recovery of natural enemy populations and accelerates the post-treatment restoration of biological control. Frequent monitoring (especially during growth flushes), proper identification, and timely application of the appropriate control measures are all essential to reducing the impact of these pests. If insecticide treatment is needed, select in priority a product that is also efficient in controlling Asian citrus psyllid (ACP) in order to include the treatment for these erratic pests in your ACP program and reduce insecticide applications.

Plant Bugs

Plant bugs are Heteropteran insects that feed on a wide variety of plants and occasionally migrate into citrus in large numbers when adjacent field crops are harvested. The most important species affecting citrus are the citron bug (*Leptoglossus gonagra*), the leaf-footed plant bugs (*L. phyllopus* and *L. zonatus*), and the southern green stink bug (*Nezara viridula*). They may also develop on decaying undergrowth within the grove. Under normal conditions, plant bugs are rarely numerous enough to be any cause for concern. However, in large numbers, they tend to aggregate and move into trees during the fruit ripening period. In this period, they can cause substantial direct damage by puncturing the peel to suck juice. Pathogens enter through the puncture wound, producing a surrounding sunken area of necrotic tissue. If damage is done early enough, fruit will fall before harvest. Thin-skinned varieties such as Hamlin are especially vulnerable, as well as fruits destined for the fresh market. Timely weed control can avert plant bug problems, whereas mowing or herbicide treatment of infested weeds may exacerbate a problem. In such a case, insecticidal control may be necessary. If possible, spot treatments of infested areas are always preferable in the interest of conserving natural enemies.

Orange Dog

The adult of the orange dog is the giant swallowtail butterfly (*Papilio cresphontes*). Orange-dog eggs are large, round, semitranslucent, orange, and easily recognized on the expanding terminals where they are typically laid. The developing larvae are shiny brown and white, resembling bird droppings, and they feed preferentially on the new leaves. Under normal conditions, populations are low, and the damage is sufficiently dispersed such that there is little cause for concern. However, especially in the fall, situations can arise wherein large numbers of butterflies deposit numerous eggs on very young trees that then suffer severe defoliation from developing larvae. As with most caterpillars feeding on fruits, damage can only be averted by chemical treatment if the problem is detected early (i.e., when most of the larvae are still in early stages of development). When larvae reach later instars, they are more resistant to insecticides, and most feeding damage will have already occurred. Careful monitoring of young groves early in flush cycles is necessary for timely detection and treatment. For all caterpillar issues, *Bacillus thuringensis* (Bt)-based materials provide effective control with the added advantage of being listed by OMRI, the Organic Materials Review Institute, as not affecting beneficial species.

Grasshoppers, Crickets, and Katydids

These insects rarely require chemical control because they are only a problem sporadically and in specific circumstances. Grasshoppers, primarily the eastern lubber grasshopper (*Romalea microptera*) and the American locust (*Schistocera americana*), can cause serious damage to growth flushes and may also damage fruit, especially in its early stages. The broad-winged katydid (*Microcentum rhombifolium*), the restless bush cricket (*Hapithus agitator*), and the jumping bush cricket (*Orocharis luteolira*) may also attack citrus. However, these insects typically do not spend their entire life cycles on citrus and are usually only a problem if they enter groves in large numbers. Adjacent pastures, hay fields, and fallow lands can be significant sources of these insects, as can weedy swales and row middles. Timely weed control and regular mowing of the surrounding vegetation can often prevent this problem.

Asian Cockroach

The Asian cockroach (*Blattella asahinai*) is very similar in appearance to the German cockroach (*Blattella germanica*), although their habits are quite different. The Asian cockroach flies readily and rarely invades dwellings, in contrast to its German cousin. First detected in Lakeland in 1986, the Asian cockroach quickly spread throughout the state and is now present in most citrus-growing areas. They feed primarily on decaying vegetation and largely inhabit moist litter under trees. However, they can also climb into the canopy, especially at night, where they feed on tender flush, giving it a ragged appearance. Insecticide applications, if deemed necessary, should be directed at the soil under the canopy where the population resides and takes refuge.

Fire Ants

While fire ants (*Solenopsis invicta*) are largely predaceous and may attack pests such as citrus leafminer larvae or newly hatched root weevil larvae, some situations can favor a high density of fire ants and lead to direct damage to citrus. For example, trunk wraps applied to very young trees can provide a protected environment for fire ants to attack tender young bark. Density of fire ants can also dramatically increase on soil mounted to protect young trees from frost. Fire ant damage to trunks of young trees produces sap flows that are collected by the ants. Girdling and death of the tree may result from direct effects of ant feeding or foot rot caused by infection of Phytophthora. Leaf buds may also be damaged by feeding. Fire ants also disrupt biological control against ACP and aphids by attacking natural enemies (e.g., ladybugs and lacewings) of those pests. High densities of fire ant mounds can create problems for grove workers during maintenance of irrigation systems and for fruit pickers at harvest. Long-term control is best obtained with food baits, although soil applications of contact insecticides or even foliar applications of oil may provide temporary relief sometimes needed during harvest. Trying to eradicate fire ants completely from a citrus grove is not a desirable or reasonable objective. Only treat mounds directly adjacent to citrus trunks where ants can cause direct damage.

Eastern Subterranean Termite

The eastern subterranean termite (*Reticulitermes flavipes*) is a native inhabitant of forests throughout the eastern United States, where it plays a major role in the decomposition cycle of wood into soil. Subterranean termites feed on seasoned wood, especially pines, and are major pests of wooden structures throughout their range. Only rarely do they attack living trees. This habit is poorly documented in the literature. Nevertheless, they can become serious pests of citrus in groves where pine woods had supported large termite populations. They persist on buried remnants of the original wood but will also girdle and kill young citrus. Populations in groves have been estimated at 5 million individuals and may range over thousands of square yards. Termites are most prone to attack citrus in the summer when rising water tables force them to abandon other food sources, but attack may occur in any season. Attack commences below the soil line and thus may escape detection until tree death. The termites chew bark and cambium, generally above the scaffold roots and down to bare wood around the trunk. Lesions are characteristically clean and free of gumming. Feeding may advance above the soil line below the bark, in covered galleries, or under tree wraps. Rapid tree decline once girdling is 90% or more complete is characterized by shock bloom, interveinal chlorosis, loss of foliage, and death. Attack is usually limited to trees 5 or fewer inches in diameter.

Control consists of preventing the problem, first by meticulous removal of wood residues from new grove sites, and then by creating physical or chemical barriers around trees. Eventually, the problem will usually subside due to tree growth beyond the susceptible stage or natural attrition of the colony through lack of sufficient food supply. The following recommended practices can be employed to avoid most losses:

- Remove as much wood as possible when preparing a new grove site, particularly on pine land.
- Scout suspected infested areas by looking for signs of girdling and inspecting tree crowns below the soil line for lesions and termite activity.
- Do not use tree wraps in infested areas.
- Wash soil from crowns, exposing scaffold roots to discourage termites from their preferred attack site.
- Create a chemical barrier directly around the tree crown, preferably with a granular insecticide. This practice will give a maximum of three months of protection.

Caribbean Fruit Fly

The Caribbean fruit fly, *Anastrepha suspensa*, is a pest of many tropical and subtropical fruits of south and central Florida. The Caribfly is about ¼ inch long with a yellow and brown body and black markings on the wings. Eggs are laid singly under the surface of the peel on ripe or overripe fruit and hatch in two to three days. Larvae feed for 10 to 14 days and develop in decaying fruit. Larvae develop into pupae, and the adults emerge later to complete the cycle.

Caribfly does not pose a direct threat to Florida citrus production, but the management of this pest may be necessary to export fruit to certain domestic and foreign markets. Fly-free zones may be created to produce fruit for export. The primary requirements are (1) the designated area and a buffer zone must be maintained free of preferred hosts such as loquat, rose apple, guava, and Surinam cherry, and (2) routine trap surveys must be conducted to monitor any Caribfly movement into the area and document absence. When populations are sufficiently high on the survey traps, bait sprays are used to reduce fly numbers. In addition, postharvest protocols may be implemented to ensure that fruit arrives at its destination free of live flies.

Growers and others interested in participating in the Caribfly program must contact the Florida Department of Agriculture and Consumer Services, Division of Plant Industry, Caribbean Fruit Fly Protocol, 3501-0-03 South US #1, Ft. Pierce, FL 34982-6666; phone (772) 468-4092.

Thrips

Thrips are small, elongate insects in the order Thysanoptera, varying in size from less than 0.2 mm to over 2.0 mm in length. They are easily overlooked because of their minute size. The life cycle of a thrips species consists of an egg, two larval feeding stages, a nonfeeding prepupal stage, a nonfeeding pupal stage, and feeding adults. About 14–18 days are required to complete development from egg to adult in some *Frankliniella* species.

Flower Thrips

Flower thrips, *Frankliniella bispinosa* and *F. kelliae*, have been identified as causing injury to developing flowers of navel and Valencia oranges. Crop loss on other citrus varieties has not been evaluated to date. *F. bispinosa* is the prevalent species throughout the citrus-growing areas of the state, while *F. kelliae* occurs on citrus from Vero Beach and Hardee County in the north to Dade County in the south. Thrips feeding results in cellular evacuation one to five cells deep and subsequent necrosis that can result in abortion of the flower or small fruitlet. Adult populations of these two species migrate as “aerial plankton” prior to and during the regular flowering cycle between January and April each year. Both species have very wide host ranges and utilize flowers and pollen of many plants as food sources. High populations of these thrips can cause economic loss in navel or Valencia orange by reducing fruit set. Both thrips species insert eggs singly into all floral parts.

Examine orange blocks during flowering at least twice each week to identify periods when high populations of thrips (i.e., *Frankliniella* spp.) are migrating into the trees. The number of thrips per citrus flower that causes economic loss has not been determined. Adult thrips are about 1 mm long and yellow to straw-colored. Dark banding along the upper surface of the abdominal segments may be evident on some adult specimens. Larvae are white or yellow. Thrips are capable of entering buds as soon as individual petals begin to separate. Examine individual flowers at random with a 5–10x magnification and observe their numbers. Residual activity of insecticides is very short (i.e., three to seven days). Timing of one insecticide application to protect the major flowering period between maximum bud swell and full bloom should be considered when thrips are abundant. This is best achieved by treating the block at maximum bud swell or onset of full bloom. Delay will allow thrips to enter the opening flowers and reduce exposure to the insecticide. Treatment recommendations (Table 1) are based on the need for chemical control to optimize fruit set for the fresh market. The recommended insecticides are toxic to honeybees, which are also active around citrus blooms.

Orchid Thrips

Orchid thrips (*Chaetanaphothrips orchidii* and *Danothrips trifasciatus*) and greenhouse thrips (*Heliothrips haemorrhoidalis*) cause rind-blemish problems on developing fruit (i.e., ring spotting or irregular russeting), on immature and mature clustered fruit, or where a leaf or twig is in direct contact with a fruit. For all these species, economic loss has been restricted to fruits directed to the fresh market, mainly red grapefruit and satsuma.

Orchid thrips females are yellow to straw-colored with distinctive dark banding on the wings. Larvae are white or yellow with distinctive minute spines present on the upper surface of the eighth abdominal segment. Adult female greenhouse thrips are black, while the larval and pupal stages are white. All stages of the greenhouse thrips are occasionally found on fruit. Orchid thrips is the most commonly found species associated with damaged grapefruit and occurs throughout the year. *D. trifasciatus* is usually present in lower numbers than other orchid thrips. Examine interior clusters of red grapefruit at random with a 5–10x magnification beginning the first week of May or just as clustered fruit begin to touch for presence of orchid and greenhouse thrips larvae and adult females. Either wash suspected infested fruit individually in a bucket containing 80% alcohol and record the grove location to verify pest thrips or collect three or more samples of 20 clustered fruit at random from each 10-acre red grapefruit block. Each of the 20 interior-canopy red grapefruit should be immediately washed in a bucket containing about 1 pt of 80% alcohol. Fruit should be collected at random with not more than four fruit taken per tree and a minimum of five trees per sample. The presence of 20 or more adult or larval thrips warrants an insecticide treatment. If more than five thrips are found, the area should be resampled in a week. One or two insecticide applications (Table 1) between May and July may be required to prevent rind blemish damage on red or white grapefruit varieties.

Chilli Thrips

Chilli thrips (*Scirtothrips dorsalis*) is an increasingly common pest in screenhouse citrus production — e.g., in CUPS (see chapter 20) and nurseries. Chilli thrips are approximately one-third the size of flower thrips and can enter through most screens currently used to exclude insect pests. Chilli thrips cause feeding damage to leaves that reduces photosynthetic capacity and inflict rind damage to fresh fruit similar to fruit damage caused by broad mite. Management of this pest is currently under evaluation.

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2026–2029 Florida Citrus Production Guide: Citrus Root Weevils[1]

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Citrus root weevils represent a complex of species known to infest citrus trees and various alternate host plants in Florida. The most common species infesting citrus, in order of greatest geographical distribution, are the *Diaprepes* root weevil, *Diaprepes abbreviatus*; the blue-green citrus root weevils, *Pachnaeus litus* and *Pachnaeus opalus*; the little leaf notcher, *Artipus floridanus*; and the Fuller rose beetle, *Asynonychus godmani*. Other lesser species inhabit citrus on occasion.

All citrus root weevils have a similar life cycle. They have three immature stages: egg, larva, and pupa. Adult weevils emerge from the soil and lay eggs on host plants aboveground, the larvae drop to the soil to feed on roots, and the pupae and teneral adult stages are spent belowground. Adults emerge from the soil throughout the year. Peak emergence varies within species and by geographical region (ridge vs. coastal and interior flatwoods). Peak adult emergence for the blue-green root weevils and Fuller rose beetle is normally April and May. *Diaprepes* adult emergence from the soil peaks in late May to early July, while peak adult abundance on the tree canopy parallels adult emergence in May/June but can have a second peak in late August to mid-October. The second peak is sporadic. The little leaf notcher has three generations per year. Although there is some overlap of generations, adults appear most abundant on trees in April/May, July/August, and October/November. All adult weevils are attracted to the nonreflective silhouette of the citrus tree trunk. The little leaf notcher and Fuller rose beetle are flightless and must crawl up the trunk, but other species will fly to the canopy.

The most visible plant damage resulting from adult feeding is notching of the margins of leaves of young, tender shoots. Notching patterns differ slightly among species and can be confused with grasshopper injury. Prolonged leaf feeding by adults appears to cause no economic effects in mature groves; however, on occasion, feeding will cause virtual defoliation of small replants.

With the exception of little leaf notchers, which prefer a weed host, larval feeding injury to the roots by other root weevils, particularly *Diaprepes* root weevil, can have a devastating effect on citrus trees because all larval stages feed on the roots for most of the year. Tiny hatchlings feed on fibrous roots, whereas larger larvae feed on the larger structural roots, forming deep grooves as they consume the outer bark, including the cambium layer. Roots may be girdled and killed in the process, or the crown may be girdled, causing tree death. Larval feeding sites predispose the root system to infection and girdling by *Phytophthora* spp., thereby exacerbating economic loss.

Pest Management

Methods of Sampling Root Weevil Larvae and Adults

The population abundance and distribution of endemic citrus root weevils, regardless of species, vary from grove to grove, within a grove, and within a season. The peak seasonal soil emergence of adults within a citrus grove can be monitored using ground traps to capture emerging adults or via visual sighting of adults in the tree canopy. No methods exist for monitoring larvae in the soil. By monitoring adult emergence and abundance, the approximate time and intensity of peak adult emergence can be estimated for each infestation. Depending on the species of weevil and their seasonal abundance pattern, a grower can apply adult control measures when weevil populations are highest. Research suggests that adult emergence in spring often coincides with the onset of summer rains in late May through June, increasing soil temperature and the summer flush in central Florida groves.

Cultural Considerations

Citrus root weevil management begins with the selection of a phytophthora-resistant rootstock that is certified weevil-free. Optimal soil drainage is fundamental to citrus root weevil management, particularly in heavier soils common to the coastal and interior flatwoods where insect and pathogen populations are highest. Tree decline associated with *Diaprepes* distribution is often patchy within groves and most obvious in lowlands. Stressed trees frequently harbor higher populations of adults because these stressed trees frequently generate more leaf flushes as food for adults. Spot-treating these locations with a chemical or biological agent should help. Regular fertilization and irrigation are crucial to new root growth in weevil-infested groves. Fertigation at monthly intervals has been used by growers to promote the growth of fibrous roots after *Diaprepes* has destroyed the taproot and inner crown of the tree. Skirt pruning and trunk banding can be effective in controlling flightless weevil species. Weed control is also needed to prevent movement into trees from stems of grasses and/or broadleaf weeds. Weed control is probably beneficial in reducing populations of alternate host plants. **The use of sound cultural practices by the grower should be adequate for managing all citrus root weevils on mature trees except for the *Diaprepes* root weevil and blue-green citrus root weevils.**

A wide range of parasites, predators, and pathogens attack citrus root weevils at one or more developmental stages within the tree canopy or in the soil. Most of these natural enemies are widely distributed and are general feeders. When focusing on cultural tactics favoring tree health and not using chemical methods, growers are conserving and augmenting the natural enemies of citrus root weevils.

Pest Control Considerations

Pest management of *Diaprepes* and, to a lesser extent, other citrus root weevils must begin with control of different life stages, particularly adult weevils, using the following options: (1) foliar sprays for egg and adult suppression, (2) chemical barriers for larval control, and (3) biological control of all subterranean stages with nematodes. The application of these control tactics is timed according to monitoring of adult emergence and the onset of leaf flushing in the spring/summer period. Any of these tactics should reduce root injury and help sustain root health from grove to grove. For many groves, however, pest management might differ according to (1) rootstock susceptibility to soilborne diseases (i.e., *Phytophthora* spp.) and (2) root stress caused by excessive flooding and poor drainage of sandy loam soils. In certain grove situations, a soil fungicide for control of *Phytophthora* spp. should be advised.

Newly planted resets and groves younger than five years old with an established *Diaprepes* infestation on a susceptible rootstock can decline within two years without adult and/or larval control. A similar grove situation involving a resistant rootstock will have lesser tree decline but will require adult suppression. **Remember, groves planted on deep, sandy soils will often require no supplemental control and can rely on biological control agents.**

Foliar sprays of different contact (knockdown) insecticides that include petroleum oil to improve residual effect are used to target adult weevils in the tree canopy. Although foliar sprays have been used by growers to suppress adults any time of the year, research in central Florida has shown conclusively that root injury is lessened and overall tree health improved when two foliar sprays are used 4 weeks apart during peak summer flush in late May through June, along with an egg sterilant in the last application. The purpose of adult suppression with foliar sprays is to limit the number of gravid females and egg deposition, thereby reducing the number of larvae entering the soil. An egg sterilant such as Micromite 80WGS has a six-week residual effect, during which females lay sterile eggs and eggs contacting the leaf surface are nonviable. The addition of petroleum oil to the spray mixture affects the bonding characteristics of the substance bonding the egg mass to the leaf.

Multiple applications of most foliar sprays within a season can incite an abnormal increase in spider mite populations; any pesticide, when used frequently, might cause secondary pest outbreaks or lead to resistance.

A chemical barrier applied as a band to the soil surface beneath the tree through an herbicide applicator provides a treated surface that will kill newly hatched invasive larvae before they reach the root system. The chemical must be uniformly applied from the trunk to the dripline of the tree to a moistened soil surface devoid of litter. Greater spray volume (~40 gal/ac) should ensure greater uniformity of coverage. Disturbance of the soil beneath the trees should be minimized to protect the soil barrier. Because neonates are killed upon exposure to treated soil as they pass through the barrier, this control tactic is best used for resets and young plantings infested with phytophthora, where root injury by larvae must be minimal.

Timing chemical application to the time of year when larval entry into the soil is highest requires monitoring of adult weevils in the tree. Because highest larva recruitment occurs just after peak adult emergence, growers should apply soil treatment in early July, about two weeks after peak adult emergence in central Florida. Peak adult emergence is generally two to three weeks earlier in coastal groves.

Currently, Brigade WSB, a synthetic pyrethroid, is the only chemical registered for neonatal larvae control and applied as a soil barrier. Brigade has about three weeks of residual presence in the soil and will suppress ants foraging on the soil surface. Generally, ant predators will recover after 30 days.

Physical barriers consisting of landscape fabric on the soil surface were shown experimentally to be highly effective in preventing the newly hatched larvae from entering the soil and newly developed adults from escaping beneath the fabric. These barriers have been used for weevil management in California and Texas with some success and are increasingly employed in Florida on both flat-ground and raised beds. In addition to weevil management, the fabric has been shown to conserve water use and increase root and tree growth rates. Various ground-cover fabric products have been used in citrus trials (e.g., Lumite, Ultraweb 3000), but it is critical to use a product with high water infiltration rate to avoid irrigation runoff. The cost of the fabric and installation is high, but the savings in reduced water use and weed and insect pest management, as well as better tree growth and reduced weevil damage, would potentially make the treatment profitable where weevil damage is high.

The use of individual protective tree covers (IPC) for psyllid management will also prevent adult *Diaprepes* from laying eggs on young trees. Protecting trees from both huanglongbing and *Diaprepes* root feeding during the first several years, when trees are most susceptible to damage, makes the use of these devices an especially promising IPM tactic.

Parasitic nematodes that specifically attack insects are infectious to all larval stages of citrus root weevils. They are naturally found in citrus soils, where they inflict mortality to all weevil life stages they contact. Depending on availability, nematodes are also sold as biopesticides to control citrus root weevil larvae. They should be applied during months when soil surface temperatures are expected to exceed 70°F. Weevil larvae are generally most abundant in the soil during the summer (mid-July through September); therefore, one or more nematode applications are recommended at this time of year if soil moisture via natural causes and/or irrigation is adequate. Nematodes should not be applied within four weeks of nematicide use. Properly modified herbicide applicators or microsprinkler irrigation systems are used to deliver nematodes into premoistened soil. Approximately one acre-inch of water should also be applied to the irrigated acre immediately following application. Application late in the day or on cloudy days is encouraged to reduce nematode desiccation and exposure to lethal UV radiation.

Nematode products are most effective when applied in sandy soils with coarser soil texture and are less effective in very fine-textured soils at recommended rates. Higher rates can be applied to very fine-textured soils. *Nematode products that have been tested and recommended by UF/IFAS are currently unavailable.*

A fungicide for control of *Phytophthora* spp. may be recommended under the following conditions as a supplemental strategy to larval and adult weevil control: (1) the soils are fine-textured, poorly drained, or high in pH and calcium carbonate; (2) the trees are on rootstocks susceptible to *Phytophthora* spp.; and (3) populations are above the damaging levels (20 and 40 propagules per cm^3 soil) for *P. nicotianae* and *P. palmivora*, respectively. Remember, larval and/or adult weevil control must be effective before fungicide treatment is justified.

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2026–2029 Florida Citrus Production Guide: Nematodes[1]

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Integrated pest management (IPM) for nematodes requires (1) determining whether pathogenic nematodes are present within the grove; (2) determining whether population densities of some nematodes are high enough to cause economic loss; and (3) selecting a profitable management option. Attempting to manage nematodes may be unprofitable unless the above procedures are carefully followed. Similarly, some management methods pose risks to people and the environment, and therefore it is important to know that their use is justified by the actual conditions in a grove.

Nematode Pests

Although many different species of nematode have been found in association with citrus roots, relatively few have been documented to be economically important. The nematode species of major economic importance in Florida include the citrus nematode (*Tylenchulus semipenetrans*), causal agent of "slow decline" of citrus; the burrowing nematode (*Radopholus similis*), causal agent of "spreading decline" of citrus; the coffee lesion nematode (*Pratylenchus coffeae*); the sting nematode (*Belonolaimus longicaudatus*); and the dagger nematode (*Xiphinema vulgare*). The first three species listed are endoparasites, which parasitize feeder roots either by establishing a feeding site within the cortical root tissue, where they remain throughout their life (citrus nematode), or by continuously migrating through the feeder roots, thereby impairing root function and permitting further infection by microbial pathogens. Sting and dagger nematodes are ectoparasites that remain in the soil feeding at the tips of fibrous roots, stopping root growth, which causes stubby root symptoms that greatly reduce fibrous root mass and function. These ectoparasites are especially damaging to newly planted trees.

Typical Symptoms

Most nematode species that are known pathogens of citrus do not actually kill the tree but can significantly reduce tree vigor, growth, and grove productivity. Nematode-infested trees generally grow more slowly and may ultimately be of smaller size and lower quality. Aboveground symptoms that develop due to root damage include thinner canopies with less new foliar growth and twig dieback within the upper tree canopy. Symptoms of decline frequently increase with time and are more apparent during periods of environmental stress (i.e., drought or freezing temperature) or when combined with other damaging soil pests (e.g., root weevils, *Phytophthora*) or other adverse soil conditions (flooding, high salinity).

Monitoring Nematodes

The distribution and abundance of nematodes in soil prior to or after planting will affect the severity of the problem and define the need for nematode management. The only effective way of determining the presence or distribution of nematodes within a grove is by soil and root tissue sampling of undercanopy areas of individual trees. A representative grove sample for most nematode species consists of soil and roots (using a shovel or soil sampling tube) collected from the undercanopy areas of 20–30 trees within a 5-acre block. When sampling for burrowing nematodes, collect a large quantity of fibrous roots from the surface 0–12 inches beneath 10–12 declining trees (enough to loosely fill a 1-gal freezer bag). Immediately after collecting the sample, thoroughly rinse soil from the roots and from inside the bag and place the roots back in the freezer bag. Once soil and root samples have been collected, they should never be subjected to overheating, freezing, drying, or prolonged periods of exposure to direct sunlight. Samples should be submitted immediately to a commercial laboratory or to the UF/IFAS Nematode Assay Laboratory for analysis and recommendations. Damaging levels of citrus nematode have been estimated based on when samples are taken. In Florida, the citrus nematode population densities are highest during mid- to late spring, just prior to the onset of the summer rainy season. Sample accuracy is highest at this time of year. Springtime numbers of 800–3600 citrus nematodes extracted from 100 grams of soil or 300–1400 females from one gram of roots are moderate levels that may respond to management, primarily at the higher ends of these ranges. Numbers of citrus nematode below these levels require no management, but annual monitoring is advisable. Numbers exceeding these ranges are likely to decrease the size and quantity of harvested fruit. Vigorous, highly productive groves are capable of supporting very high population levels of the nematode, but at the expense of carbohydrates otherwise destined for fruit. High nematode levels will also slowly impair tree health. If samples are taken at other times of year, comparable ranges are 400–2400 soil stages or 100–1100 females. Detection of any burrowing or coffee lesion nematodes indicates that serious root damage is likely occurring. No threshold ranges are available for sting or dagger nematodes because their population levels are not seasonally predictable. However, when detected in samples, damaging levels of these nematodes are evidenced by the stubby or swollen roots of declining trees.

Managing Nematodes

Nematode management should be considered only after the results of soil and root sampling are available. The agency or company that processed the samples should be able to indicate whether potential nematode problems exist within a grove. In most cases, nematode management should not be considered until all other potential causes of tree decline are evaluated and corrected. For more detailed information on treatment decisions and methods of nematode management in citrus, consult the *Florida Citrus Rootstock Selection Guide*; chapter 6 of this guide, "Best Management Practices for Soil-Applied Agricultural Chemicals"; or local UF/IFAS Extension personnel.

Sanitation

Once established, nematodes cannot be eradicated from groves, so the best method to manage plant-parasitic nematodes in new plantings is to exclude them from a grove by using only trees from nurseries certified nematode-free by FDACS Division of Plant Industry. Use of certified trees will virtually eliminate the possibility of nematode problems in new groves planted in virgin soils or in old citrus soils never infested by nematodes, provided that care is taken to always use clean equipment in those groves. Use of certified trees also reduces damage during the early years of growth in old, previously infested groves if soil nematode populations are low. High soil nematode densities hinder the beneficial effects of the use of certified trees. Sanitation of equipment to remove soil and root debris before moving between groves is an effective means of preventing the spread of nematodes.

Cultural Practices

Proper grove management is critical to mitigate damage caused by plant-parasitic nematodes. Managing nematodes is of little value if other serious problems (citrus greening, poor soil drainage, insufficient irrigation, foot rot and fibrous root rot, root weevils, improper fertilization, or acid or alkaline irrigation water) limit root function and/or otherwise reduce tree health. In the case of burrowing nematodes, specific cultural practices (avoidance of disking, frequent irrigation, and fertigation) are critical to maintain a vigorous root system in the shallow soil horizons where the nematode is much less active. Individual protective tree covers (IPC) that prevent citrus greening disease have been shown to mitigate damage to young trees by sting nematodes.

Rootstock Resistance

Resistant rootstocks are also available to manage citrus and burrowing nematodes. Swingle citrumelo and C35 are widely planted rootstocks with resistance to citrus nematode. Neither rootstock tolerates high soil pH. In less common instances in Florida where calcareous conditions occur, Forner-Alcaide #5, a rootstock developed in Spain, is resistant to citrus nematode and tolerant of high soil pH. Milam lemon, Ridge Pineapple, and Kuharski Carrizo citrange are all resistant to burrowing nematode. The existence of races of these nematodes capable of breaking resistance compromises their value somewhat; nevertheless, large numbers of groves are currently growing well on resistant rootstocks in the presence of these nematodes. To avoid the development of resistance-breaking races, these rootstocks should only be utilized when replanting groves, not when replacing unthrifty trees in existing groves where the nematodes occur.

Chemical Control

Environmental concerns and deregistration of numerous pesticides, particularly those of older chemistry, have dramatically reduced the availability of chemical products for nematode management. In recent years, however, the discovery and commercialization of new chemical nematicides have advanced rapidly. Currently, there are no soil fumigants recommended for preplant nematode control, mainly because of a variety of labeled use restrictions, including minimum soil depths to soil layers restrictive to water movement, requirements for buffer zones, personal protective equipment, and mandatory good agricultural practices. For example, most citrus grown on deep sandy soils of the central ridge soil cannot utilize Telone II because these soils do not have a relatively shallow hard pan or soil layer restrictive to downward water movement (such as a spodic horizon) within 6 ft of the ground surface. Nevertheless, fumigation with Telone II is permitted in those areas where confining layers are present and growers are willing to comply with label requirements. Postplant nematicides can provide temporary suppression of nematodes in the shallow part of the root zone. Fluensulfone (Nimitz) and fluopyram (Velum) were registered recently for nematode management in citrus. Both compounds are highly toxic to plant-parasitic nematodes and far less toxic to humans and other animals than the carbamate nematicide oxamyl (Vydate), which has long been used in Florida. Ongoing research is evaluating the profitability of using these products to manage nematodes on trees with severely reduced root systems due to huanglongbing.

Because of Florida's uniquely porous soils, soil-applied pesticides have the potential to contaminate surface sources and groundwater. Consequently, their use should be restricted to the mid-to-late autumn and early spring, when rainfall is least in Florida. These materials should not be applied near irrigation or drinking-water wells or where the water table is close to the soil surface. Irrigation systems should always be inspected prior to pesticide application to soil to prevent overapplication of pesticide or water due to line breaks, faulty line-end pressure valves, or missing emitters. Additional considerations for the application of fumigants (where permitted) and nonfumigant nematicides to soil are outlined further on in the chapter.

In the case of citrus nematode, response to preplant fumigants in newly planted young trees may be particularly slow, because nematode population increase may be delayed until canopy closure of adjacent trees occurs. To protect groundwater, some preplant fumigants can only be used in areas with an underlying impermeable layer within 6 ft of the soil surface; the area must also be capable of supporting seep irrigation. Tree response to postplant chemical treatment often requires a period of one to two years of repeated treatment for growth improvement and significant yield returns. Because postplant nematicides are not eradicants, repeated treatments are required to periodically suppress nematode repopulation of soil and roots. Preplant nematode management programs (sampling, selection of appropriate rootstocks, use of certified trees) are therefore important considerations for maximizing young tree growth and eventual long-term productivity, because it may not be possible to assure satisfactory tree growth with postplant chemical management programs alone. However, if nematode problems do arise on young trees, early management of the populations can have a prolonged beneficial effect on the trees' subsequent growth and productivity. Nematode control with postplant, nonfumigant nematicides occurs primarily within the zone of application and, to a much lesser degree, within and around roots outside of the zone of application due to the systemic activity of some of these pesticides. Because a large majority of fibrous roots grow within the surface 24–30 inches of soil and decrease in abundance from the tree trunk to the row middle, proper nematicide placement to maximize undercanopy coverage is of critical importance. Nematicide placement under the tree canopy can significantly improve overall nematode control by targeting applications to areas of highest fibrous root and nematode density. Treatments will be most effective if made when soil temperatures are warm enough for nematode development and uptake by the tree. Natural degradation of nematicides moving downward in soil also increases with increasing soil temperature, thereby reducing the likelihood of groundwater contamination. To confirm the value of treatment programs, it is wise to designate areas of grove that will remain untreated in order to evaluate product performance and tree growth response.

A lack or loss of nematicidal efficacy and citrus yield response can be associated with factors other than improper pesticide application rate, placement, and application timing. The repeated use of nematicides often results in diminishing activity due to accelerated microbial degradation when populations of microorganisms capable of metabolizing these products increase in response to the compound. Rotation of products is desirable because the degradation process can be initiated after a single treatment. Postplant nematicides do not necessarily kill nematodes upon direct contact: efficacy usually requires long, continuous exposure to sublethal, yet toxic, concentrations in soil. Nematode population reduction results from a disruption of normal nematode behavior necessary to complete the life cycle. Disappearance rates of nematicides in soil (due to leaching and/or microbial degradation) are therefore critical determinants of treatment efficacy.

Pesticide leaching to depths below the primary root zone can occur as a direct result of excessive irrigation or rainfall. Given the sandy, permeable nature of citrus soils and generally low soil organic matter content, irrigation schedules based on soil moisture deficits are likely to improve nematode control and grove response to treatment by maximizing retention of toxic concentrations within the citrus tree root zone and prevent problems of environmental contamination. Undercanopy weed growth may reduce nematicide effectiveness by interception or absorption of pesticide residues targeted for citrus roots or nematodes in soil. Undercanopy weeds also interfere with microsprinkler operation and can prevent uniform coverage of chemigated nematicides.

Web Address for Link

Florida Citrus Rootstock Selection Guide: https://ask.ifas.ufl.edu/publication/HS1260

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2026–2029 Florida Citrus Production Guide: Huanglongbing (Citrus Greening)[1]

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Huanglongbing (HLB; citrus greening) is caused by the bacterium *Candidatus* Liberibacter asiaticus (*C*Las). The name huanglongbing means "yellow shoot disease," and it derives from the bright-yellow shoot symptom that commonly occurs on a sector of an infected tree. HLB is an extremely serious citrus disease because it causes tree decline and affects all citrus cultivars. The HLB-causing bacterium found in Florida is the Asian species, which occurs in warm low-altitude areas and is transmitted by the Asian citrus psyllid (*Diaphorina citri* Kuwayama). The Asian citrus psyllid was discovered in Florida in 1998 and is now found throughout the state wherever citrus is grown.

Early HLB symptoms on leaves include vein yellowing and an asymmetrical chlorosis referred to as "blotchy mottle." The blotchy mottle of the leaf is the most diagnostic symptom of the disease, especially on sweet orange. For a visual representation of HLB symptoms, see PP327, "Huanglongbing (HLB; Citrus Greening) Leaf and Fruit Symptom Identification." The blotchy mottle symptom also may be confused with other diseases or damage such as severe forms of citrus tristeza virus (CTV), *Phytophthora* root rot, waterlogging, citrus blight, leafminer tunnels, or citrus stubborn disease (an exotic disease to Florida). Leaves may be small and upright with a variety of chlorotic patterns that often resemble mineral deficiencies such as those of zinc, iron, and manganese. Some leaves may be totally devoid of green or exhibit green islands. Young trees decline quickly and rarely become productive if they are infected shortly after planting. As mentioned above, early symptoms of yellowing may appear on a single shoot or branch. The yellowing usually spreads throughout the tree canopy over several years. It is common for affected trees to show twig dieback. Fruit are often few in number and small, may be lopsided with a curved central core, and fail to color properly, remaining green at the stylar (flower) end. Many fruit drop prematurely from afflicted trees in the month prior to harvest. A yellow stain may be present just beneath the peduncle (stalk) on a cut fruit. The affected fruit often contain aborted seeds and have a salty, bitter taste reminiscent of unripe fruit. Root systems are heavily damaged by HLB, with 30%–50% root loss occurring in the early phases of the disease. More than 70% root loss has occurred by the time canopy decline is visible. Current information about the effects of HLB on root systems is available in chapter 16, "Root Health Management."

The causal bacterium present in Florida, *C*Las, has not been cultured, and formal diagnosis is done by PCR. Detection of the bacterium is usually only possible from blotchy mottle symptomatic tissues. The host range of the *Ca.* Liberibacter spp. that cause HLB includes all citrus species regardless of rootstock. Normally symptoms are severe on sweet orange, mandarins, and mandarin hybrids and moderate on lemon and sour orange. Grapefruit symptoms are moderate initially but become suddenly severe after several years. Lime, pomelo, and trifoliate orange are listed as more tolerant, but this does not mean that the bacterium is unable to infect and multiply in those cultivars. Severe symptoms have been observed on pomelo and lime.

The consequences of unmanaged HLB can be grave. Mature trees start to decline slowly and eventually become nonproductive after infection. The outcomes are worse for young trees. In most cases, the trees never reach full production, and in the worst case, the trees die within one to two years of planting. Because HLB also can be transmitted with infected budwood, the use of certified disease-free planting materials is essential to maximize planting success.

Psyllids are the primary vector for HLB spread and are present in Florida year-round, so their management is a necessary part of an integrated management program. Peak activity and movement occur in the spring and summer with the development of new flush. Because HLB is very common in Florida citrus, psyllids are likely to carry the bacterium between plants when they move, increasing the disease pressure in plants that are already infected and establishing the bacteria in young plants. New tools are also under evaluation to determine the best way to protect young trees from HLB. In addition to management within the field, noncrop hosts for psyllids require attention because they can be a source of this pest. The Asian citrus psyllid feeds on many rutaceous plant species. Of these plants, orange jessamine (*Murraya paniculata*) and box orange (*Severinia buxifolia*) serve as hosts for both the psyllid and *Ca.* Liberibacter spp. Movement of these ornamentals is restricted under state compliance agreements, and they should not be moved from areas where the disease occurs.

Recommended Practices

Overall, integrated pest management strategies should focus on the following: use of disease-free nursery trees, an optimal nutritional regime, reduction of the inoculum by frequent disease surveys, removal of symptomatic trees, and focused management of Asian citrus psyllid populations. Growing trees in Citrus under Protective Screen (CUPS) is another option detailed in chapter 20. Specific recommendations based on tree age are listed below.

A. Young Trees/New Plantings

1. The use of clean budwood and certified healthy trees is essential for successful replanting. It is now mandatory in Florida that budwood sources and nursery production be carried out under psyllid-proof enclosures and certified HLB-free.
2. Preventing psyllid access to flush is important in managing HLB. Systemic insecticides, such as imidacloprid, have traditionally been used for this purpose (see chapter 21, "Asian Citrus Psyllid"). However, resistance to imidacloprid and several other commonly used insecticides has been detected in specific regions in the state in the past. Therefore, it is recommended to contact your local UF/IFAS Extension agent or citrus entomology state specialist to assist in developing insecticide-based management plans. Some biological control for psyllids is available, but the amount of control provided by introduced parasitoids has been insufficient to slow disease spread. Exclusion netting has been demonstrated to be an effective tool to keep psyllids from feeding on trees for up to two years. For more information on this non-insecticide-based tool, see UF/IFAS publication HS1425, "Individual Protective Covers (IPCs) for Young Tree Protection from the HLB Vector, the Asian Citrus Psyllid."
3. Scouting for HLB-affected trees should be done routinely in young plantings in areas where HLB is not widespread (e.g., north Florida or compromised CUPS structures) so that infected trees can be removed quickly. It is recommended that scouting be conducted four or more times per year. Symptoms are the easiest to find from October to March, although they may be present at other times of the year, too. The current methods used to scout are walking or all-terrain vehicles. Symptomatic tree numbers and the rows in which they are found should be marked with colored flagging tape. GPS coordinates should be taken or the sites should be marked on a map to facilitate relocation and removal of these trees. In some cases, an HLB PCR diagnostic test may be necessary to confirm the disease (see diagnosis below).

B. Mature Trees

Diagnosis of HLB by symptoms alone may be difficult because some nutrient deficiency symptoms and other problems are often confused with some of the symptoms associated with HLB. Samples of trees suspected to be infected with HLB may be sent for PCR diagnosis to the FDACS Division of Plant Industry or the UF/IFAS Plant Diagnostic Center.

In mature groves, psyllid management will vary based on growers' needs but should be based on the goal of reducing the population to minimize impacts of reinoculation and potential for spread to young plantings. Population reduction is most often achieved using insecticides. When using insecticides, modes of action must be rotated for resistance management (see ENY-854, "Quick Reference Guide to Citrus Insecticides and Miticides"). Insecticide resistance has been detected in several counties; therefore, it is prudent for growers to contact their county Extension agents or state specialist for advice on which materials to use in programs.

Windbreaks in the form of trees have been evaluated and found to reduce psyllid migration into fields. Windbreaks may also provide habitat for predatory insects that can help reduce local psyllid populations. Predatory insects — including lady beetles, lacewings, and the imported parasitoid *Tamarixia radiata* — can help in reducing the young psyllid populations within a field.

C. Horticultural Management for All Groves

1. Plant nutrition is essential for optimum growth and yield of high-quality fruit. A fertilizer program should include all mineral nutrients. An excess or deficiency of any single nutrient can adversely affect tree performance. HLB-affected trees have smaller and weaker root systems compared to healthy trees; therefore, nutrient uptake is limited in HLB-affected trees. Hence, it is suggested to apply fertilizer and irrigate in frequent, small doses because this can increase the uptake potential of the tree. Controlled-release fertilizer and fertigation can be strategic alternatives to multiple applications of conventional dry granular fertilizer. Recent research indicates that secondary macronutrients and micronutrients are critical for maintaining tree health of HLB-affected trees; however, these nutrients should not be applied in high doses. The focus should be on balanced and constant application of all nutrients in split doses throughout the year.

   Soil and irrigation-water pH also play an important role in nutrient availability to the plant. HLB-affected trees perform better when the soil pH is around 6.0–6.5. Intensive fertilizer and irrigation management will not cure the tree of HLB but can potentially improve the quality and productivity of HLB-affected trees. It is highly recommended that before making any changes to a fertilizer program for HLB-affected or healthy trees, leaf and soil nutrient analysis is performed and taken into consideration. The goal of the fertilization program should be to have all the leaf nutrients in the high end of the optimum range. For more information, refer to chapter 13, "Irrigation Management of Citrus Trees"; chapter 14, "Nutrition Management for Citrus Trees"; and chapter 16, "Root Health Management."

2. Irrigation management is crucial for HLB-affected trees because these trees experience a significant reduction in root biomass following infection. This decline compromises their ability to absorb water and nutrients from the soil, making them more susceptible to drought stress. This is particularly concerning during the dry season (October–May), when trees rely heavily on supplemental irrigation for their water needs. Recent field trials have shown that more frequent irrigation, applied in smaller amounts, improves soil water availability throughout the day and leads to higher leaf water potential. The better water status of trees receiving frequent irrigation likely helps prevent flowering induced by late-season drought stress. Additionally, this improved water status supports greater reproductive and vegetative growth during the spring flush. As a result, the trees benefiting from more frequent irrigation consistently achieve significantly higher yields over the years. Refer to chapter 13, "Irrigation Management of Citrus Trees."
3. Recent studies suggest that HLB-affected trees undergo an imbalance in plant hormones due to a growth-plant defense tradeoff. In several multiyear field trials with plant growth promoting hormone, gibberellic acid (GA) showed that it can promote vegetative growth and improve productivity of HLB-affected trees. It is recommended to use GA from August–December to promote vegetative and fruit growth and suppress excessive flowering. However, precautions must be taken as GA-treated fruit stay externally green. GA is thus an additional tool that growers can use to improve the growth of HLB-affected trees, but it cannot substitute for other integrated grove management practices.

   Another multiyear field trial on plant growth regulators (PGRs) has demonstrated that single applications of 2,4-D and GA (alone) are not effective in reducing HLB-associated preharvest fruit drop. Nonetheless, a combination application of 2,4-D (Citrus Fix; 3.2 oz/acre) and GA (Progibb LV Plus; 10 oz/acre) can reduce fruit drop significantly in HLB-affected 'Valencia' sweet oranges when applied in the November–December period.

   Refer to chapter 18, "Plant Growth Regulators," for more information.

D. Removal or Pruning of Infected Trees

1. Removal of infected trees is the only way to ensure that they will not serve as a source of the bacterium for psyllid acquisition and subsequent transmission. Generally, removal happens when the tree is no longer productive or is infected very early and will never be productive. In regions where HLB is not widely established, infected trees should be treated with a foliar insecticide (e.g., Danitol, fenpropathrin) to kill all adult psyllids feeding on that tree. Failure to control psyllids will result in them dispersing to new plants once the diseased tree is removed, potentially infecting new resets or plantings.
2. Pruning of trees and symptomatic limbs has been attempted; however, because HLB is systemic, pruning is not successful because tree roots are infected before canopies are symptomatic. Additionally, because the tree is still infected after pruning, the new flush produced will serve as a feeding site for adult psyllids to acquire an even higher concentration of the bacterium than before. The infected psyllids may then disperse to uninfected trees once the new flush hardens off. Moreover, pruning can stress the root system even further, resulting in an overall weak tree and reduced root system. Refer to chapter 17, "Canopy Management."

Note: Oxytetracycline (OTC) Trunk Injection

Oxytetracycline trunk injection for HLB management was widely adopted in 2023 after the registration of two injectable formulations of OTC in Florida. While there are promising results from trunk injections in some locations, this is not universal. Until more information is available on what factors determine success and the long-term outcomes of OTC trunk injection, we cannot make a formal recommendation of the practice. We will evaluate the available data each year to include revisions. Visit the UF/IFAS Citrus Research website for more information about OTC trunk injections.

Additional Information

Links to resources on HLB and UF/IFAS documents can be accessed through the UF/IFAS CREC website at the following addresses:

https://crec.ifas.ufl.edu

https://citrusresearch.ifas.ufl.edu/

OTC Trunk Injections:
https://citrusresearch.ifas.ufl.edu/production-systems/trunk-injections/

Web Addresses for Links

UF/IFAS publication ENY-854, "Quick Reference Guide to Citrus Insecticides and Miticides": https://edis.ifas.ufl.edu/publication/IN807

UF/IFAS publication HS1425, "Individual Protective Covers (IPCs) for Young Tree Protection from the HLB Vector, the Asian Citrus Psyllid": https://edis.ifas.ufl.edu/publication/HS1425

UF/IFAS publication PP327, "Huanglongbing (HLB; Citrus Greening) Leaf and Fruit Symptom Identification": https://doi.org/10.32473/edis-pp327-2019

FDACS Division of Plant Industry HLB sample submission: https://www.fdacs.gov/Agriculture-Industry/Pests-and-Diseases/Plant-Pests-and-Diseases/Citrus-Health-Response-Program/Citrus-Pests-and-Diseases/HLB-Citrus-Greening

UF/IFAS Plant Diagnostic Center: https://plantpath.ifas.ufl.edu/extension/plant-diagnostic-center/

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2026–2029 Florida Citrus Production Guide: Citrus Canker[1]

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Citrus canker is a leaf-, fruit-, and stem-blemishing disease that affects most citrus. Severe infections can cause significant fruit drop. It is caused by the bacterium *Xanthomonas citri* subsp*. citri*. Grapefruit, Mexican lime, and some early oranges are highly susceptible to canker. Lemons, limes, and the oranges Navel, Pineapple, and Hamlin are moderately susceptible to canker. Midseason oranges, Valencias, tangors, tangelos, and other tangerine hybrids are less susceptible, and tangerines are the least susceptible. Little is known about the canker susceptibility of most new cultivars released recently. If you notice that one cultivar is highly susceptible or particularly tolerant, inform your local UF/IFAS Extension specialist.

Symptoms

Young lesions are raised on both leaf surfaces, particularly on the lower leaf surface. The pustules later become corky and crater-like with raised margins, sunken centers, and a surrounding yellow halo. Fruit lesions vary in size, because the rind is susceptible for a long time, and more than one infection cycle can occur on fruit. Twig and stem infections resemble those on fruit. The lesions are raised with a corky appearance and can support long-term survival of the bacterium. Older lesions may darken when they become colonized by saprophytic fungi such as *Colletotrichum* spp.

Major citrus canker outbreaks generally occur when new shoots emerge or when fruit are in the early stages of development, especially if a major rainfall event occurs during this critical time. Frequent rainfall in warm weather, especially storms, contributes to disease development. Citrus canker is mainly a cosmetic disease, but when conditions are highly favorable for infection, it causes defoliation, shoot dieback, and fruit drop. Leaf susceptibility is complicated by the citrus leafminer. The galleries caused by leafminer larvae do not heal quickly, and they increase leaf susceptibility. Leaves then have highly susceptible wounds for long periods of time where the bacterium can infect the leaf. Lesion number and individual lesion size increase greatly and magnify the inoculum pressure in a grove compared to citrus canker without leafminer. The citrus leafminer is not a vector of the bacterium, but the presence of leafminer makes management more difficult because of the wounding it causes.

Biology

The bacterium reproduces in lesions on leaves, stems, and fruit. When there is free moisture on the lesions, the bacteria ooze out and can spread to new growth and other trees. Wind-driven rain is the main means of movement, and wind speeds >18 mph aid in the penetration of bacteria through the stomatal pores or wounds made by thorns, insects, and blowing sand. Tissues become resistant to infection as they mature, except when exposed to extreme windblown rain such as in a hurricane. Almost all leaf and stem infections occur within the first six weeks after growth initiation unless there is a leafminer infestation or tropical-storm-force winds. The most critical period for fruit infection is when the fruit are between 0.5–1.5 inches in diameter for grapefruit and 0.25–1.25 inches in diameter for oranges. At this stage, the stomates on the fruit surface are opening, and fruit are particularly susceptible to bacterial penetration. After petal fall, fruit remain susceptible during the first 60 to 90 days for oranges or tangerines and 120 days for grapefruit. Infection after this time can result in the formation of small, inconspicuous pustules.

Spread of the bacterium caused by wind and rain is mostly over short distances, such as within trees or to neighboring trees. Canker is more severe on the side of the tree exposed to wind-driven rain. Spread over longer distances, up to miles, can occur during heavy winds, severe tropical storms, hurricanes, and tornadoes. Long-distance spread occurs more commonly with the movement of diseased plant material such as budwood, rootstock seedlings, budded trees, or less commonly, fruit and leaves. Workers can carry the bacterium from one location to another on hands, clothes, and equipment. Grove equipment can spread the bacteria within and among plantings, especially when trees are wet.

Management

The Citrus Health Response Program (CHRP) does not require removal of affected trees. Thus, growers should use their best judgment in management of citrus canker. The entire state of Florida is under quarantine, and fruit movement is subject to specific regulations depending on market destination. For more information and resources, visit the Citrus Health Response Program Resources webpage.

Canker losses can be severe under Florida conditions and can be difficult to control on grapefruit and the most susceptible early-season orange varieties. Areas that are currently canker-free should be protected to the extent possible.

Protecting Canker-Free Areas

Decontamination

Where canker is absent, decontamination protocols are still in place and should be followed. With widespread canker around the state, the likelihood of further spread is greater than ever. When moving equipment and personnel from grove to grove, every effort should be made to make sure that plant material is not moved inadvertently, and that all equipment has been thoroughly decontaminated. Decontamination is especially important in harvesting operations, hedging and topping, and any other practices involving extensive contact with foliage. Obviously, when equipment is moved from blocks where canker is endemic to other infected blocks, decontamination serves little purpose.

Tree Removal

If canker is detected in areas previously free of the disease, removal and burning of trees on site may slow the establishment of the disease. For tree removal to be effective, canker has to be localized and limited to a small number of trees. Tree removal is not likely to be effective if canker is already present within a mile of the grove, because it can spread with the wind and rain; therefore, tree removal is no longer a viable option in most of Florida.

Defoliation and Pruning

Defoliation and pruning are not recommended because they induce large, highly susceptible flushes. The young flushes are vulnerable to infection from stem lesion inoculum or infected neighboring groves during storms with high winds.

Endemic Canker

In most of Florida where canker is endemic, the primary means of control are (1) plant windbreaks, (2) protection of fruit and leaves with copper or an integrated program of a plant immune system activator and copper applications, and (3) control of leafminer populations.

Windbreaks

Windbreaks are highly effective to reduce canker spread, but more importantly, they reduce the severity of the infection in endemic situations. When canker lesions are wetted, millions of bacteria ooze onto the leaf surface. While the bacterium can drip down to lower leaves and fruit, the vast majority of the infection occurs by windblown rains that spread the bacteria throughout a tree and to neighboring trees. Winds above 18 to 20 mph are needed to force bacteria into stomates on leaves and fruit; in so doing, bacteria can bypass copper barriers.

Windbreaks reduce wind speed for a distance of five to ten times the height of the windbreak. For example, a 30 ft tall windbreak will exert an effect for about 150 to 300 ft. To be effective for canker control, windbreaks do not need to be dense. All that is required is to reduce wind speed to < 20 mph. The need for windbreaks and the distance between rows will depend on the destination of the fruit, fresh or processed, and cultivar susceptibility. Fresh-market grapefruit in Florida is best with a windbreak that surrounds each 5- to 10-acre block. Replacement of windbreak trees that fail to thrive or have been killed by lightning is recommended to prevent breaches that allow for local wind penetration and incursions of the bacteria. In many groves with less-susceptible citrus cultivars, a windbreak down the row about every 300 ft may be sufficient. In situations where some protection exists and tolerant varieties are grown for processing, windbreaks are unnecessary. Additionally, not topping outside rows of citrus can also serve as a viable, harvestable windbreak. It is best to plan a windbreak while replanting a citrus block, so it can be integrated into block design. That is not always possible; thus, currently, the recommendation is that growers plant windbreaks along fence lines, ditches, around wetlands, or wherever they can plant without removing citrus trees. If it becomes obvious that more windbreak protection is needed, rows of citrus or end trees can be removed to accommodate more windbreaks.

For more information on selection of plant species and design, see UF/IFAS publication FOR227, “Windbreak Designs and Planting for Florida Agricultural Fields.”

Copper Sprays

Over the last 30 years, UF/IFAS has evaluated dozens of products for canker control. Products such as antibiotics, compounds that induce resistance in plants, and disinfectants provide limited canker control, but no material has proven more effective than copper products.

Copper products are quite effective for preventing fruit infection but much less effective for reducing leaf infection. Application of copper to young leaves protects against infection, but the protection is soon lost due to rapid expansion of the surface area. Also, copper has limited value in reducing disease spread. Fruit grows more slowly than leaves and is easier to protect. Oranges develop resistance in mid- to late July. Grapefruit remain moderately susceptible through full expansion in late September to mid-October. Infection through wounds can occur at any stage of fruit growth.

For orange groves with endemic canker, most infections will occur from April to July. No more than five copper sprays applied at 21-day intervals are recommended for early processing oranges: one in early April (fruit at 0.25- to 0.5-inch stage), a second in late April, a third in mid-May, a fourth in early June, and a fifth in late June to early July when the fruit is about 1.5 inches in diameter. Three applications at 21-day intervals should be sufficient for Valencias and midseason varieties, in mid-April (fruit at 0.25- to 0.5-inch stage), in early/mid-May, and late May/early June. Varieties of early oranges grown for higher color score (Early Gold, Westin, Ruby, Itaborai) and Navel are more susceptible than Hamlin. They may require additional sprays before April and beyond July. HLB results in early bloom, so first applications may need to be adjusted into late March. Consult the Citrus Copper Application Scheduler to ensure that copper residue levels are adequate for disease control. The 21-day intervals are approximate timings, but growth rate and rainfall can cause copper residues to decay faster or slower than otherwise expected. More details are available in UF/IFAS publication PP289, "A Web-Based Tool for Timing Copper Applications in Florida Citrus."

Programs for fresh fruit are more complex, but many copper sprays are already used on these varieties. For fresh-market grapefruit, a low rate of copper should be added to the last spray of spring flush for scab. Subsequently, the copper spray program used for melanose control should also control canker, but additional applications will be required every 21 days when the fruit reach 0.5- to 0.75-inch size until fruit are fully grown in October. Copper may need to be added to applications of fungicides or petroleum oil. Use caution when mixing copper with oil because it increases the phytotoxicity risk.

Most tangerines are fairly tolerant to canker. Copper programs used for *Alternaria* control should also protect against canker. Fallglo is less susceptible, and three sprays — one in April, another in May, and the last in June — would probably suffice.

Newly planted trees in canker-exposed settings are more susceptible because they produce leaf flushes more often, and the flush tissue represents a high proportion of the canopy volume. The recommendation for the more susceptible varieties (grapefruit and early oranges) is that the trees be sprayed every three to four weeks to coincide with vegetative flush cycles from spring though the fall. Sprays should be applied with a hoop sprayer that thoroughly covers the foliage on all sides of the canopy. Trees covered with individual protective covers (IPC) are much less susceptible to canker. The trees should be monitored for canker as they fill the IPCs, but few copper applications are likely to be needed.

The rates of copper products depend on the length of protection expected and the weather. As little as 0.5 to 1.0 lb of metallic copper will protect spring flush growth or fruit during the dry spring season. However, in the rainy season, more than 1 lb of metallic copper may be required to protect fruit for three-week periods.

To the extent possible, copper usage should be minimized because this metal accumulates in soil and may cause phytotoxicity to the fruit peel or create environmental concerns.

Leafminer Control

Leafminers do not spread canker, but damage from leafminer larval feeding galleries enables entry of the bacterium into leaves and greatly increases inoculum levels, making the disease difficult to control. Leafminers are not usually a problem on the spring flush, and no control is needed at that time. Leafminer control on the first summer flush can reduce disease pressure considerably. If properly timed, applications of recommended insecticides will reduce damage by leafminer (see chapter 22, "Citrus Leafminer"). Late summer flushes tend to be erratic, and effective control at that time is more difficult.

Activation of Plant Immune Systems

Plant immune systems are natural processes plants use to survive diseases and pests. In some cases, these immune systems can be induced by chemical stimulation, in this case for canker management. Systemic acquired resistance (SAR) is the most well-known system which induces resistance throughout the plant. The disease may occur or continue to develop before plant immune systems can be naturally induced or become fully effective.

The SAR activator, Actigard (formerly Blockade), triggers the natural defense mechanism before the onset of disease but has no direct effect on the pathogen. High inoculum levels can overcome defense activation, so it is important to apply Actigard before weather and host flush conditions are favorable for infection at the beginning of each season. There are two methods of application, drench or chemigation, but drench was found to be more effective. Use-scenarios for Actigard vary based on whether trees are bearing or nonbearing.

Nonbearing Trees

- Actigard can be used to limit the establishment of citrus canker infections in newly planted trees. For the best results, treatments should start prior to infection.
- Initiate treatments after planting when trees have overcome transplant shock and begun active growth. Continue through the entire nonbearing cycle.

- Applications on dormant trees or excessive doses can reduce tree growth. Start with the lowest dose within range and increase with tree age and size (Table 2).
- Use in conjunction with soil-applied neonicotinoid (Group 4A) insecticides, which can also induce SAR. Actigard cannot replace a soil-applied neonicotinoid scheduled for Asian citrus psyllid management.
- Continue applications throughout the spring, summer, and fall at 60-day intervals.

Bearing Trees

- Actigard limits development of lesions on foliage, thereby reducing potential for fruit infection.
- Initiate postbloom but prior to conditions favorable for citrus canker.
- Applications on dormant trees or excessive doses can reduce tree growth. Start with the lowest dose within range and increase with tree age and size (Table 2).
- Use in conjunction with other canker management tactics like windbreaks, copper applications, and leafminer management. Do not reduce rates of other products.
- Continue throughout spring, summer, and fall at 45- to 60-day intervals, depending on tree size and planting density (Table 2).

Aura Citrus, a second plant immune system inducer, was recently registered. It activates the immune system by inducing both systemic and local immune responses. While it can be used alone, the recommended use pattern for Aura Citrus is to apply it with a copper hydroxide product at the major flush periods of the spring, summer, and fall for a total of two to four applications of both products. The number of applications should be determined by the disease pressure of a particular season. This combination has been shown to reduce canker symptoms on leaves and reduce fruit drop from canker. If a current season has high disease pressure, treatment can start on the fall flush to improve the subsequent season's outcomes. At this time, we recommend this product for canopy management and hope to make a full canopy and fruit recommendation in the future.

The rules and regulations regarding canker are changeable. For current information on disease status and regulations, see the website of the Florida Department of Agriculture and Consumer Services or the UF/IFAS CREC website.

Contact your local UF/IFAS Extension citrus agent for additional information, training materials, and programs at https://citrusagents.ifas.ufl.edu/.

Web Addresses for Links

Citrus Copper Application Scheduler: http://agroclimate.org/tools/citrus-copper-application-scheduler/

Citrus Health Response Program, Florida Department of Agriculture and Consumer Services website: https://www.fdacs.gov/Agriculture-Industry/Pests-and-Diseases/Plant-Pests-and-Diseases/Citrus-Health-Response-Program/CHRP-Resources-for-Industry

UF/IFAS publication FOR227, "Windbreak Designs and Planting for Florida Agricultural Fields": https://edis.ifas.ufl.edu/publication/fr289

UF/IFAS publication PP289, "A Web-Based Tool for Timing Copper Applications in Florida Citrus": https://doi.org/10.32473/edis-pp289-2012

UF/IFAS CREC website: https://citrusresearch.ifas.ufl.edu/pest-management/diseases/citrus-canker/

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2026–2029 Florida Citrus Production Guide: Phytophthora Foot Rot, Crown Rot, and Root Rot[1]

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Foot rot results from scion infection near the ground level, producing bark lesions that extend down to the bud union on tolerant rootstocks. Crown rot results from bark infection below the soil line when susceptible rootstocks are used. Root rot occurs when the cortex of fibrous roots is infected, turns soft, and appears water-soaked. Fibrous roots slough off their cortex, leaving only a white thread-like stele (inner tissue of the fibrous root). Foot rot, crown rot, and root rot can be caused by *Phytophthora nicotianae* or *P. palmivora*. When managing phytophthora-induced diseases, integration of chemical control methods and cultural practices (e.g., disease exclusion with phytophthora-free planting stock, tolerant rootstocks, proper irrigation practices [see chapter 13, "Irrigation Management of Citrus Trees"]) is necessary. Phytophthora management with chemical control should not be considered until other potential causes of decline in tree production are evaluated and corrected. See also chapters (39, 28, and 27, respectively) on "Blight," "Huanglongbing (Citrus Greening)," and "Nematodes." The decision to treat should follow soil sampling to determine how much phytophthora is present in the soil. Details are given below.

Cultural Practices to Manage *P. nicotianae*

Field locations not previously planted with citrus are probably free of citrus-specific *P. nicotianae.* Planting stock should be free from *Phytophthora* spp. in the nursery, and inspection for fibrous root rot in the nursery or grove before planting is advised. If uncertain, testing of nursery stock for *Phytophthora* spp. is recommended. In groves with a previous history of foot rot, consider use of Swingle citrumelo or other tolerant rootstocks (see *Florida Citrus Rootstock Selection Guide*) for replanting. Tolerance to *Phytophthora* spp. can be compromised when planted in unfavorable soils for the rootstock (e.g., Swingle citrumelo in calcareous soils). Rootstocks tolerant to foot and root rot normally do not support damaging populations once trees are established. Cleopatra mandarin should be used with caution because it is prone to developing crown and foot rot when roots are infected in the nursery or when trees are planted in flatwoods situations with high or fluctuating water tables and fine-textured soils. When resetting, never use Cleopatra mandarin in a grove with a history of damaging phytophthora, regardless of region. Plant trees with the bud union more than 6 inches above the soil line and provide adequate soil drainage. Additionally, care should be taken to ensure the planting hole is adequately sized for the root system to avoid root damage. Overwatering, especially of young trees, promotes buildup of phytophthora populations in the soil and increases risk of foot rot infection. Prolonged wetting of the trunk, especially if tree wraps are used on young trees, should be avoided by using early to midday irrigation schedules. Control of fire ants prevents their nesting under trunk wraps and feeding damage to moist, tender bark, which is then susceptible to infection.

Sampling for *Phytophthora* Spp.

Determine population densities of the fungus-like organism in grove soils to assist decisions of whether to treat with fungicides. Collect soil samples containing fibrous roots from March to November from under the canopy within the irrigated zones. When sampling trees of average canopy condition, combine individual small amounts from the top ten inches of soil from 20 to 40 locations in the microsprinkler zones within a 10-acre block into one resealable plastic bag to retain soil moisture. Samples must be kept cool but not refrigerated for transport to an analytical laboratory. Currently, populations in excess of 10 to 20 propagules per cm^3 soil of total *Phytophthora* spp. (*P. nicotianae + P. palmivora*) are considered damaging. The same soil sample should be tested for populations of nematodes to assess whether they occur at damaging levels.

Chemical Control

Use of fungicides in young groves should be based on rootstock susceptibility, likelihood of *Phytophthora* spp. infestation in the nursery, and history of phytophthora disease problems in the grove. For susceptible rootstocks, such as Cleopatra mandarin and sweet orange, fungicides may be applied to young trees for foot rot on a preventive basis. For young trees on other rootstocks, fungicide treatments should commence when foot rot lesions develop. The fungicide program for foot rot should be continued for at least one year for tolerant rootstocks but may continue beyond the first year for susceptible rootstocks. In mature groves, the decision to apply fungicides for root rot control is based on yearly soil sampling to determine whether damaging populations of *P. nicotianae* occur in successive growing seasons. Timing of applications should coincide with periods of susceptible root flushes after the spring leaf flush, usually from late spring to early summer and after the fall leaf flush in October to November. Soil application methods with fungicides should be targeted to irrigated areas under the canopy with the highest fibrous root density. To avoid leaching from the root zone, soil-applied fungicides should not be followed by excessive irrigation. Aliette, phosphite salts, Ridomil Gold, or Presidio are effective, but alternation of the materials should be practiced to minimize the risk of the development of fungicide resistance. It is recommended to alternate the soil-applied Ridomil and Presidio on the major spring and fall root flushes as well as to continue to apply Aliette or phosphite salts on a calendar schedule per the label.

Larval Feeding Injury to Citrus Roots and Its Relationship to Invasion by *Phytophthora* Spp.

Association of phytophthora root rot with root damage by larvae of *Diaprepes abbreviatus* has been called the *Phytophthora*-*Diaprepes* (PD) complex (see chapter 26, "Citrus Root Weevils," or the Diaprepes Root Weevil website). A far more severe interaction has been identified between *P. palmivora* and Diaprepes root weevil than for *P. nicotianae*. The damage caused by *P. palmivora* is often associated with poorly drained, fine-textured soils and rootstocks like Swingle citrumelo and Carrizo citrange that are normally tolerant of *P. nicotianae*. In the more severe form, structural roots collapse from what appears to be moderate larval damage followed by aggressive spread of *P. palmivora* through the structural roots.

Rootstock susceptibility to damage by the PD complex depends on which *Phytophthora* sp. is present and whether the soil and water conditions are conducive to the fungus-like organism or to rootstock stress. In most situations, *P. nicotianae* is the predominant pathogen, and Swingle citrumelo appears to perform acceptably as a replant in weevil-infested groves, provided soil conditions are suited for this rootstock (e.g., favorable pH and calcium carbonate status, sandy soil texture, well-drained, etc.). When *P. palmivora* is present in poorly drained soils high in clay, pH, or calcium carbonate, *Diaprepes* root weevils render normally tolerant Swingle citrumelo and Carrizo citrange susceptible to phytophthora root rot infection. Thus, tolerance of Swingle citrumelo is restricted to the ridge and certain flatwoods soils. For more information about rootstock selection, refer to chapter 11, "Rootstock and Scion Selection", and the *Florida Citrus Rootstock Selection Guide*.

Management of the *Phytophthora*-*Diaprepes* Complex

Selection of tolerant rootstocks for replanting *Diaprepes* root weevil-affected groves is important for management of future losses. For existing trees, fungicides in conjunction with careful water and fertilizer management have been utilized to maintain tolerance to *Diaprepes* root weevil and phytophthora damage. Fertigation maximizes water and nutrient uptake efficiency by roots in well-drained soils. However, use of fertigation to regenerate roots is limited in poorly drained soils and high water tables typical in the flatwoods. In these situations, there may be increased reliance on fungicides to control root damage by *Phytophthora* spp.

Based on studies of the PD complex, aggressive control of *Diaprepes* root weevil larvae and adult stages should be implemented as soon as infestation is discovered to minimize the more severe phytophthora damage that follows larval feeding on roots. The IPM program may include carefully scheduled fertigation in well-drained soils to promote regeneration of fibrous roots after damage. In the flatwoods, IPM may include use of fungicides under the following conditions: (1) the soils are fine-textured, poorly drained, high in pH, or calcareous, (2) the trees are on rootstocks susceptible to either or both *Phytophthora* spp., and (3) populations are above the damaging levels (10 to 20 propagules per cm^3 soil). A key to assist growers making *Phytophthora*-*Diaprepes* management decisions is available at the Diaprepes Root Weevil website as well as the Florida Citrus Rootstock Selection Guide.

Management of the Phytophthora-HLB Interaction

Management of phytophthora root rot is complicated by huanglongbing (HLB; see chapter 28, "Huanglongbing [Citrus Greening]") because the causal bacterium infects all parts of the citrus tree, including the roots. HLB accelerates phytophthora infection and fibrous root damage. HLB predisposes roots to *P. nicotianae* infection apparently by increasing attraction of zoospores to roots, accelerating infection, and lowering resistance to root invasion. The spread of HLB has led to more frequent cases of damaging phytophthora populations. Most recently, there has been a multiyear cycling of phytophthora populations apparently associated with lower fibrous root density and bursts of root growth as trees continue to decline from HLB. This has heightened concern for the root health of HLB-affected trees and initiation of measures to reduce root stress, which includes *Phytophthora* spp., citrus nematodes, *Diaprepes*, and abiotic soil factors. While all of these factors need to be considered and assessed on a case-by-case basis depending on site and rootstock, specific factors must be considered when controlling phytophthora with high-incidence HLB.

Although HLB causes fibrous root dieback, it also increases new growth of fibrous roots. Similar to leaf flushing, new root growth is no longer as synchronized into flush events. This is important because phytophthora preferentially infects new root growth. Constant availability of new root growth is a likely cause of the rapid development of damaging phytophthora populations under favorable conditions. The cycles of root dieback and root flushing caused by HLB lead to large swings in phytophthora propagule counts in a grove. Preliminary data indicate that chemical management has reduced effectiveness for control of *Phytophthora* spp. and prevention of root loss. Therefore, it is important to monitor phytophthora propagule counts before major summer and fall root growth events. If a damaging population is developing, it is important to time chemical applications to protect those major root flushes.

Web Addresses for Links

Diaprepes Root Weevil:
https://citrusresearch.ifas.ufl.edu/pest-management/insects/diaprepes-root-weevil/

Florida Citrus Rootstock Selection Guide: https://ask.ifas.ufl.edu/publication/HS1260

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2026–2029 Florida Citrus Production Guide: Brown Rot of Fruit[1]

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Management of brown rot, caused by *Phytophthora nicotianae* or *P. palmivora*, is needed on both processing and fresh-market fruit. While the disease affects all citrus types, it is usually most severe on Hamlin, Navel, and other early-maturing sweet orange cultivars. See chapter 30, "Phytophthora Foot Rot, Crown Rot, and Root Rot," for information on other phytophthora diseases.

Phytophthora brown rot is a localized problem, usually associated with restricted air and/or water drainage. It commonly appears from mid-August through October following extended periods of high rainfall. It can be confused with fruit drop from other causes at that time of year. If caused by *P. nicotianae*, brown rot is limited to the lower third of the canopy because the fungus-like organism is splashed onto fruit from the soil. *P. palmivora* produces abundant sporangia on infected fruit that can splash onto fruit throughout the canopy.

Early-season inoculum production and spread of *Phytophthora* spp. are minimized with key cultural practice modifications. Skirting of trees reduces the opportunity for soilborne inoculum to contact fruit in the canopy. The edge of the herbicide strip should be maintained just inside of the dripline of the tree to minimize the exposure of bare soil to direct impact by rain. This will limit rain splash of soil into the lower canopy.

Fruit on the ground become infected and produce inoculum, especially in *P. palmivora*, where fruit-grown sporangia can readily splash upward into the tree canopy. The sporangia can infect green fruit and result in brown rot infection in the canopy as early as July. The beginning of the epidemic is very difficult to detect before the fruit are colored and showing typical symptoms. Boom application of herbicides and other operations dislodge low-hanging fruit. Furthermore, trees affected by huanglongbing (HLB; citrus greening) are prone to premature fruit drop. Early-stage inoculum production from fallen fruit may be reduced by using residual herbicides early in the summer rather than late-summer postemergence herbicide applications that can knock fruit off the trees.

Before the first signs of brown rot appear in late July, a single spray application of Aliette, Phostrol, ProPhyt, or another product with a FRAC MOA P 07 (formerly FRAC 33) mode of action should be made. Doing so protects fruit, usually through most of the normal infection period. Alternatively, the newer fungicides Orondis Ultra (FRAC MOA 40+49) or Revus (FRAC MOA 40) can be used from September to November, before symptoms of brown rot. If more than one disease management application is required in a season, rotate to an alternate mode of action for resistance management. *Phytophthora* spp. resistance to FRAC P 07-containing products has been observed in California but not in Florida at this time. No more than 20 lb/acre/year of Aliette should be applied for the control of all phytophthora diseases. Aliette, Phostrol, and ProPhyt are systemic fungicides that protect against postharvest infection and provide 60–90 days of control. It is not legal to use products containing phosphite salts without a fungicide label for disease management. Orondis Ultra and Revus are also systemic and estimated to protect fruit up to 30 days, but the full period of protection is not yet certain. Reports of resistance in other *Phytophthora* spp. have occurred. Rotate modes of action for each application. Copper fungicides are primarily protective but are capable of killing sporangia on the fruit surface, thus reducing inoculum. They may be applied in August before or after the appearance of brown rot and provide protection for 45–60 days. If the rainy season is prolonged into the fall, a follow-up application of either systemic fungicide at one-half of the label rate or copper in October may be warranted. If a second application is needed, follow the preharvest intervals carefully (see *"Pesticides Registered for Use on Florida Citrus"*). With average-quality copper products, usually 2–4 lb of metallic copper per acre are needed for control.

Precautions should be taken during harvesting to exclude fruit affected by brown rot from field containers because this could result in rejection at the processing or packing facility.

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2026–2029 Florida Citrus Production Guide: Greasy Spot[1]

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Greasy spot is caused by the fungus *Zasmidium citri-griseum*, formerly known as *Mycosphaerella citri*. Management must be considered in groves intended for processing and fresh-market fruit. Greasy spot is usually more severe on leaves of grapefruit, pineapple oranges, Hamlins, and tangelos than on Valencias, Temples, Murcotts, or most tangerines and their hybrids. Greasy spot rind blotch (GSRB) is particularly problematic for grapefruit destined for the fresh-fruit market.

A new symptom has been described on fresh-market grapefruit. Greasy-green disorder was originally thought to be a new disease or disorder. It consists of green patches on the rind of fruit that are not removed with degreening practices (see chapter 41, "Decay Control of Florida Fresh Citrus"). There are no symptoms of greasy spot on the leaves or classic rind blotch on fruit from affected groves. *Z. citri-griseum* has been found growing on the patches with greasy-green, and the fungus was also found in the leaves despite there being no symptoms, showing that greasy-green is a new symptom of greasy spot rind blotch. Greasy-green should be managed like greasy spot.

Airborne ascospores produced in decomposing leaf litter on the grove floor are the main inoculum source for greasy spot. These spores germinate on the fruit and the underside of the leaves, where the fungus grows for a time on the leaf surface before penetrating through the stomates (natural openings on fruit and lower leaf surfaces). Internal growth is slow, and symptoms do not appear for several months. Warm, humid nights and high rainfall, typical of Florida summers, promote infection and disease development. Major ascospore releases usually occur from April to early June with favorable conditions for infection occurring from June through September. Leaves are susceptible throughout their lives.

On processing Valencias, a single spray of oil (5–10 gal/acre) or copper + oil (5 gal/acre) should provide acceptable control when applied from mid-May to June. With average-quality copper products, 2 lb of metallic copper per acre usually provides adequate control. The strobilurin-containing (FRAC MOA 11) fungicides (Amistar Top, Gem, Headline, Pristine, or Quadris) and Enable 2F are also suitable with or without petroleum oil. On early and mid-season oranges as well as processing grapefruit, two sprays may be needed, especially in the southern part of the state, where summer flushes constitute a large portion of the foliage. Two applications also may be needed where severe defoliation from greasy spot occurred in the previous year. In those cases, the first spray should be applied from mid-May to June and the second soon after the major summer flush has expanded, often early to mid-July. Copper fungicides provide more consistent control than oil sprays. Control of greasy spot on late summer flushes is less important than on the spring and early summer flush because the disease develops slowly and defoliation will not occur until after the next year's spring flush. Thorough coverage of the underside of leaves is necessary for maximum control of greasy spot, which can be achieved with higher spray volumes; slower tractor speeds may be needed compared to control of other pests and diseases.

The treatment program is essentially the same for fresh fruit. That is, a fungicide application once anytime from May to June and a second in July should provide control of rind blotch. A third application in August may be needed if rind blotch has been severe in the grove. Petroleum oil alone is less effective than other fungicides for control of GSRB. Heavier oils (455 or 470) are more effective for GSRB control than lighter oils (435), but the former have a greater potential for phytotoxicity. Copper fungicides are effective for control of GSRB but may result in fruit spotting, especially if applied with petroleum oil or at high rates in hot, dry weather. If copper fungicides are applied in summer, they should be applied when temperatures are moderate (<94°F) at rates no more than 2 lb of metallic copper per acre, without petroleum oil or other additives, and using spray volumes of at least 125 gal/acre. Copper residue levels can be monitored with the Citrus Copper Application Scheduler. More details are available in UF/IFAS publication PP289, "A Web-Based Tool for Timing Copper Applications in Florida Citrus." Enable 2F can be applied for greasy spot control at any time but is especially indicated in mid-to-late summer for rind blotch control.

The strobilurin-containing fungicides (Amistar Top, Gem, Headline, Pristine, or Quadris) or Enable 2F can be applied at any time to all citrus and provide effective control of the disease on leaves or fruit. Use of a strobilurin is especially recommended in late May and early June because it controls both melanose and greasy spot and avoids potential fruit damage from the copper fungicides applied at that time of year. A strobilurin-containing fungicide should not be applied more than once a year for greasy spot control because of the potential for the development of resistance. The addition of petroleum oil increases the efficacy of these products.

Fungicide Resistance

The fungus responsible for greasy spot has a history of developing fungicide resistance. Recently, isolates were shown to be resistant to strobilurin (FRAC MOA 11) fungicides. Whether the problem is widespread is currently unknown. It is advised not to use strobilurin fungicides frequently. It is best to use them in a premixture with an additional mode of action. If control failure is observed after strobilurin use, discontinue use.

Web Addresses for Links

Citrus Copper Application Scheduler: http://agroclimate.org/tools/citrus-copper-application-scheduler/

UF/IFAS publication PP289, "A Web-Based Tool for Timing Copper Applications in Florida Citrus": https://doi.org/10.32473/edis-pp289-2012

[1] This document is PP-144, one of a series of the Department of Plant Pathology, UF/IFAS Extension. Original publication date December 1995. Revised annually. Most recent revision August 2026. Visit the Ask IFAS website at https://ask.ifas.ufl.edu for the currently supported version of this publication.

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2026–2029 Florida Citrus Production Guide: Melanose[1]

Megan M. Dewdney[2]

Management of melanose, caused by the fungus *Diaporthe citri*, is often necessary in mature groves where fruit is intended for the fresh market, particularly if recently killed twigs and wood are present because of freezes or other causes. Melanose management is not usually needed in groves under 10 years old or in those where fruit is intended for processing. As a caveat, more dead wood is present in canopies of young trees because of huanglongbing (HLB) than historically was the case. Growers should monitor young groves for dead wood and start applications before melanose becomes economically damaging. Grapefruit is especially susceptible to melanose, but all citrus may be damaged by the disease.

Spores produced by *D. citri* in the asexual stage are the primary inoculum of this fungus. The sexual stage is relatively unimportant for routine disease management. The asexual spores are produced in flask-shaped structures embedded in dead twigs of 1/8 to ¼ of an inch diameter (3 to 6 mm) in the tree canopy, especially those twigs that died within the last several months. In addition to producing spores on melanose-affected twigs after they die, *D. citri* can colonize dead twigs that were originally healthy and can produce inoculum on them as well. Spores are produced during wet periods and dispersed to young, susceptible fruit, leaves, and twigs by rain splash. No spores are produced from symptomatic leaves, fruit, or living twigs. At 75°F–80°F (23.8°C–26.7°C), 10–12 hours of leaf wetness are required for infection, and at lower temperatures, up to 18–24 hours may be needed. These leaf wetness periods are not uncommon in Florida.

The sexual stage spores for *D. citri* are important for longer-distance spread of the pathogen. This becomes important for management when there is a young grove where the pathogen is absent or at low levels. These spores occur on larger-diameter twigs or twigs that are no longer producing the asexual spores. A common source of the sexual spores are brush piles or burn piles if they are present for long periods. It is advisable to make sure they are disposed of as soon as it is practical.

One or two applications are sufficient for melanose control on oranges and most tangerines unless the trees have abundant dead wood, as in a year after a freeze. Grapefruit is susceptible to melanose infection from fruit set until it reaches 2.5–3.0 inches (6.4 cm–7.6 cm) in diameter, normally in late June or early July. Fungicides are effective for only short periods when applied to rapidly expanding fruit or leaves. Because April is usually a low-rainfall month and fruit is small and growing rapidly, the first spray for melanose control is not usually applied until mid- to late April. For fresh-market grapefruit, the first application should be made when the fruit reaches a diameter of 0.25 inch to 0.5 inch (0.64 cm–1.3 cm) (about mid- to late April depending on local conditions). With average-quality copper products, usually about 2 lb/acre of metallic copper are needed for each 3-week period. If using a calendar application schedule, applications should continue until the fruit become resistant. Rates can be reduced if applications are made more frequently or increased if applications are made less often. For melanose control on large trees, no more than 8 lb–12 lb metallic copper are needed per year even if copper is also used for the control of scab, canker, or greasy spot.

Copper residues are reduced with fruit expansion and rainfall. The Citrus Copper Application Scheduler is a model that estimates whether residues remaining on fruit are sufficient to control the disease. It is based on fruit growth models, the rate and time of the last application, and rainfall since the last application. It has proven helpful for optimizing the timing of applications for melanose control. More information about the model is available in UF/IFAS publication PP289, "A Web-Based Tool for Timing Copper Applications in Florida Citrus."

An early-June application of copper to manage late melanose damage will serve as the first greasy-spot spray. However, applications of copper in hot, dry weather may cause fruit spotting or darken existing blemishes. If copper fungicides are applied from May to September, they should be applied when temperatures are moderate (<94°F) at rates no more than 2 lb of metallic copper per acre, without petroleum oil, and using spray volumes of at least 125 gal/acre.

The strobilurin-containing fungicides Amistar Top, Gem, Headline, Pristine, and Quadris are also effective for melanose control and can be used at any time for disease control. Copper fungicides are more economical and are most important for melanose control. However, because copper fungicides applied in hot weather can damage fruit, use of strobilurin-containing fungicides at that time will avoid phytotoxicity and control greasy spot as well as melanose. Strobilurins appear to have lower residual activity for melanose control than do copper fungicides. Thus, applications may have to be made at shorter intervals, especially when rainfall is high.

Fungi may develop resistance to strobilurin fungicides. These materials (FRAC 11) should never be used more than twice in a row, and no more than two strobilurin-containing applications should be used for melanose control.

Web Addresses for Links

Citrus Copper Application Scheduler: http://agroclimate.org/tools/citrus-copper-application-scheduler/

UF/IFAS publication PP289, "A Web-Based Tool for Timing Copper Applications in Florida Citrus": https://doi.org/10.32473/edis-pp289-2012

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2026–2029 Florida Citrus Production Guide: Citrus Black Spot[1]

Megan M. Dewdney, Callie Walker, Pamela D. Roberts, and Natalia A. Peres[2]

Citrus black spot is caused by the fungus *Phyllosticta citricarpa* (formerly known as *Guignardia citricarpa*). The disease causes fruit blemishes and significant yield losses, especially on sweet oranges. Black spot can affect all commercial citrus species and cultivars commonly grown in Florida. In Florida, sweet oranges, especially mid- to late-maturing types such as 'Valencia', are highly susceptible to this disease, although lemons are reported to be even more susceptible in other regions. 'Hamlin' sweet oranges and tangerine/mandarin types are moderately susceptible. Based on symptoms in Florida, grapefruit is thought to be moderately susceptible, but little information is available on relative susceptibility. Management is required in groves intended for processing and fresh-market fruit in quarantine and surrounding areas. Need for citrus black spot management should be evaluated annually in all other locations.

Black spot fruit symptoms are wide-ranging and have many different names (see UF/IFAS publication PP274, “Citrus Black Spot”). Hard spot is the most diagnostic symptom of black spot. The 0.1–0.4-inch (3–10-mm) diameter lesions are nearly circular and depressed with gray necrotic tissue at the middle and a brick-red to black margin that can be cracked around the edges. Fruiting structures (pycnidia) that produce the asexual spores (conidia) are often present in the center of lesions and resemble slightly elevated black dots. Hard spot lesions appear as the fruit begin to color before harvest. They first occur on the side of the fruit with the greatest light exposure. False melanose symptoms appear on green fruit early in the season and do not contain pycnidia. The slightly raised lesions are 0.04–0.1 inch (1–3 mm) in diameter and can vary in color from tan to chocolate brown. Under favorable infection conditions, false melanose can resemble the mud-cake symptoms of authentic melanose but are very dark brown rather than rust red. False melanose symptoms can develop into hard spot as the season progresses. Cracked spots are a symptom that has only been observed in the Americas and is reported to be an interaction between rust mites and *P. citricarpa*. Cracked spots are large, diffuse smooth lesions that form raised cracks. Hard spots can form in these lesions. The most concerning black spot symptom is virulent spot. Early virulent spot (freckle spot) lesions start as irregularly shaped, sunken lesions with a reddish color. Early virulent spot can either coalesce to cover a large proportion of the fruit surface or become hard spot. When early virulent spot lesions coalesce to form virulent spot, they turn brown to black, and the older lesion surface becomes leathery. Many pycnidia can be found in early and expanded lesions. Virulent spot occurs on mature, severely infected fruit at the end of the season. Virulent spot symptoms can appear postharvest on apparently symptomless fruit, sometimes in transit to markets. Despite the unsightliness of black spot lesions, they rarely cause internal fruit rot, so those fruit that remain on the tree until ripe are still suitable for processing. Significant fruit drop from citrus black spot is a common symptom in heavily infected groves.

Only one type of spore from *P. citricarpa* is present in Florida. These spores are the asexual spores (conidia), which are formed in fruit lesions, leaf litter, and twigs. The conidia are spread by rain splash and can infect fruit and leaves. These spores germinate and directly infect the leaves and fruit. There is a long latent period for this disease, which means that most symptoms do not appear for several months, usually only once the fruit begins to ripen. The fungus requires a long wetting period of 24–48 hours to infect, and the disease is favored by warm, humid weather such as occurs during the summer months. Conidia are present in the leaf litter most of the year, but the most favorable infection conditions occur from May through September. Fruit remain susceptible most of the growing season. It is not known exactly how long leaves remain susceptible but is thought to be approximately 10 months.

Despite having only one type of spore, monthly applications of fungicides such as copper, strobilurins (Gem, Headline, or Quadris; FRAC MOA 11), or other labeled fungicides [Amistar Top (FRAC MOA 11 + 3), Enable (FRAC MOA 3), Pristine (FRAC MOA 11 + 7)] will be needed from early May to mid-September to control black spot. If there is substantial rain in April, starting fungicide applications in April is advised. Our fungicide recommendations are based on efficacy data collected from field trials in Florida. Field tests in Florida of fungicides including Amistar Top, copper-based products, Enable, Gem, Headline, Pristine, and Quadris indicate that all of these fungicides can be useful in a black-spot management program. Only four strobilurin fungicide applications, including the premixes Pristine and Amistar Top, can be used in a season for any purpose. Therefore, for fresh fruit it is recommended to reserve the strobilurin-containing fungicides for times when phytotoxicity from copper applications is a concern (temperatures >94°F). For processing fruit, fungicides containing strobilurins can be used earlier in the season and applications combined with those for greasy spot and melanose. To manage pathogen resistance, it is recommended that fungicides containing strobilurins not be applied in two consecutive sprays but instead rotated with a fungicide containing another mode of action.

It is important to remember that copper residues are reduced with fruit expansion and rainfall. A model, the Citrus Copper Application Scheduler, is available to determine whether residues remaining on fruit are sufficient to control the disease. It is based on fruit growth models, the copper rate and time of the last application, and rainfall since the last spray. It has proven helpful for timing of sprays for black spot control. More information about the model is available in UF/IFAS publication PP289, "A Web-Based Tool for Timing Copper Applications in Florida Citrus."

In addition to chemical control measures, practices to accelerate leaf litter decomposition beneath the trees to reduce the leaf litter inoculum may be beneficial. Enhancing leaf litter degradation should commence in mid-March. There are three methods that have reduced the ascospore inoculum of *Zasmidium citri-griseum* (formerly *Mycosphaerella citri*), the fungus that causes greasy spot. The first is to increase the microsprinkler irrigations to at least five times a week for approximately a half hour per irrigation period for one and a half months. The leaf litter decomposition will be greater compared to that with the traditional irrigation frequency. A drawback is that leaf litter reduction will be confined to the areas where the microsprinklers reach. A second method is to apply urea (187 lb/treated acre) or ammonium sulfate (561 lb/acre) to the leaf litter. If using ammonium sulfate as a method to control leaf litter inoculum, make sure you monitor your soil pH to ensure that it does not become too low. The leaf litter decay will be less than without urea, but when tested with *Z. citri-griseum*, the number of spore-producing structures was reduced, and fewer spores were produced. Nitrate-based fertilizers are ineffective. The final method is to apply dolomitic lime or calcium carbonate (2226 lb/treated acre) to the leaf litter. The decay rate is greater for litter treated with lime, and inoculum production is reduced. All treatments worked equally well with *Z. citri-griseum*, and there is no indication that one method is better than another. Lime or irrigation methods should not be used in conjunction with the high N treatments, because they have opposite methods of action.

Several cultural practices can aid control and help restrict further spread of black spot. It is essential to minimize plant trash movement among groves and even among blocks within groves. While there are generally few symptoms on leaves, the main inoculum is formed within the fallen leaves. As leaf litter decomposes, the spores form and are splashed into the canopy. It is very easy to inadvertently move the fungus from one site to another with symptomless leaves and other trash. This is the basis of the tarping requirement from quarantine areas, but any grove equipment or vehicle can move leaf litter or trash from one location to another.

Declining trees should be removed from a grove regardless of the cause. This is less practical with widespread HLB, but those trees that are particularly stressed usually have more symptoms. Trees that are declining will often have off-season bloom as a symptom of stress. Where there is more than one age of fruit present on the tree, the asexual spores on the fruit can be transferred to new fruit, amplifying the disease. This problem is especially troublesome on Valencia when new and old fruit crops overlap. Fruit do not appear to become resistant to infection as they age. In addition, nutritionally stressed trees will often express black spot symptoms first. A good nutritional program helps to minimize symptoms and maintain yields (see UF/IFAS publication SL253, *Nutrition of Florida Citrus Trees*).

Where possible, open the tree canopy by skirting to reduce the leaf wetness periods. The fungus requires between 24–48 hours of leaf wetness to infect. It is also important to minimize dead wood in the canopy. Like the melanose pathogen, the black spot fungus can colonize and reproduce in dead twigs. Canopies with significant numbers of dead twigs will have more problems with black spot than those without.

Finally, as with all fungal diseases, it is important to use clean nursery stock. Currently, there are no nurseries within the geographical citrus black spot quarantine zones; however, this may change as we gain a better understanding of the distribution of the disease.

Regulatory Considerations

Care must be exercised in handling and moving citrus fruit with leaves, twigs, and debris from citrus black spot (CBS) quarantined areas, because the disease may be easily and unwittingly spread to other citrus trees, nurseries, or groves. The following rules are in addition to stipulations imposed as a result of Florida's statewide citrus canker quarantine.

Visit the state's Citrus Health Response Program (CHRP) website to see details of current regulations, other relevant compliance information, and current quarantined areas of record for CBS. To see the details of Federal Citrus Quarantine Boundary, visit the USDA's Animal and Plant Health Inspection Service's website at https://www.aphis.usda.gov/aphis/maps/plant-health/citrus-map.

Growers, Caretakers, Harvesters, and Haulers

Citrus growers, caretakers, harvesters, and haulers must operate under compliance agreements with regulations that serve to protect the citrus industries of Florida, the United States, and international trade partners. When harvesting citrus in groves, vehicles used to transport fruit from CBS quarantined areas must meet the following minimum standards: all conveyances, whether bulk-filled with fruit or loaded in pallet boxes or field bins and stacked on trucks or trailers, must be completely covered with no openings greater than ½ inch, with the exception of bulk loads with side and rear walls constructed of expanded metal, with openings not to exceed ¾ × 1-11/16 inches. Tarpaulins (tarps) used as fruit covers may be of any fabric with a weave of less than ½ inch. Details of transport vehicle regulations may be found in CBS Federal Order DA-2012-09.

Each load of fruit must be identified by issuing a clearly written, serially numbered trip ticket with the following information: Grove Name, Multi-Block ID Number, Land Owner or Agent, Lessee, Harvester; Number of Boxes, Variety; Tag Number; Grower C/A Number; Destination (Receiving Facility or Disposal Site ID); Date of Harvest; and Harvesting Permit Number if issued; additionally, "TARP" and "Q" must be written clearly on the ticket as "TARP-Q," preferably near the bottom.

Prior to departing any citrus grove, all personnel are required to inspect all vehicles and equipment for plant material and debris and to clean all vehicles, equipment, picking sacks, and clothing to ensure that they are free of fruit, limbs, leaves, soil, and debris prior to applying a microbial decontaminant. All plant material and debris cleaned from said vehicles and equipment is to be left on the grove property or, if moved, must be transported under a limited permit to an approved site. Once cleaned, citrus waste hauling equipment and grove caretaking and harvesting equipment must be decontaminated using one of the materials from List A (under "Disposal of Citrus Debris").

Processing and Packing Facilities and Haulers

All citrus fruit harvested from a citrus black spot quarantined area must move intrastate either directly to a processor operating under a state compliance agreement for processing into a product other than fresh fruit, or to a packinghouse operating under a federal compliance agreement. Distribution of fresh citrus fruit from a CBS quarantined area directly to markets within Florida is prohibited.

Each load of fruit harvested from a quarantined area is required to be covered by a tarp in accordance with federal regulations to preclude the loss of leaves, fruit, and debris in transit to a packing or processing facility. The load must arrive tarped at the receiving facility, and all quarantined fruit, leaves, and debris in the truck or trailer must be unloaded completely. The vehicle must be thoroughly cleaned out and decontaminated prior to departing the receiving facility. If any citrus leaves or other citrus waste material are to be moved from a receiving facility (or from a grove), they must be placed in bags or be covered in transit to prevent the loss of leaves, fruit, or debris. Once emptied and cleaned of all leaves and plant debris, all trailers, truck beds, field boxes, and bins must be disinfected by using one of the decontaminant materials in List A (below).

Disposal of Citrus Debris

All leaves, culled or eliminated fruit, and other plant debris originating from a CBS quarantined area; cleaned from trailers, tarpaulins, field boxes, or field bins at a receiving facility; or hauled from a CBS quarantined area must be moved with a limited permit or completed trip ticket in an enclosed or covered conveyance, as stipulated in the Federal Order, that will prevent the loss of fruit, leaves, or debris while in transit. When citrus plant material comes in contact with a vehicle, the vehicle must be decontaminated following movement with a sanitizer in List A (below). All fruit that fails maturity standards either at a packinghouse or processor and is required to be destroyed can either be tarped and moved with a limited permit to a certified dumpsite or landfill. A permit for a certified dumpsite must be requested prior to dumping so that a risk assessment can be done on the site. Contact your local CHRP office for permitting questions and issuance.

List A — Equipment Decontaminants

A1. 200 ppm solution of sodium hypochlorite with a pH of 6.0 to 7.5; or

A2. 0.2% solution of a quaternary ammonium chloride (QAC) cleaner/disinfectant compound; or

A3. Peroxyacetic acid (PPA) solution at 85 ppm.

Citrus waste in the form of culls, peel, pulp, leaves, limbs, or plant debris originating from a CBS quarantined area must be handled or treated by one of the following methods subject to monitoring by an authorized CHRP inspector.

List B — Waste Treatments

B1. Heat-treated to a minimum of 180°F for at least 1 hour; or

B2. Incinerated; or

B3. Buried at a landfill or other FDACS- or APHIS-approved disposal site and covered with dirt at the end of each day that dumping occurs.

Interstate Shipment of Fruit

Fresh fruit from groves within a CBS quarantined area is eligible for movement interstate *under federal certificate* to all states under the following conditions:

The fruit must be washed and brushed, disinfected, and sanitized with a product from List C, then treated at labeled rates with imazalil or thiabendazole (TBZ) and waxed at the time of packing in a packinghouse operating under an APHIS-approved packinghouse procedure prior to shipment. The fruit must be free of leaves and other plant material, and attached stems must be less than 1 inch in length. The fruit must be packed in a packinghouse with a signed APHIS compliance agreement. The fruit must be accompanied by a federal certificate issued by a person or inspector operating under compliance with APHIS, and the certificate must be present on the packed cartons or containers of fruit and the accompanying paperwork.

Fresh fruit from groves within a CBS quarantined area is eligible for movement interstate *under federal limited permit* to noncommercial citrus-producing states under the following conditions:

The fruit must be washed, brushed, and surface disinfected with a treatment from List C or an organic disinfectant, such as hydrogen dioxide at labeled rates in a packinghouse operating under an APHIS-approved packinghouse procedure prior to shipment. The fruit must be free of leaves and other plant material, and attached stems must be less than 1 inch in length. The fruit must be packed in a packinghouse with a signed APHIS compliance agreement. The fruit must be accompanied by a limited permit issued by a person or inspector operating under compliance with APHIS. In addition, the limited permit must be present on the packed cartons or containers of fruit and the accompanying paperwork.

List C — Fruit Treatments

Must be applied in accordance with APHIS-approved packinghouse procedures for CBS.

C1. Sodium hypochlorite solution at 200 PPM for at least two minutes; or

C2. Sodium o-phenylphenate (SOPP) solution at 1.86% to 2.0% total solution; or

C3. Peroxyacetic acid (PAA) solution at 85 PPM for at least one minute.

Export Shipment of Fruit

Rules for Grove Operations outside Citrus Black Spot Quarantines

Growers planning to ship fresh citrus fruit to the European Union (EU) must comply with the following provisions to meet 2017 amendments to EU Annexes of Council Directive 2000/29/EC on plant protective measures. These amendments affect growers planning to ship fruit from areas of Florida outside of counties quarantined for citrus black spot (CBS), under statewide citrus canker quarantine (refer to chapter 29, "Citrus Canker," for recommended cultural practices and guidance in pest and disease management):

Cultural Practices

Citrus growers and caretakers must implement cultural practices to minimize the incident and spread of citrus canker disease in each production unit and buffer area under caretaker's supervision. These practices could include, for example, the planting and maintenance of windbreaks such as eucalyptus trees.

- Note that production unit freedom (from citrus canker) is no longer required.
- Appropriate treatment — Copper (for example) should be applied to a grove to prevent disease damage to fruit, leaves, and stems caused by citrus canker, along with maintaining an appropriate pest management program as recommended by the UF/IFAS *Florida Citrus Production Guide* (refer to chapter 29, "Citrus Canker").
- The packinghouse must also treat the fruit with sodium o-phenylphenate (SOPP) or equivalent.
- Fruit harvested from source block(s) must be found free of citrus canker symptoms during an official packinghouse inspection of a representative sample defined in accordance with international standards.
    - All packed citrus fruit must be traceable back to the grove block (production unit) as provided on the Federal Phytosanitary Certificate, and trip tickets must include the Grower C/A Number.
    - CHRP regulatory staff will conduct random inspections to determine grower compliance with appropriate cultural practices, treatments, and decontamination.

- In addition, trip tickets for fresh fruit destined for the EU must include the notation "CC" to indicate that the grower is following the recommended practices in the UF/IFAS *Florida Citrus Production Guide* to mitigate the incidence of citrus canker disease.

Growers planning to ship fresh citrus fruit to the European Union (EU) must also comply with the following provisions to meet 2017 amendments to EU Annexes with respect to citrus black spot (CBS) in areas outside the EU observed countywide quarantines in Florida:

- Inspection of the fruit is required in the packinghouse with no symptoms of citrus black spot observed.
- Proof of area freedom from citrus black spot (CBS) is required and must be validated by Citrus Black Spot Survey, Multi-Pest Survey, both Grove and Residential, statewide.

Rules for Grove Operations in Citrus Black Spot Quarantine Areas

Florida growers planning to ship fresh citrus fruit to the European Union (EU) must comply with the following provisions to meet 2017 amendments to EU Annexes of Council Directive 2000/29/EC on protective measures with respect to citrus black spot (CBS) in areas within the EU-observed countywide CBS quarantines. Refer to other chapters of this UF/IFAS *Florida Citrus Production Guide* for recommended cultural practices and instructions in pest and disease management.

Cultural Practices

Citrus growers and caretakers must implement cultural practices as recommended by UF/IFAS to minimize the incidence and spread of citrus black spot disease in each production unit (with no buffer area required). As an example, leaves may be raked from under trees or be treated in place with an approved material. Additionally, dead wood should be removed from the trees and any diseased and declining trees removed from the groves.

- Appropriate treatment — Fungicides, such as copper, strobilurins, or other labeled fungicides, should be applied to the trees at intervals as recommended by UF/IFAS to help prevent the damage and spread of citrus black spot disease. Leaf litter should also be controlled by various methods and treatments as recommended by UF/IFAS.
- Growers seeking a Citrus Fruit Harvesting Permit (FDACS 08123) to ship fresh fruit to the European Union (EU) or to other restricted markets must request and fill out an Application for Participation (FDACS 08415) and send it to the local FDACS CHRP field office in order to receive a field inspection of the proposed source grove block(s) for symptoms of citrus black spot.
- Upon receipt of a grower's Application for Participation, the FDACS field office will schedule a field inspection of the grove block(s) requested. The fruit will be field-inspected by the department in the production unit by Multi-Block(s), with no buffer required; if no symptoms of citrus black spot are observed on the fruit, the grower will be issued a Citrus Fruit Harvesting Permit.
- Fruit harvested for fresh-fruit shipment must be packed in an APHIS-compliant packinghouse, washed, brushed, surface disinfected with sodium o-phenylphenate or equivalent, treated at labeled rates with imazalil and/or thiabendazole at the time of packing, and waxed.
- Fruit harvested from source block(s) must be found free of CBS and citrus canker symptoms during an official packinghouse inspection of a representative sample defined in accordance with international standards.
- All packed citrus fruit must be traceable back to the grove block (production unit) of origin as provided on the Federal Phytosanitary Certificate. Trip tickets must include the Grower C/A Number.
- CHRP regulatory staff will conduct random inspections to determine grower compliance with appropriate cultural practices, treatments, and decontamination.
- Each load of fruit must be identified by issuing a clearly written, serially numbered trip ticket with the following information: Grove Name, Multi-Block ID #, Land Owner or Agent, Lessee, Harvester; Number of Boxes, Variety; Tag Number; Grower C/A Number; Destination (Receiving Facility or Disposal Site ID); Date of Harvest; and Harvesting Permit Number. In addition, trip tickets must include the following information near the bottom of the ticket: "TARP-Q" and "CC," to indicate that the fruit is moving from a citrus black spot quarantine area, under statewide citrus canker quarantine, that the fruit is destined for the EU, and that the grower is following the recommended practices in the UF/IFAS *Florida Citrus Production Guide* for pest and disease management. If using a computer-generated trip ticket, the grower/harvester must make sure that all of the above information is on the ticket and that it highlights whether the load is tarped and from a citrus black spot quarantine area.

Regulated fruit from groves in a CBS quarantined area that is not eligible for interstate movement under the conditions stated for consumption in the United States may be moved through Florida or interstate only for immediate export. Regulated fruit for export must be accompanied by a "Limited Permit for Export" issued by an inspector or a trained individual operating under a compliance agreement and must be moved in a container under APHIS seal directly to the port of export. No transloading will be allowed at ports located in citrus-producing states.

Regulatory Remarks

Although truckloads of citrus fruit harvested from perimeter areas of CBS quarantines have not been required to be covered by tarpaulins destined to receiving facilities, covering this fruit is highly recommended as a precautionary measure for the protection of citrus groves in nonquarantine areas of our state.

Check for updates and information on federal quarantines, regulations, and the interstate movement of citrus at the APHIS Citrus Diseases website.

Web Addresses for Links

APHIS-Approved Packinghouse Procedures for CBS: https://www.aphis.usda.gov/plant_health/plant_pest_info/citrus/citrus-downloads/citrus-black-spot/cbs-packing-house-procedures.pdf

APHIS Citrus Disease Program: https://www.aphis.usda.gov/aphis/ourfocus/planthealth/plant-pest-and-disease-programs/pests-and-diseases/citrus

Citrus Copper Application Scheduler: http://agroclimate.org/tools/citrus-copper-application-scheduler/

UF/IFAS publication PP274, "Citrus Black Spot": https://edis.ifas.ufl.edu/publication/PP274

UF/IFAS publication PP289, "A Web-Based Tool for Timing Copper Applications in Florida Citrus": https://doi.org/10.32473/edis-pp289-2012

UF/IFAS publication SL253, *Nutrition of Florida Citrus Trees*, 3rd Edition: https://edis.ifas.ufl.edu/publication/SS478

FDACS Citrus Health Response Program, Citrus Quarantine and Disease Detection Maps: https://www.fdacs.gov/Agriculture-Industry/Pests-and-Diseases/Plant-Pests-and-Diseases/Citrus-Health-Response-Program/Citrus-Quarantine-and-Disease-Detection-Maps

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PP-146
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2026–2029 Florida Citrus Production Guide: Citrus Scab[1]

Megan M. Dewdney[2]

Citrus scab, caused by the fungus *Elsinoë fawcettii,* affects grapefruit, Temples, Murcotts, tangelos, and some other tangerine hybrids. There is no need to control citrus scab on processing fruit, except possibly on Temples, where severe early infection reduces fruit size. Reduction or elimination of foliage wetting on susceptible varieties during the active growth period of the fruit will reduce disease severity.

Spores of this fungus are produced directly on the scab pustules that occur on leaves and fruit. One to two hours of wetting are sufficient for spore production, and only an additional three to four hours are needed for infection. Spores are spread to healthy tissues by water splash.

If leaves from the previous season are heavily infected by citrus scab, three fungicide applications are needed to control the disease: the first at about one-fourth expansion of the spring flush, a second at petal fall, and a third about three weeks later. Timing of the fungicide applications is critical for citrus scab management, but if there is little carryover of disease from the previous season, the first spray can be omitted. Enable 2F, Gem, Headline, or Quadris are good choices for the first application because they are all able to kill the fungus in old lesions and thus reduce inoculum as well as protect foliage. Any of these products can be used in the petal fall spray, but do not use strobilurin (FRAC MOA 11) products (Gem, Headline, or Quadris) twice in a row. Copper fungicides, Gem, Headline, or Quadris are good choices for the third spray because they will protect fruit from early melanose as well as from scab. However, copper products are less effective for scab and should not be selected where scab pressure is high.

On Minneola tangelos, Murcotts, and certain other varieties, Alternaria brown spot and scab can occur in the same grove. In those cases, copper fungicides, Gem, Headline, or Quadris may be preferred because Enable 2F is less effective for Alternaria control. If canker is a concern, the only product that can manage both diseases is copper. With average-quality copper products, about 2 lb of metallic copper per acre is usually sufficient for scab control. The scab fungus may develop resistance to Gem, Headline, or Quadris if these products are not frequently rotated with alternate modes of action. Resistance has been documented in Florida for citrus scab. These products are all strobilurin fungicides (FRAC MOA 11), and only one should be selected for scab control each season. The registration of Ferbam was withdrawn in 2025. This means that there is no longer a broad-spectrum fungicide, other than copper, to manage citrus scab.

Fruit usually becomes resistant to scab by sometime in May, about two months after petal fall.

DO NOT APPLY GEM, HEADLINE, OR QUADRIS IN NURSERIES. Application of these fungicides in nurseries can result in selection of resistant strains, which are then distributed on nursery stock to groves.

[1] This document is PP-146, one of a series of the Department of Plant Pathology, UF/IFAS Extension. Original publication date May 2000. Revised annually. Most recent revision August 2026. Visit the Ask IFAS website at https://ask.ifas.ufl.edu for the currently supported version of this publication.

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2026–2029 Florida Citrus Production Guide: Alternaria Brown Spot[1]

Megan M. Dewdney[2]

Alternaria brown spot, caused by the fungus *Alternaria alternata*, affects Minneola tangelos, Dancy tangerines, Murcotts, and less frequently Orlando tangelos, Novas, Lees, and Sunburst. The susceptibility of many newer tangerine cultivars to Alternaria brown spot is currently unknown. Of the newer cultivars, Sugar Belle® is known to be highly tolerant, but Marathon is at least moderately susceptible and possibly highly susceptible. In rare cases, *Alternaria* may also infect grapefruit. Where severe, the disease results in extensive fruit drop and must be controlled on processing and fresh-market fruit.

Spores of *Alternaria* are airborne. Most spores are produced by lesions on mature leaves in the canopy or recently fallen infected leaves in the leaf litter on the grove floor. Many cultural management practices are helpful in reducing the severity of Alternaria brown spot. When new groves of susceptible cultivars are planted, they should be established with disease-free nursery stock. Trees grown in greenhouses without overhead irrigation are usually free of Alternaria but should be inspected carefully to ensure that no trees have unexpected lesions. Even though spores are airborne, plantings of healthy trees will remain disease-free for long periods. If Alternaria is present from the outset, the fungus builds to high populations when young trees have the most vegetative growth and subsequently is difficult to control on fruit. When establishing new plantings, it is best to locate susceptible cultivars in higher areas where air drainage and ventilation are good and leaves dry more rapidly. Less vigorous rootstocks, such as Cleopatra mandarin, should be selected rather than vigorous stocks, such as Carrizo citrange. Minneola tangelo groves in low, wet areas have conditions so favorable for Alternaria brown spot that it may be virtually uncontrollable there. Susceptible trees should be spaced more widely than oranges to promote rapid canopy drying. In existing plantings, it is important to minimize excessive vegetative growth. Overwatering and excessive fertilization should be avoided. Light hedging should be done regularly rather than hedging severely but less frequently.

Copper fungicides, Amistar Top, Gem, Headline, Pristine, and Quadris are the registered products that are effective for disease control. Disease favorability varies considerably according to the cultivar susceptibility, the grove disease history, and the environmental conditions each year. Generally, the first spray should be applied before disease development when the spring flush is about ¼–½ of full expansion. In severe cases, another spray may be needed when the flush is near full expansion because, if high levels of infection occur on the spring flush, brown spot becomes difficult to control on fruit. Another spray should be applied shortly after petal fall. Amistar Top, Gem, Headline, Pristine, or Quadris may be the best choice for one or both of these two applications, especially if the grove has problems with both citrus scab and Alternaria brown spot. Thereafter, all sprays should be applied solely to maintain a protective coating on the fruit. During April and May, applications may be needed as often as every 10 days or as infrequently as once per month. Spray intervals should be determined based on the frequency of rainfall and grove disease history. By June, high rainfall and humid nights usually assure an abundant supply of inoculum and favorable conditions for infection. In most cases, two applications will be needed during this month. Copper fungicides may blemish the fruit if applied during hot weather. Thus, Amistar Top, Gem, Headline, Pristine, or Quadris are good substitutes for copper applications as needed from May to July. The fruit generally becomes resistant by early to mid-July, although affected fruit may continue to drop for some time afterward. The scenario described is for difficult cases, and it is sometimes possible to use many fewer sprays.

Amistar Top, Gem, Headline, Pristine, and Quadris are all strobilurin-containing fungicides, and Alternaria has been documented to be resistant to strobilurins in most parts of the Florida tangerine production areas. The susceptibility of the pathogen may vary by block and history of strobilurin use. Strobilurin (FRAC MOA 11), DMI (FRAC MOA 3), or SDHI (FRAC MOA 7) fungicides should not be used for Alternaria control more than four times in a season; never use more than two applications of the same mode of action in a row. Gem is slightly less effective for control of this disease and should be used at the highest rate where disease is moderate to severe. Ferbam is no longer registered as of 2025. This has removed the only multi-site broad-spectrum fungicide other than copper for Alternaria brown spot. Keep this in mind when designing rotation plans.

The preferred method to time fungicide sprays is the ALTER-RATER, a weather-based model. Brown spot is most severe when rainfall is greater than 0.1 inch, daily leaf wetness duration exceeds 10 hr, and average daily temperature is between 68°F and 83°F. Daily leaf wetness estimations for FAWN stations can be found on the Citrus Advisory System website, under the daily summary tab for each station. Once the suggested ALTER-RATER thresholds are reached, make a fungicide application. Refer to the *Florida Citrus Production Guide* tables booklet for the thresholds.

With such frequent sprays, low rates of copper may be used. With average-quality products, usually about 2 lb of metallic copper per acre is needed for each three-week period, or 1 lb if sprays are more frequent. Even lower rates of metallic copper can be used if high-quality products are employed. The copper residue levels over time can be monitored with the use of the Citrus Copper Application Scheduler. More details are available in UF/IFAS publication PP289, "A Web-Based Tool for Timing Copper Applications in Florida Citrus."

DO NOT APPLY AMISTAR TOP, GEM, HEADLINE, PRISTINE, OR QUADRIS IN NURSERIES. Application of these fungicides in nurseries can result in selection of resistant strains, which are then distributed on nursery stock to groves.

Web Addresses for Links

Citrus Advisory System: http://agroclimate.org/tools/cas/

Citrus Copper Application Scheduler: http://agroclimate.org/tools/citrus-copper-application-scheduler/

UF/IFAS publication PP289, "A Web-Based Tool for Timing Copper Applications in Florida Citrus": https://doi.org/10.32473/edis-pp289-2012

[1] This document is PP-147, one of a series of the Department of Plant Pathology, UF/IFAS Extension. Original publication date December 1995. Revised annually. Most recent revision August 2026. Visit the Ask IFAS website at https://ask.ifas.ufl.edu for the currently supported version of this publication.

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2026–2029 Florida Citrus Production Guide: Postbloom Fruit Drop[1]

Natalia A. Peres and Megan M. Dewdney[2]

Postbloom fruit drop (PFD) must be controlled on processing and fresh-market fruit. PFD, caused by a fungus in the species complex *Colletotrichum acutatum,* affects all species and cultivars of citrus, but severity on a given cultivar varies according to the time of bloom in relation to rainfall. Navel and Valencia oranges have experienced the most severe damage in Florida because they tend to have extended or multiple blooms.

Most spores of this fungus are produced directly on the surface of infected petals. Spores are splash-dispersed by rain to healthy flowers, where they infect within 24 hours and produce symptoms in 2–3 days. The fungus survives between bloom periods as resistant resting structures on the surface of leaves, persistent calyxes (buttons), and twigs. Flowers are susceptible from the button stage (with white tissue present) until they are open.

Groves with persistent calyxes (buttons) from the previous year should be closely examined once the bloom begins. If infected flowers are present on scattered early bloom, fungicide application recommendations should be followed once sufficient bloom is present for the fungicide application to be economical. Groves with a history of PFD should be scouted twice weekly during the bloom period. Ground and aerial applications are effective for control of PFD when properly timed. Low-volume application equipment can be used if good coverage of the flowers is provided. For aerial and low-volume applications, minimum volume levels should be followed according to the label. Ideally, to reduce disease severity, remove declining trees, such as those with HLB, blight, or Phytophthora, where off-season blooms may provide a site for fungal spore buildup. Note that this may not be practical in groves with many trees affected by HLB.

The Citrus Advisory System (CAS; Figure 1) was developed to further facilitate growers' decisions on the need for fungicide applications. The system uses real-time weather data from Florida Automated Weather Network (FAWN) stations throughout the state to determine whether risk for PFD is low (green), moderate (yellow), or high (red) based on leaf wetness duration and temperature during the wetting period. At least 15 hours of continuous wetness are usually required to trigger moderate or high-risk conditions. Low areas in the grove that accumulate fog in the mornings should be monitored more closely because they stay wet longer than the open areas where the weather stations are located. In these areas, if the risk level is just below the moderate threshold based on the FAWN data, the extended wetting period may raise the risk to above the moderate threshold and an application may be warranted. Specific fungicide spray recommendations are given according to the disease risk conditions and crop phenology, that is, the stage and intensity of the bloom. The CAS system can send notifications via SMS or email for an alert to check the system because an infection event has occurred.

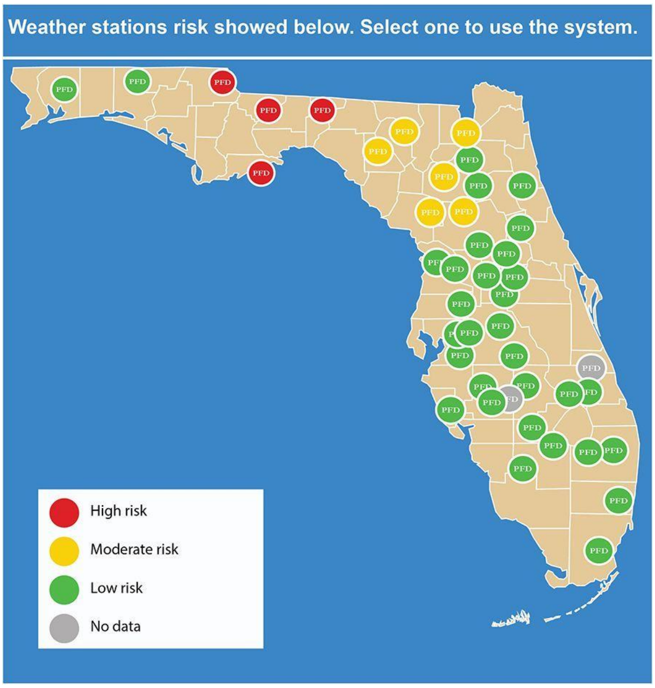

Figure 1. Citrus PFD Advisory System available at http://agroclimate.org/tools/cas.

Because the number of fungicides available as well as the number of applications for each fungicide are limited, preventive fungicide programs are difficult to implement, especially in groves with large numbers of declining trees, which might bloom for an extended period. As a reminder, groves with a history of PFD should be checked semiweekly during bloom. If symptomatic flowers are found on scattered bloom, CAS recommendations should be followed once sufficient bloom is present to justify a fungicide application.

Of the products recommended for control of PFD, all contain strobilurin fungicides (FRAC MOA 11). They are effective but do not have a long residual effect since new flowers are always emerging. No strobilurin resistance has been detected to date. Ferbam is no longer registered as of 2025. This means there is no longer an effective multisite or non-strobilurin-containing fungicide recommended for use for PFD currently. Copper is ineffective against PFD. Resistance management solutions at this time are simply limiting the use of fungicide applications.

Web Address for Link

Citrus Advisory System (CAS):
http://agroclimate.org/tools/cas

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2026–2029 Florida Citrus Production Guide: Exocortis, Cachexia, and Other Viroids[1]

Amit Levy, Ozgur Batuman, and Ronald H. Brlansky[2]

Exocortis and cachexia are diseases caused by viroids and can lead to stunted growth and reduced yields in infected plants. Viroids are small and circular, virus-like, infectious RNA molecules. Exocortis causes dwarfing and bark scaling on rootstocks such as trifoliate orange and many of its hybrids, including Rangpur lime, Carrizo citrange, and others. Stunting is usually severe on trifoliate orange rootstock, less severe on citranges and Rangpur lime, and mild on Swingle citrumelo. Swingle citrumelo does not usually show bark scaling.

Cachexia, also called xyloporosis, causes severe pitting and gumming in the bark and wood of the trunks and branches on some tangerines and their hybrids. Orlando tangelo is especially sensitive. Affected rootstocks include *Citrus macrophylla*, some mandarins, and sweet lime.

Another viroid that occurs commonly in Florida is citrus dwarfing viroid (formerly citrus viroid III), which affects the same rootstocks as citrus exocortis viroid and causes stunting but no scaling.

Viroids are transmitted primarily by the introduction and propagation of infected budwood. There is a constant risk that symptomless budwood is actually carrying viroids and will spread them without showing any disease symptoms. Viroids will also spread mechanically from tree to tree on pruning equipment, budding knives, and hedging and topping equipment if they are not disinfected. Viroids are relatively easy to detect and identify by sensitive molecular procedures in the laboratory, such as PCR and hybridization techniques. In addition, viroids can be detected by indexing on sensitive biological indicators, such as Etrog citron for exocortis and dwarfing viroids, and Parson's Special mandarin for cachexia. Biological indexing on Etrog citron requires three to six months, and indexing on Parson's Special mandarin for cachexia requires at least one year. In Florida, the decrease in the incidence of viroid diseases is because budwood sources used by nurseries are always certified free of viroids through the Bureau of Citrus Budwood Registration.

Recommended Practices

1. Budwood sources used by nurseries should be certified free of viroids, especially if the rootstock or cultivars employed are sensitive to these viroids. Growers should only purchase trees propagated from certified sources.
2. Knives and pruning tools in the nursery should be disinfected with a *fresh* solution of bleach (1% free chlorine) when moving from one budwood source to another.
3. Groves suffering from severe stunting caused by exocortis or from cachexia should be removed and replaced with healthy trees.
4. Although hedging and topping can spread viroids, infection of mature trees with viroids is usually not detrimental to productivity. It is recommended to disinfect equipment when using sensitive rootstock varieties.
5. Extra cautions are needed when using newly released citrus rootstock varieties, whose sensitivity to viroids is still unknown.

Web Address for Link

Bureau of Citrus Budwood Registration:
https://www.fdacs.gov/Agriculture-Industry/Pests-and-Diseases/Plant-Pests-and-Diseases/Citrus-Health-Response-Program/Citrus-Budwood-Program

[1] This document is PP-179, one of a series of the Department of Plant Pathology, UF/IFAS Extension. Original publication September 1999. Revised annually. Most recent revision August 2026. Visit the Ask IFAS website at https://ask.ifas.ufl.edu for the currently supported version of this publication.

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2026–2029 Florida Citrus Production Guide: Blight[1]

Ozgur Batuman, Amit Levy, and Ronald H. Brlansky[2]

Citrus blight is a wilt-and-decline disease of citrus, and its cause has not been determined. The first symptoms on huanglongbing (HLB)-free trees are usually a mild wilting and grayish cast to the foliage, often accompanied by zinc deficiency symptoms on trees. Trees rapidly decline with extensive twig dieback, off-season flowering, and small fruit. Blighted trees reach a stage of chronic decline but seldom die. Currently, however, it is difficult to recognize blight due to HLB symptoms, and there is an increased incidence of rapid decline and death among trees with mixed infections of blight and HLB.

The disease affects only bearing trees and usually first appears when the trees in the grove are six to eight years old. The first affected trees in a grove are usually randomly distributed, but groups of blighted trees may eventually occur, either as clusters or down the row. The disease has been transmitted in the grove by root grafts, but not by limb grafts or with budwood. The means of spread, other than by root grafts, is not known.

Blight symptoms can be confused with other decline diseases (e.g., HLB, tristeza decline, etc.), and accurate diagnosis is important in order to follow proper practices. Citrus blight is characterized by (1) high zinc content in trunk bark and wood; (2) presence of amorphous plugs in the xylem; (3) failure to absorb water injected into the trunk; and (4) presence of blight-associated citrus proteins in roots and leaves. The best procedure for diagnosis of individual trees in the field, particularly if you are practicing trunk injection in spring months (March, April, and May), is to test water uptake into the trunk, which is done by using a battery-powered drill to open a small hole (1/8 inch) and injecting water from a plastic syringe without a needle. Healthy trees or trees declining from phytophthora root rot, nematodes, water damage, tristeza, or HLB will usually take up about 10 ml of water in 30 seconds. *Trees affected by citrus blight take up no water regardless of the amount of pressure applied*. If you find that this is the case, particularly when you are practicing trunk injection, you should label the affected trees. It is very unlikely that antibiotic injection for HLB would be effective in those trees. A laboratory test is being developed that will be more accurate, and with proper equipment, many samples will be processed in a short time. However, the syringe test is the only method currently available for confirmation of blight.

All scion varieties of citrus as well as ungrafted seedlings may be affected by citrus blight. Trees on all rootstocks are susceptible, but significant differences between rootstocks exist. The rootstocks that are the most severely affected by blight are rough lemon, Rangpur lime, trifoliate orange, Carrizo citrange, and some others. Those most tolerant to blight are sweet orange, sour orange, and Cleopatra mandarin. Swingle citrumelo was listed as tolerant; however, there appears to be an increase in blight incidence on that rootstock. Sweet orange and sour orange have not been recently recommended because of susceptibility to phytophthora root rot and tristeza, respectively.

Recommended Practices

There is no cure for citrus blight. Once trees begin to decline, they never recover. Severe pruning of blighted trees will result in temporary vegetative recovery, but trees decline again once they come back into production. The only procedure recommended for management of citrus blight is to remove trees promptly once yield of affected trees has declined to uneconomical levels.

When planning to plant or replace trees, there are three strategies recommended:

- Plant or replace trees with trees on rootstocks that do not develop blight at an early age, such as Cleopatra mandarin (if phytophthora root rot is not present in the grove) or Swingle citrumelo; or
- Plant trees on vigorous and productive rootstocks that develop blight at an early age, such as Carrizo citrange or rough lemon, and replace trees that decline as soon as they become unproductive.
- Note that when trees cannot uptake water, antibiotic injection for HLB is not effective. Remove the tree and replant a healthy tree under an individual protective cover.

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2026–2029 Florida Citrus Production Guide: Tristeza Decline[1]

Ozgur Batuman, Amit Levy, and William O. Dawson[2]

Citrus tristeza virus (CTV) is a major cause of the decline and eventual death of trees on sour orange rootstocks. Initially, affected trees have small leaves and twig dieback. Diseased trees often produce small fruit, and the yield declines. Eventually, large limbs die back and the tree gradually declines. In extreme cases, trees may suffer from quick decline and wilt, dying in a matter of weeks. On sour orange rootstock, some isolates of CTV cause graft incompatibility at the bud union, which results in the loss of fibrous roots and reduced ability for water uptake. Bark flaps cut from across the graft union of declining trees often show pitting consisting of small holes (honeycombing) on the inside face of the bark flap from the rootstock side of the union. Quick-decline trees may only have a yellow-brown stain at the bud union and not show the honeycombing. Only trees on sour orange rootstock are affected by tristeza decline. Sweet oranges usually are more affected than grapefruit, whereas lemons on sour orange rootstock may not be affected. Losses from CTV-induced decline have been offset by the use of nonsusceptible rootstocks, primarily trifoliate hybrids. Because huanglongbing (HLB) is endemic in Florida, many trees are now mixed infected with CTV and HLB and may show more profound decline regardless of the rootstock used.

Citrus tristeza virus is transmitted by aphids. They acquire it within minutes of feeding on the plant and transmit the virus to healthy plants equally rapidly. The brown citrus aphid (*Toxoptera citricida*), which first appeared in Florida in 1995, is considered the most efficient vector of the virus. The cotton or melon aphid (*Aphis gossypii*) is a less efficient but still effective vector, whereas the green citrus or spirea aphid (*Aphis spiraecola*) and the black citrus aphid (*Toxoptera aurantii)* are considered to be less efficient vectors of CTV in Florida. The establishment of brown citrus aphid in Florida is believed to have resulted in a more rapid spread of decline-inducing isolates of tristeza.

Mild isolates, inducing no stem-pitting nor decline, have been widely disseminated in Florida by aphids and in infected budwood. The incidence of decline has been reduced due to the use of tolerant (non-sour orange) rootstocks such as Swingle citrumelo and Carrizo citrange. This also can be attributed to reduced brown citrus aphid populations and CTV reinfection rates probably due to recent, more aggressive pest management practices for Asian citrus psyllid in the groves. However, many of the trees on these tolerant rootstocks are shown to be infected with CTV decline isolates without showing symptoms. Therefore, there is still a high risk for reemergence of tristeza decline disease if the sour orange rootstock is used in Florida.

In some countries, certain CTV isolates also cause stem-pitting (see UF/IFAS publication PP-227, "Citrus Diseases Exotic to Florida: Citrus Tristeza Virus-Stem Pitting [CTV-SP]") in citrus scions including grapefruit and sweet orange, regardless of the rootstock used. Isolates that cause decline of sweet orange on sour orange also may cause stem-pitting in trees on other rootstocks, but many decline isolates produce no stem-pitting in grapefruit or oranges. Isolates that are genetically similar to severe stem-pitting isolates found in other countries have been found in Florida. Some of these isolates give a degree of stem-pitting on sweet orange, but it is difficult to assess whether they cause economic losses in field trees due to the widespread presence of HLB.

Virtually all isolates of CTV can be detected by graft inoculation onto sensitive biological indicators, such as Mexican lime. The virus can be detected in young leaves, or in psyllids nymphs feeding on the leaves. More modern and much faster techniques, such as molecular tests including reverse transcriptase (RT) polymerase chain reaction (PCR) or ELISA using polyclonal antisera, are nowadays preferred. The monoclonal antibody MCA-13 detects most CTV isolates that cause decline on sour orange rootstocks in Florida and also reacts with most stem-pitting isolates, but it does not react with mild Florida isolates. If an appropriate and reliable laboratory test for CTV is needed, contact your local Extension agents, Extension specialists, or FDACS-DPI (FDACS-DPI Helpline Number: 1-888-397-1517).

Budwood propagated for commercial distribution must be free of CTV. Most stem-pitting isolates are MCA-13-reactive, but not all. PCR-based methods can identify stem-pitting isolates, but the only absolute means to detect stem-pitting isolates is by graft inoculation of grapefruit and sweet orange seedlings and examination of symptoms after 6–15 months (a.k.a. indexing).

Recommended Practices

1. Budwood propagated for commercial distribution must be free of CTV. Even in the presence of HLB, it is still recommended that growers avoid sour orange and use only decline-resistant rootstocks. The key to preventing problems with stem-pitting in Florida is to avoid introduction, propagation, and distribution of stem-pitting isolates.
2. Once tristeza-affected trees on sour orange rootstocks begin to decline, there is no treatment. The diseased trees should be replaced with certified trees on tolerant rootstocks as the yields of affected trees decline to uneconomical levels. Even though it may be hard to determine if decline results from CTV or HLB, these trees should nonetheless be replaced with a CTV-tolerant rootstock (See the *Florida Citrus Rootstock Selection Guide*).
3. In groves with trees on sour orange rootstock that are currently unaffected by tristeza decline, it may be possible to inarch trees with seedlings of a tolerant rootstock. Inarching is most effective with relatively young groves that are still actively growing, and in order to be effective, the inarches must be well established before trees become infected. Given the high cost of the practice, it is probably advisable only in the case of high-value crops in groves that are well separated from areas with severe strains of tristeza virus. It is more likely to be successful with younger than with older trees.
4. Keeping aphid populations in check in the grove may help reduce feeding damage and secondary spread of the virus onto resets (see chapter 24, "Soft-Bodied Insects Attacking Foliage and Fruit").
5. Cross protection, which is the practice of inoculating trees with mild virus strains to protect them from the effects of severe strains, has been effective in South Africa and Australia in reducing losses in grapefruit due to stem-pitting, and against losses in sweet orange in Brazil. Cross protection against tristeza decline on sour orange rootstock has not yet been developed as an effective control measure.

Web Addresses for Links

UF/IFAS publication PP-227, "Citrus Diseases Exotic to Florida: Citrus Tristeza Virus-Stem Pitting (CTV-SP)": https://edis.ifas.ufl.edu/publication/PP149

Florida Citrus Rootstock Selection Guide: https://ask.ifas.ufl.edu/publication/HS1260

UF/IFAS publication ENY-604, "Soft-Bodied Insects Attacking Foliage and Fruit": https://ask.ifas.ufl.edu/publication/CG004

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2026–2029 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* (see chapter 31, "Brown Rot of Fruit")], 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 UF/IFAS publication CIR1170, "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.

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 UF/IFAS publication HS761, "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 (FRAC MOA 1) 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 (FRAC MOA 3) 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 (FRAC MOA NC) 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 (FRAC MOA 12) and azoxystrobin (FRAC MOA 11) 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 (FRAC MOA 9) 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 31, "Brown Rot of Fruit," for more details.

Summary of Fungicide Treatments

Effective fungicide treatments are summarized in booklet 2, 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 (booklet 2, 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; see UF/IFAS publication HS936, "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 UF/IFAS publication HS935, "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/

UF/IFAS publication CIR1170, "Recommendations for Degreening Florida Fresh Citrus Fruits":
https://edis.ifas.ufl.edu/publication/HS195

UF/IFAS publication HS935, "Chilling Injury of Grapefruit and Its Control": https://edis.ifas.ufl.edu/publication/hs191

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

UF/IFAS publication HS936, "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

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2026–2029 Florida Citrus Production Guide: Weeds[1]

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Weed management in Florida citrus is an important component of any successful integrated pest management (IPM) program. IPM programs utilize a combination of control practices including but not limited to cultural, preventive, mechanical, chemical, or biological methods. Weed management is expensive and a major component of the total citrus production program. Time spent developing this production program can provide significant economic and environmental returns. The goal of weed management is to minimize the competitive effect of weeds on the citrus tree, be it young or mature. An understanding of the growth and competitive nature of the weed is important. The objective of today's weed management program is to suppress and control weeds so that they do not cause damage to the tree, impact yield, or impede grove and harvesting operations. Complete and total elimination of all weeds from the grove floor is neither necessary nor warranted.

When developing a weed management program, growers must consider the (1) application site (tree age, soil type, and location, including ridge vs. flatwoods and county limitations); (2) weeds present; (3) stage of weed growth; (4) herbicide selection; (5) spray nozzle and herbicide band width; (6) spray volume and pressure; and (7) amount of herbicide used. All these factors will directly affect cost and the success of the weed management program.

Tree Age and Variety

From years of experience and trials, growers know that weed growth is greater in young groves compared to mature groves. Generally speaking, young groves will require greater attention to material selection and rate because the areas around the trees are more sun-exposed and have greater weed pressure than do larger trees, which have greater shaded areas with lower weed pressure. An exception to lower weed pressure for mature trees is where vines are present. Vines can germinate in shaded areas and grow into the tree canopy, creating a host of problems for the tree and fruit-harvesting operations. Young trees generally will not tolerate herbicide rates as high as mature trees. Additionally, weeds compete with young trees for nutrients, water, light, and space at a greater rate as compared to mature trees.

When using herbicides for weed control, rates should be adjusted for tree age, with lower rates on young trees. Also, be aware that some herbicide products may only be labeled for nonbearing sites, which means that product can only be applied if a crop is not going to be harvested within 12 months.

Consideration should also be given to product selection based upon variety. Some products specify that they may only be used on oranges, thus prohibiting their use on tangerines.

Impact of Weeds on Tree Growth

Weeds can impact tree growth and subsequent yields by altering the spray pattern of low-volume irrigation systems, intercepting soil-applied chemicals (fertilizer and agricultural chemicals), reducing grove temperatures during freeze events, and interfering with harvesting operations. The presence of weeds in a grove can also affect insect populations and disease incidences.

Ground cover in the row middles also plays an important role in grove management by reducing soil erosion, sandblasting during windy conditions, and retaining nutrients, but it can also impact tree growth when allowed to compete with the citrus tree. Sod-forming bahiagrass and bermudagrass are typically used as ground cover between the tree rows, but bermudagrass can be more competitive than bahiagrass. Ground cover can be beneficial if it is less competitive than any weeds that may be present in the grove. Thus, the selection of row-middle vegetation is an important consideration in IPM.

Direct reduction in citrus tree growth and yield can occur when weeds compete with trees for light, water, nutrients, and space. However, not all weeds compete with citrus trees in the same way or with the same level of competition. Water requirements for vegetation regrowth after mowing can impact water availability within the grove. During this regrowth period, grasses use more water from the soil compared to broadleaf plants. Vines can be more competitive for sunlight than other plants. Weeds can also compete with citrus trees in many ways, but with varying intensities. The ability of plants to intercept varying levels of water, light, and nutrients makes some weeds more competitive with citrus than other species. Therefore, highly competitive weeds should be of great importance to the production manager. Successful weed control is extremely important in groves containing weeds that are highly competitive. In an IPM program, the most competitive weeds are identified and removed before they produce seeds. With time, seeds in the soil can be reduced through suppression, cultural, and sanitation methods.

To ensure competitive weeds are suppressed, proper plant identification is a critical first step in developing an effective program. Weed species will vary with location, climate, season, soil type, previous site history, and current and past management programs. Scouting should be conducted in all areas in and near the grove but not limited to tree rows, row middles, water furrows, ditch banks, fence rows, and adjacent off-site locations. Each of these sites may receive different cultural practices, but different weeds may be found. Scouting off-site locations may prevent small, isolated problems from becoming larger problems. Because weeds emerge throughout all growing seasons, schedule weed surveys throughout the year. Scouting should occur even if weeds are not easily visible or appear to be dead. A rapid regrowth from perennial plants that appear to be dead can occur and is particularly problematic when replanting new trees into weed-infested sites. Scouting should be conducted by walking throughout the groves, because small, easy-to-control weed seedlings may go unnoticed when driving through the grove. If weeds are properly identified while in the seedling or vegetative stage, then proper control can be achieved through (1) increased flexibility in timing control options; (2) possible reduced herbicide application rate; and (3) reduced impact from control measures.

When scouting for weeds, records should be developed and recorded as to species abundance, location, and identity. Changes over time can be tracked to provide control strategy effectiveness. When scouting a large area, it is common to find a large number of weed species. The species present will vary with season and location.

Weeds can be identified or grouped as (1) broadleaf (including vines); (2) grass; or (3) sedge. The identification of weeds can be aided by looking for specific characteristics of the plant. These specific characteristics can include shape of the leaves, stems, seed, seed head, plant size, root system, and the type and color of flowers, if present. Weeds can be classified by their life cycle: annual, biennial, or perennial. Annual plants have a one-year life cycle, growing from seed, maturing, and producing seed for the next generation of plants in one year or less. Annuals can be further divided into summer (sprout in spring, grow, mature, and produce seed and die before winter) or winter (sprout in the fall, grow, mature, produce seed and die before summer). Biennials have a two-year life cycle, growing from seed and developing a heavy root system the first year, followed by seed production in the second year and then plant death. Perennials live more than two years, with seed production occurring as early as the first year.

Detailed information on weed identification in citrus groves is available from the following UF/IFAS publications: HS926/HS185, "Identification of Vine Weeds in Florida Citrus"; HS896/HS150, "Identification of Broadleaf Weeds in Citrus"; HS955/HS175, "Identification of Grass Weeds in Florida Citrus"; and HS962/HS205, "Identification of Sedge and Sedge-Like Weeds in Florida Citrus."

Weed Management Options

Many approaches are used to suppress or control weeds (vegetation) within the grove. These practices will vary with location, time (season), tree spacing, vegetation species present, cost, and grower preference. Each method of weed control has its own advantages and disadvantages.

Preventive

Preventive programs are often overlooked as a method of weed control. Preventive programs entail the use of such practices as sanitation, spot spraying, or hand labor to prevent the source of weed infestation (seed or vegetative) from widespread dissemination throughout an area. By removing the undesirable weed species prior to seed development, dissemination by the wind or mechanical transport on equipment can be effectively delayed. While preventive programs will not stop the spread of new weed species, these practices may slow the spread of undesirable weed species, thereby reducing the cost of current weed control programs.

Mechanical

Cultivation or tillage has been used in the past for many years in citrus production. Tillage is an effective method of controlling annual weeds by severing stems and roots of the weeds, but it is not very effective on perennial grasses. Tillage use is decreasing as a weed control method as more groves are planted on raised beds, and tillage increases the chances for soil erosion. Additionally, tillage damages the fibrous roots close to the soil surface, which is the main reason for the reduction in use. These shallow fibrous roots close to the soil surface are very important in groves where the root systems are limited due to high water tables, *Phytophthora* root rot, or root weevils. With the use of low-volume irrigation systems and closer in-row planting distances, tillage in both directions is no longer possible.

Mechanical mowing is generally more expensive than tillage due to the cost of equipment and energy requirements. Mechanical mowing can also throw seed under the tree canopy, increasing weed pressure in the undercanopy area of the tree. The frequency of cultivation or mechanical mowing is dependent on the weeds present and the season.

Chemical

Chemical weed-control programs will vary from location to location within the state and can even vary within a given site based on specific conditions such as soil type, variety, method of herbicide application, and the presence of specific weed species. Herbicides used in a grove are generally divided into two groups: (1) soil-applied preemergence herbicides that should be applied to fairly clean soil surfaces prior to weed emergence, and (2) foliar-applied postemergence herbicides that are applied after germination of weed seed.

Preemergence herbicides can be absorbed through emerging stems in the soil or through roots. Preemergence herbicides are most effective before germination and early seedling growth stages.

Postemergence herbicides can be further divided into systemic or contact. Systemic herbicides are translocated within the target plant, killing the foliage and root system of the contacted plant. Contact herbicides kill only the plant parts that are contacted by the spray application. All herbicides used in citrus are selective in that they kill some plants (weeds) without significantly injuring other plants (citrus trees) if applied at the correct rate and manner.

Preemergence herbicides are generally applied two to three times per year, and the total annual amount of herbicide materials will be nearly the same, regardless of the application frequency. For preemergence materials, application should be properly timed so that the maximum amount of herbicide is in the upper soil profile (0–2 inches) slightly before peak weed emergence. Material applied too early will not have enough herbicide concentration to provide adequate weed control due to herbicide losses caused by leaching or degradation on the soil surface or within the soil profile.

Chemical Mowing

Chemical mowing use is increasing each year as the cost of mechanical mowing increases due to rising equipment, maintenance, and fuel costs. Chemical mowing consists of sublethal rates of systemic herbicide (glyphosate) to suppress the growth or regrowth of grasses and broadleaf weeds that grow in the row middle for up to 45–90 days. Prior to the chemical mowing application, the vegetation within the row middle is mowed and allowed to slightly regrow.

Chemical Weed Control Programs

Successful herbicide programs start with selecting the right herbicide or herbicide mixtures. All herbicides have a label that states the use requirements, application rates, weeds controlled, and personal protective equipment required during mixing and application. Remember that the label is the law and must be followed.

The herbicide use rate, the stage of weed growth, climate, and method of application can affect control. Climatic extremes that stress plants, including drought, flooding, and extreme temperatures, could result in reduced herbicide performance. Stressed plants take up and translocate less herbicide than nonstressed plants. Poor herbicide performance is minimized when the proper herbicide is selected and applied at recommended rates in the correct spray volume to the right stage of the seedling's growth.

Selecting the proper herbicide requires an understanding of how herbicides work on plants. Herbicides applied to the soil before weed emergence are referred to as preemergence (Table 1). Other herbicides can be applied directly to weeds and are referred to as postemergence (Tables 2–5). These tables are found in booklet 2 of the *Florida Citrus Production Guide*.

Environmental Considerations

Herbicide selection should be based upon a number of factors, including weed species that are present or anticipated from weed surveys, vegetation developmental stages, product solubility and leaching potential, soil type at the location of application, rainfall distribution, county location, and other factors present on the product label.

Herbicides may move through the soil to groundwater if used improperly. Factors influencing the rate of herbicide movement in the soil include but are not limited to irrigation practices, rainfall, herbicide solubility, soil type, and organic matter.

Additional consideration should be given to products containing bromacil, which are prohibited on deep, sandy, ridge-type soils. Also, some product labels restrict the annual application of diuron within Highlands County. Consult your local UF/IFAS Extension or USDA-NRCS office for information on soil type restrictions.

Application Technology

Advances in herbicide application technology have resulted in the development of sophisticated equipment for the precision application of selected products within a grove setting. This sophisticated equipment is capable of selective delivery of multiple herbicide products, each directly injected or contained in multiple tanks that are injected into multiple lines or controlled by electronic sensors.

When applying preemergence herbicides via an herbicide boom, complete uniform coverage of the soil surface is important for improved weed control. Factors that can affect the uniformity of coverage include worn or damaged nozzle tips, boom height, and vegetation present. As nozzles become worn, delivery rates increase and distribution patterns from the individual nozzles become distorted. Weeds present will also affect spray patterns as well as block the herbicide from reaching the soil surface when preemergence herbicides are being applied. The herbicide label may also state application equipment requirements. These requirements may include special herbicide boom designs that minimize material drift or potential contact with tree foliage.

Application pressure is also important because it affects the size of the spray droplets. Higher spray pressure decreases the spray droplet size, thereby increasing the chances of off-target damage due to spray drift. The manufacturer's specified operating pressure range should be considered when selecting nozzles.

Additional information about herbicide equipment and its calibration can be found in UF/IFAS publication HS-1012/HS252, "Citrus Herbicide Boom Sprayer Calibration."

Band Width

Application band width has a major impact on the amount of herbicide material applied per grove acre, thus directly affecting total weed control costs. When trees are small, herbicide band width should be rather narrow, only covering an area of 3–4 feet on each side of the tree. As the canopy width increases, the herbicide band width should likewise increase. Narrow band widths on small trees will aid in minimizing soil erosion and assist in maintaining water quality in bedded-grove situations.

Position of the Off-Center Nozzle on the Herbicide Boom

Herbicide applicators should think about the angle of the off-center (OC) nozzle on the end of the herbicide boom. The nozzle angle as well as the distance from the end of the boom will have a major impact on where the spray is directed. The greater the nozzle angle, the higher and farther beyond the end of the boom the spray is directed, greatly increasing the chances of phytotoxicity occurring in the tree canopy. The height of the boom and its angle will also impact the distance and height that the spray is directed into the canopy of the citrus tree.

Herbicide Resistance Management

In many crops, the discovery of resistance to various herbicides has been well documented. Resistance is the ability of a specific weed to survive treatment with a given herbicide to which the species is normally susceptible. With repeated use of the same herbicide, the risk of resistance is increased. Due to its frequent and widespread use, glyphosate is a particular concern in Florida citrus. Weed resistance to glyphosate is a documented issue in numerous crop systems and should be expected. Rotating between herbicide classes will minimize the potential for development of herbicide resistance. A listing of the recommended herbicides is provided in Table 7, which identifies the chemical class of each herbicide material. Table 7 is found in booklet 2 of the *Florida Citrus Production Guide*.

Chemical Control of Root Sprouts

Various forms of glyphosate and triclopyr currently have label recommendations allowing these products to be used on recently cut citrus stumps. Triclopyr (Remedy Ultra) has an EPA 24(c) special local need registration for application to citrus stumps in Florida. This product should be applied in a manner that minimizes the application to the soil surface adjacent to the cut tree trunk.

Complete coverage of the cut surface will enhance control of vegetative regrowth from the stump. Stumps should be treated as soon as possible after cutting because effectiveness is reduced with time. If root grafting with desirable adjacent trees is present, the material may be translocated to healthy trees, causing significant damage.

Products should be applied in a manner that minimizes drift from the application site (cut stump) to the adjacent tree(s).

Be sure to read and follow all label requirements.

Recommended herbicide tables for weed management in citrus are in booklet 2 of the *Florida Citrus Production Guide*.

Web Addresses for Links

UF/IFAS publication HS-896/HS150, "Identification of Broadleaf Weeds in Citrus": https://doi.org/10.32473/edis-hs150-2003

UF/IFAS publication HS926/HS185, "Identification of Vine Weeds in Florida Citrus": https://doi.org/10.32473/edis-hs185-2003

UF/IFAS publication HS955/HS175, "Identification of Grass Weeds in Florida Citrus": https://doi.org/10.32473/edis-hs175-2004

UF/IFAS publication HS962/HS205, "Identification of Sedge and Sedge-Like Weeds in Florida Citrus": https://doi.org/10.32473/edis-hs205-2004

UF/IFAS publication HS-1012/HS252, "Citrus Herbicide Boom Sprayer Calibration": https://doi.org/10.32473/edis-hs252-2005

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