Cir 1241

UF UNIVERSITY of FLORIDA
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Florida Crop/Pest Management Profiles: Citrus (Oranges/Grapefruit)[1]

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Production Facts

Oranges

- Even with four hurricanes impacting Florida oranges in 2004, Florida growers produced 70 percent of the oranges harvested in the U.S. in 2005. This represents a 38 percent decrease from the previous season. This decrease was almost entirely due to citrus being stripped from trees by high winds (1).
- Approximately 13,464,000,000 pounds of oranges, valued in excess of $842 million, were produced during the 2004-2005 crop year on 541,800 acres, which represents 74 percent of the national orange acreage (1).
- Approximately 95 percent of the Florida orange crop is processed for juice while the remainder goes to the fresh market (1).

Grapefruit

- Florida growers produced 50 percent of the grapefruit harvested in the U.S. in 2005. This represents a 69 percent decrease from the previous season. Although there was a 14 percent decrease in acreage, most of the production decrease was due to citrus being stripped from trees by high winds (1).
- Approximately 1,088,000,000 pounds of grapefruit, valued in excess of $208 million, were produced during the 2004-2005 crop year on 71,000 acres, which represents 69 percent of the national grapefruit acreage (1).
- Approximately 42 percent of the Florida grapefruit crop is processed for juice while the remainder goes to the fresh market (1).

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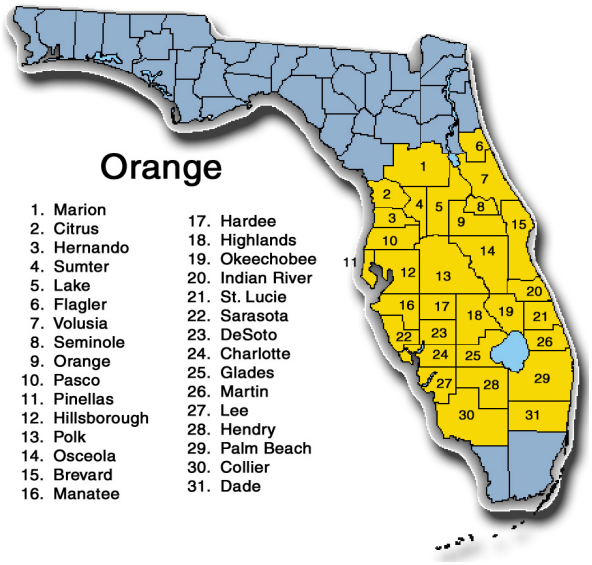
Production Regions

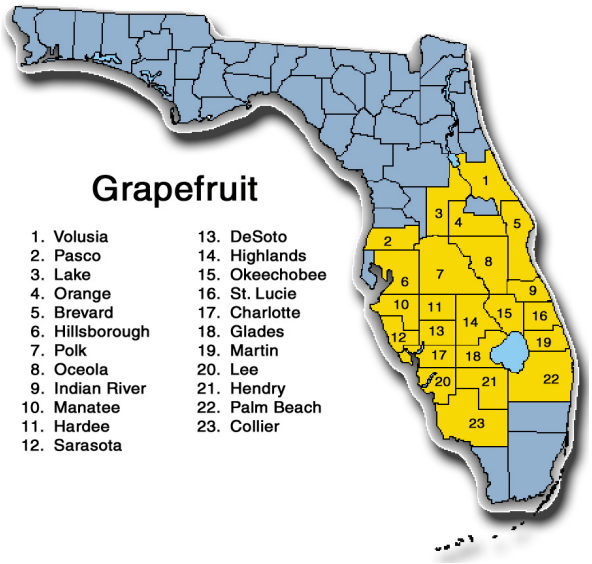
The acreage devoted to citrus production is not distributed uniformly throughout the state. Citrus acreage is decreasing on the central Florida ridge due to industrial and residential development. Currently, the 10,000+ citrus growers maintain about half of their production on the ridge and half in the flatwoods of central and southern Florida. Following the major tree killing freezes experienced in the 1980s, growers on the ridge who replant in citrus are taking advantage of the opportunity to institute new production practices which include smaller trees, closer plantings (so tree numbers per acre are increasing), and new varieties. As a result, while acreage has decreased, the total number of trees and boxes produced is increasing. The five counties with the highest number of citrus acres are Polk, Hendry, St. Lucie, Highlands, and DeSoto. Thirty of Florida's 67 counties reported either orange and/or grapefruit production in 2004 (2).



Major Orange Production Regions in Florida.

Production Practices

The majority of oranges and grapefruit are produced by practices recommended only for fresh market fruit, despite the fact that 90 percent of the harvested fruit will be processed for juice. There are various practices depending on the setting. The first setting is the nursery, from where plants destined for the field are produced. The other settings are the field and the packinghouse. In the nursery, scions and



Major Grapefruit Production Regions in Florida.

rootstock are grafted together. Since a plant produced from seed from any commercial citrus will have a prolonged period of juvenility (eight to twelve years), commercial production is delayed since no flowers are produced. Consequently, since the 1800s, this juvenility has been overcome by taking budwood from the desired scion and budding or grafting it into the stem of a young seedling of a different variety, the rootstock. Rootstock is selected for tolerance to pressures such as pests or cold, in addition to how well it influences the final tree's vigor, size, and fruit quality.

Production begins with grove establishment or with replacement if a catastrophic event (freeze, flood, hurricane, lightning, or pest) has occurred. In a normal year, the average rate of grove replacement is three percent. It also takes three years for the citrus to start bearing, so a mature commercial grove contains 90 percent bearing trees, as a general rule. A common spacing pattern for commercial citrus is 15-feet square, which equates to 194 trees per acre. While spacing greater than this has been used historically, the recent trend has been toward higher density planting, even to the extent that the mature tree canopies ultimately form a continuous hedgerow. Higher density plantings also maximize the use of land, water, and energy. Bearing citrus trees are mechanically hedged to keep row middles open for harvesting operations and allow maximum light penetration. The trees are hedged and topped after harvest. They are topped to a height that allows

pickers to access all fruit with 20-foot ladders. Small branches from the hedging are left in row middles and eventually mulched into the soil. Hand pruning is only done after catastrophic incidents (3).

Seasonally, about 60 percent of new leaf growth (flush) appears in the spring around mid-March. The remainder occurs in late summer. Flowering also occurs in March for most citrus. The only variety grown in Florida that usually has two crops of fruit on the tree after bloom (the new and the old fruit) is the Valencia. The bloom period affects the timing of pest control applications as well as when to set bees for pollination and honey production. Florida beekeepers widely use citrus as the first food source for the spring brood (3).

Since Florida lacks uniform rainfall throughout the year, irrigation must be set to water the plants during bloom and early fruit set. Irrigation is also used for freeze protection for young trees (up to five years in age). Micro-sprinkler systems (95 percent of the acreage) are used for under-canopy irrigation. Older groves that still have high-rise irrigation (five percent of the acreage) may use this system to form a layer of ice on the young trees when conditions are freezing. Ironically, lighter and more frequent irrigation is needed on the flatwoods soils since the root network is much reduced in comparison to citrus grown on the ridge. The state water management districts require that retention ponds be constructed to receive runoff from citrus groves. These must have the capacity to hold rainwater from a one-day storm with a 10-year frequency or a three-day storm with a 25-year frequency. The first inch of runoff must be held for five days with no more than a one-half-inch discharge in any one day. This allows for pesticide degradation to occur (3).

Florida soils, especially those on the ridge, are inherently low in nutrients. Often, soil is tested in the fall, and it is adjusted for a pH between 6 and 7. Nutrients are applied three or four times per year. However, slow release fertilizers applied once or twice a year are becoming economically competitive. Fertigation is done more frequently. Zinc and manganese often are applied as foliar sprays. Although soil analyses may help the grower with respect to pH and salinity, leaf analyses are more reflective of nutrient deficiencies (3).

In an effort to equalize bearing, plant growth regulators (PGRs) such as napthaleneacetic acid (NAA) are used to promote fruit thinning in heavy years and gibberellic acid improves fruit set in light years. NAA can be used to control seedling suckers as well. The herbicide 2,4-D is also used as a PGR to reduce fruit drop in navel and pineapple oranges as well as grapefruit. Upon the first year of bearing, an orange tree produces about a box (90 pounds) of fruit. Each subsequent year, the tree bears and additional one-third box until the age of about 35 years, after which the yield decreases at about the same rate (3).

Unlike other fruit, citrus must mature on the tree. It must be sampled to determine the amount of sugar (soluble solids) prior to harvest, as well as the acid to sugar ratio. Of the oranges grown in Florida, approximately 95 percent end up being processed (either from-concentrate or not-from-concentrate) with the remainder destined for fresh market consumption. All of the grapefruit are destined for fresh market as well. Rind color and quality are crucial only to the fresh fruit market. Such fruit, destined for packinghouses after harvest, must have cosmetic appeal to the consumer. Rejected fresh fruit is processed, which still results in approximately half of the grapefruit being processed (3). Since citrus fruit ripen throughout the year based on species or variety, harvest occurs throughout the year. Harvesters climb on ladders and pick fruit by hand, which is placed in a bag and taken to the bulk trailer. A small amount of processed oranges (15,000 acres or about 2.5 percent) were mechanically harvested in the 2004-05 season (4). Processed fruit heads to the processor, where it is washed and squeezed. Once fresh market fruit reaches the packinghouse, trash is eliminated, as well as split and rotten fruit. This is followed by a water spray, wash, and rinse, at which time the fruit is hand-graded. Off-grade fruit goes to processing, while fresh market fruit are treated with wax and fungicide(s), as mandated by Florida law, to inhibit postharvest decay. There is generally one more minor hand-grading that occurs after the waxing. Fruit is then packed (usually mechanically) and shipped (3).

Worker Activities

Development of Rootstock

Rootstock seeds are treated with a fungicide (usually thiram). Following treatment seeds are cold stored until sold to nurseries. Seeds are planted in multi-cell trays and grown in greenhouses. Pest management is performed on an as needed basis. These rootstock seedlings, called liners, are very thorny. After about three months, liners are pulled from the germinating trays using heavy leather gloves and either transplanted into pots or the field. Transplanters use latex gloves. Transplanted liners are then held in either the greenhouse or field for an additional three months, and pest management is the same as that for the germinating trays (5).

Certified virus-free mature citrus trees (mother or budwood trees) are used as a source for budwood (scions). The Florida Department of Plant Industries maintains a voluntary budwood registration program to facilitate the propagation of virus-free, true-to-type citrus nursery trees. About three-quarters of citrus trees are registered. Pest management is the same as for mature trees. Budsticks six to twelve inches in length are cut by hand and all leaves removed. In the process of budding, all leaves are stripped from the rootstock seedling by hand. Strippers wear heavy leather gloves for protection against thorns. Budders will make knife cuts in the liner stem and insert the budwood. The budder is followed by wrappers who tie plastic wrap around the bud union. There are usually two wrappers per budder. The wraps are removed after three weeks. There is no contact with foliage as all leaves have been removed by strippers. A team of one stripper, one budder, and two wrappers can bud 1,000 to 2,000 plants per day. This operation is usually conducted over a 40-hour work week throughout the year. Nurseries generally grow 30,000 to 100,000 seedlings annually, and the statewide inventory of seedlings is approximately 25 million (3,5).

After the wrapper is removed, the bud is “forced” to grow by one of three methods:

1. The liner is cut off above the bud. The plant trash remaining is removed from the greenhouse/field by workers using leather gloves. Approximately 60 percent of the nurseries use this method.

2. The stem above the bud is cut half through. The stem is bent over and will eventually be cut off and carried off by gloved workers. Approximately 30 percent of nurseries use this method.

3. The stem above the bud is bent over and tied to the base of the plant. Heavy leather gloves are worn as protection from thorns.

Once the bud begins to grow, the plant is staked and new growth periodically tied. There is minimal contact with plant parts during this process. Seedlings grown in a greenhouse are periodically moved to maximize utilization of light and water. The seedlings are ready for sale and planting within six to nine months of wrap removal. There is little foliar contact during pesticide applications during this period (5).

Grove Establishment

Grove establishment in a “normal” grove situation would be done when plants are too mature to be profitable, or when new land is to be planted to citrus. This process is done rather infrequently with respect to total citrus acreage in Florida. More common are “resets”, which are used to fill spots in the grove where previous trees have died out or become unproductive. Both of these procedures involve the use of methyl bromide or some other fumigant/sterilant to sterilize the soil. Land is tarped and sealed during entire grove establishment and holes are fumigated as needed for resets. Since groves don't sterilize on a yearly basis as do some other agricultural commodities, the entire grove sterilization process is contracted to certified applicators. The teams that perform the reset operation are often two- or three-man, equipped with a back-hoe. Once grove soil is prepared and micro-irrigation has been laid, seedlings are planted by gloved hand (5).

Irrigation

As previously described, micro-irrigation is set at grove establishment. For this type of irrigation, there

is no worker contact, except during construction, when pesticides would not be expected to be present. If high-rise irrigation is not permanently set in northern groves, it may require a number of workers working nonstop to set it up for one or more nights of freezing weather. However, these conditions are during periods where pest management is not active, and includes little of the main citrus crop acreage (5).

Cultivation/Weed Control

Although cultivation is not used in the grove setting, mowing row middles does occur on a large percentage of the citrus producing acreage. Chemical weed control is generally used under the tree canopies to maximize fertilizer and water efficiency (as well as water dispersal). In the row middles, vegetative strips are mowed as needed. This vegetation is maintained for a number of reasons - most importantly to serve as refugia for naturally-occurring biocontrol agents. As this process requires one person on a mower-equipped tractor, no hand labor is required. The operator can cover approximately 25 to 40 acres per day (5).

Scouting and Pesticide Applications

Scouting is conducted for pest pressures which are variable, such as insects and plant pathogens. Ninety-seven percent of Florida citrus acreage was scouted for pests in 2003 and the results were used to make decisions for approximately half of the citrus acreage (6). Prophylactic programs are used for pressures such as weeds, nematodes, and post-harvest diseases. The intensity of scouting is correlated to key pest emergence times and conditions. Certified crop advisors and their assistants review their counts and consult on crop protection methods, if so needed by the grower. No workers are used for scouting (5).

A survey conducted in the early 90s revealed that most growers use air-blast sprayers for field application of foliar insecticides and fungicides, while boom equipment is used for herbicides and soil-applied insecticides, nematicides, and fungicides. In addition to the tractor driver (the applicator), there is a second worker, known as the mixer/loader. The make up of the team varied among growers from one or two applicators plus one mixer/loader (the most common), to seven applicators plus four mixer/loaders. The total number of spray employees thus ranged from two to 40 workers. The range of acres serviced per employee was 140 to 767. Crews worked a 9.5- to 14-hour workday, five to six days a week, for three to 25 weeks of spraying per year. A single applicator normally applied four to 30 tanks (500 gallon) per workday, covering an area of eight to 55 acres per workday. Approximately half of the surveyed growers reported using enclosed cabs (3).

There are five basic periods throughout the year during which pesticides are applied. The post-bloom spray commences sometime between March 1 and April 15 and takes from two to seven weeks to complete. Target pests for this spray period are melanose, scab, and citrus rust mite. Nutritional materials are often added to this spray as well. The second, supplemental, application is often the same as the first application, and usually is applied over the six weeks between mid-April and the end of May. The summer spray occurs in June or July. This is the petroleum oil spray and it may also contain other active ingredients to control greasy spot, mites, or scales. The fall spray is conducted between mid-August through year end, and there may be a supplemental spray in addition, on an as-needed basis. These sprays are often miticides to control rust and/or spider mites on fresh market fruit (5).

Survey results revealed that about ten percent of growers used aerial application on about 40 percent of their acreage. When aerial application is used, it is largely for micronutrients. However, the remaining respondents said infrequent use of aerial application was not uncommon when a rapid application was necessary (especially in fresh market citrus). Pilots operated for 14 to 23 weeks per year, with wind velocities of five to ten MPH precluding spraying on 15 percent of those days (5).

Approximately a third of the survey respondents reported using hand-gun application for citrus resets (5). Additionally, most of the sprays occurring in the nursery setting are either with hand-gun or pump-up sprayers (5).

Harvest

The largest period of time that agricultural workers come in contact with mature citrus trees is during harvest, which is usually done by hand (5). Currently, approximately 95 percent is hand-harvested versus machine-picked (4). The pickers use 20-foot ladders which are propped up on the tree limbs as the fruit is picked. The fruit is placed in a long bag that is eventually emptied into either a bulk trailer (processed citrus) or bins/boxes (fresh fruit). The fruit is then transported to either the processing plant or the packinghouse. The workers dress in long-sleeve shirts and pants due to the abrasive nature of the citrus foliage. However, citrus is picked with a bare hand. Pickers never contact mechanically-harvested citrus since it is bound for the processing plant. On average, one picker can pick ten 90-pound boxes per hour. Production averages 300 to 400 boxes per acre depending on variety. Fresh fruit pickers work a 30-hour week during the harvest season and process pickers work a 40-hour week (fruit picked for the fresh market must be dry of dew/rain prior to harvest). Oranges and grapefruit mature and are ready for picking in all months but July and August.

Post-Harvest

For processing citrus, fruit coming into the processing plant is hand-graded by workers on either side of a conveyor belt. Workers remove any broken or decayed fruit prior to the wash process. The number of workers depends on the number of "lines" operated by the plant. Usually six to eight workers per line work a 40-hour week during the harvest season. No protective gloves are worn (5).

For fresh market citrus, workers conduct the same initial hand-grading, which is followed by a wash, waxing, and fungicide application. Then, a second hand-grading is performed. There are usually about half of the number of graders for the second grading in comparison to the initial grading (5).

Hedging/Pruning

Hedging and topping are carried out after fruit harvest so that fruit is not affected (except Valencia). This process is conducted by a dedicated crew of people who follow after the harvest and mechanically hedge and top throughout the year. Some managers hedge and top every tree row each year, while others hedge every other year (Valencia). The crop residue from this process is eventually mowed into mulch when the row middles are mowed for weeds (7).

Sanitation

Grove sanitation is practiced by reducing trash and soil on equipment as it leaves a field. This is done to minimize the chance of spreading nematodes and citrus canker from one grove to another. As already mentioned, hedging and topping remnants are mulched into the grove soil. Neither of these processes involve hand labor.

With regard to worker sanitation, portable toilets and non-potable water for washing are provided for workers in the grove. It is not uncommon for workers to carry toilet paper with them (5).

Rind color and quality are crucial only to the fresh fruit market. Such fruit, destined for packinghouses following harvest, must have cosmetic appeal to consumers even though apparent imperfections in the outer rind usually do not adversely affect the internal quality of the fruit. Greater pest management inputs are required for fresh fruit production. Approximately 60-65 percent of the fruit passes the fresh fruit quality tests (5). Failure of quality tests is due mainly to poor color, rind blemish caused by citrus rust mites, scab, melanose and greasy spot, or inadvertent puncturing of fruit as it is picked. Rejected fruit is usually processed. Approximately 95 percent of oranges are processed, and 50 percent of grapefruit is processed. Generally, very little grapefruit is produced with the intention of it being processing, so fruit quality and finish must be maintained which requires precise season-long management of citrus pests such as citrus rust mites, scab and melanose. As mandated by law, fresh citrus fruit is treated with postharvest fungicides to inhibit decay (8).

Insect/Mite Pests

Mites. The mite pests in Florida citrus production include the rust mites (citrus rust mite and pink citrus rust mite) and spider mites (citrus red

mite, Texas citrus mite, and sixspotted mite). Many factors are involved which affect mite abundance and potential for injury to the tree and crop. Reduction or elimination of such pesticides as copper, copper plus oil, and sulfur can avoid flare-ups of secondary pests such as spider mites to primary pest status. Control of spider mites is obtained during normal spray routines for managing the key pests in Florida citrus; namely, the citrus rust mite and greasy spot. However, all miticides, except petroleum oil, should be used only once a year to minimize resistance development. Growers are generally not too concerned about mite buildup in the spring and summer, but closer attention is needed in the fall (9,10).

Citrus rust mite. Rust mites are primary pests of fresh market fruit. Rust mites feed on fruit, stems and foliage. Mites feeding on fruit early in the season destroy epidermal cells. Further plant growth leads to a breaking up of the dead epidermis with a wound periderm forming over the newly formed epidermis. This type of early season rust mite injury is called “russetting.” Late season rust mite feeding injury causes epidermal cells to die and become a brownish-black color with no periderm formation. This condition is known as “bronzing.” Primary effects of fruit damage caused by rust mites are a reduction in fruit grade and size, increased water loss, fruit drop, and reduced juice quality. Leaf injury causes foliage to take on a dull, bronze-like color, and exhibit patchiness of yellowish cells in areas of “russetting” that have been degreened by ethylene release during the wounding process. Mite populations typically reach a peak in mid-June to mid-July, although the time of peak density can vary by several weeks depending on location and weather. After a subsequent population decline, citrus rust mite populations increase again in late October or early November. Citrus rust mites are generally more abundant on fruit and foliage on the outer margins of the tree canopy, with the north-facing bottom section of the tree being preferred and supporting the highest populations. Citrus groves producing fruit designated for fresh market may receive three or four miticide sprays per year. In contrast, groves producing fruit designated for processing receive zero to two treatments per year. The sampling unit is a mature leaf immediately behind flush leaves. For fresh-market fruit, damage should not be greater than five percent, and no more than 15 percent for processing fruit. If three or more fungus-parasitized mites are noted per lens field, a natural decline will occur and spraying is delayed (9,11).

Scales. Armored scales (purple scale, citrus snow scale, Florida red scale, Glover's scale, chaff scale) and soft scales (Caribbean black scale, brown soft scale, Florida wax scale) are sporadic pests in Florida citrus. Most of these are well controlled by a host of parasites and predators. Occasionally, citrus snow scale control is required, and it usually can be achieved by spot-spraying the large understory branches with a hand-gun, so that beneficial insects in the canopy are less affected (9).

Mealybug, Whiteflies, Blackfly, Aphids, and Psyllid. Mealybug, whiteflies, and citrus blackfly were all at one point pests of concern. However, these species are now controlled biologically with few exceptions. For aphids, some species, such as the brown citrus aphid, are known to vector citrus tristeza virus, which has yet to be detected in Florida production.

Citrus psyllid. This insect was formerly grouped with the other soft-bodied pests as adequately controlled by biological agents. However, the Florida citrus industry has been in a state of emergency since the fall of 2005 with the detection of citrus greening in the state. Citrus psyllid is a known vector of this disease. Greening is a disease caused by a fastidious type of bacteria that occupy the vasculature of the plant. Once scouting commenced, citrus greening has been found in over 650 locations in twelve counties, although not many trees (15 percent) are associated with commercial production. The disease takes several years to manifest, and by that time the tree is beyond remediation. Increases in several types of systemic insecticide have been documented as a result of this disease's presence in Florida (9,12).

Weevils. There are also about a half-dozen weevil species in Florida that affect citrus. Adult weevil feeding is not generally injurious to the tree. Female root weevils usually lay their eggs in clusters cemented between two leaves. When the larvae hatch from eggs, they fall to the soil surface and

immediately begin moving into the soil, where they begin feeding on the fibrous feeder roots of the plants. Successively larger larval stages feed on successively larger roots, proceeding to major lateral or pioneer roots of mature trees. Roots may become girdled, causing root death, or the crown may be girdled, causing tree death. In addition to direct damage, root weevil larvae feeding provides entry points for soil-borne pathogens, particularly Phytophthora. Rescue of trees may not be possible once infested. Young trees have smaller root systems and cannot tolerate the same level of feeding as those of mature trees. Although a registration for bifenthrin exists for under-canopy soil treatment, it is seldom used due to cost. More often, growers follow the recommendations to: use sound water and fertility practices, use spray oil to loosen egg masses with consequent predation, use foliar insecticides on adult weevils, and use parasitic nematodes (9).

Citrus Leafminer. Citrus leafminer development is brief, with the period from egg to adult being as short as 14 days. Within this cycle, the susceptible larval stage may occupy only 4-5 days. Eggs are laid singly on the underside of host leaves. Eggs hatch within 2-10 days, whereupon larvae immediately enter the leaf and begin feeding. Larvae make serpentine mines on young leaves (sometimes also young shoots), resulting in leaf curling and serious injury. Leaf mines are usually on the ventral leaf surface, except in heavy infestations when both leaf surfaces are used. Usually only one leaf mine is present per leaf, but heavy infestations can have 2 or 3 mines per leaf; up to 9 mines on large leaves have been found. Citrus leafminers may also help spread citrus canker (9).

Fire Ants. Citrus workers know all too well that aggressive fire ants can make harvesting and grove work miserable. When their nests are disturbed during harvesting or typical daily grove work, numerous fire ants will quickly emerge from the mound and attack any intruder. These ants are notorious for their painful, burning sting that results in a pustule and possible itching, which may persist for ten days. Infections may occur if pustules are broken. Some people have allergic reactions to fire ant stings that range from rashes and swelling to paralysis, or anaphylactic shock. In rare instances, severe allergic reactions cause death (9).

Controls

Non-Chemical

The principal non-chemical control measures used to manage insect/mite pests in Florida citrus include pest population monitoring, promoting the action (by minimum disruption) of native and introduced exotic natural enemies, modifying horticultural management practices such as irrigation, drainage and fertilizer inputs, scouting groves looking for signs of pest activity, and where necessary, removing and destroying infested trees, planting resistant rootstocks or certified pest-free trees in clean sites, cleaning equipment, and constructing buffer zones between infested and noninfested blocks (9,11).

Chemical

Commonly used insecticides on Florida citrus include abamectin, aldicarb, chlorpyrifos, diflubenzuron, fenbutatin-oxide, petroleum oil, pyridaben, and sulfur. Bifenthrin, carbaryl, cyfluthrin, dicofol, fenpropathrin, imidacloprid, oxamyl, oxydemeton-methyl, and propargite are other insecticides/miticides that are reportedly used on less than five percent of Florida citrus (13). In 2005, 88 percent of oranges and 84 percent of grapefruit were treated with some type of insecticide (13). Commonly, fresh citrus will receive 5-7 sprays while processing fruit will receive 3 or fewer (6,9).

ABAMECTIN. This microbial fermentation product is a chloride-channel activating glycoside. It is used in the management of mites, citrus psyllid, citrus thrips, and citrus leafminer. Use has been decreasing as resistance has been observed in certain mite populations. The price of abamectin is $4,570 per pound of active ingredient, and the approximate cost of a maximum labeled application (0.023 lb ai/A) is $107 (14,15). The label states that no more than 0.023 lb ai/A can be applied to any one crop and not to make more than one application per season. The restricted entry interval (REI) is 12 hours and the pre-harvest interval (PHI) is seven days.

In 2005, Florida orange growers applied an average of 0.008 pound of abamectin per acre at each application to 19 percent of their acreage, an average of 1.5 times. Total usage was 1,300 pounds of active ingredient (13). During the years in which usage data have been collected, orange growers in Florida have applied abamectin at an average rate ranging from 0.007 to 0.009 pound of active ingredient per acre at each application, to between 15 and 36 percent of their acreage. Growers have made an average number of applications ranging from 1.1 to 1.5 times each year, totaling between 900 and 2,300 pounds of active ingredient annually (13,16).

In 2005, Florida grapefruit growers applied an average of 0.01 pound of abamectin per acre at each application to 67 percent of their acreage, an average of 1.1 times. Total usage was 600 pounds of active ingredient (13). During the years in which usage data have been collected, grapefruit growers in Florida have applied abamectin at an average rate ranging from 0.009 to 0.01 pound of active ingredient per acre at each application, to between 46 and 78 percent of their acreage. Growers have made an average number of applications ranging from 1.0 to 1.3 times each year, totaling between 500 and 1,100 pounds of active ingredient annually (13,16).

ALDICARB. Aldicarb is a granular carbamate insecticide applied into the soil to manage citrus rust mite, whiteflies, citrus nematode, aphids, and citrus psyllid. The state of Florida has statewide stewardship program rules in place that limit time of application to spring flush, and on the Florida ridge there is a mandatory best management plan for irrigation management and product placement. It has been more widely used in 2005-2006 as a result of finding citrus greening in the state, which is vectored by the citrus psyllid. Approximately 56 percent of the Florida citrus crop was treated in 2005-2006 in comparison to 45 percent the previous year (12). The price of aldicarb is $25 per pound of active ingredient, and the approximate cost of a maximum labeled application (5 lb ai/A) is $125 (12,14). It is only applied once per season. The REI is 48 hours and there is no PHI since it is used so early in the season.

In 2005-2006, Florida orange and grapefruit growers treated 417,400 acres of citrus, using approximately two million pounds of aldicarb. This is the most used in one year, and reflects an effort to minimize citrus psyllid feeding/disease vectoring. During the years previous to citrus greening, orange growers in Florida have applied aldicarb at an average rate ranging from 2.5 to 3.6 pounds of active ingredient per acre at each application, to between 7 and 14 percent of their acreage. Growers have made an average number of applications ranging from 1.0 to 1.1 each year, totaling between 119,000 and 235,000 pounds of active ingredient annually (12,13,16).

During the years before greening detection, grapefruit growers in Florida applied aldicarb at an average rate ranging from 2.9 to 4.2 pounds of active ingredient per acre at each application, to between 7 and 26 percent of their acreage. Growers have always made just one application each year, totaling between 29,000 and 72,000 pounds of active ingredient annually (13,16).

BIFENTHRIN. Bifenthrin is a synthetic pyrethroid which activates the sodium channels of the arthropod nervous system. It is used in the management of citrus root (Diaprepes) weevils. The insecticide was available under Section 18 registration from 1999 to 2001, where from 400 to 1,400 pounds were used to control citrus root weevil, but now is available under national labeling. Foliar applications are not allowed (17,24).

CHLORPYRIFOS. Chlorpyrifos is used as an alternative organophosphate in managing scale and thrips, and it is also used to manage nuisance pests such as fire ants and termites in the grove. The price of chlorpyrifos is $10.60 per pound of active ingredient, and the approximate cost of a maximum labeled application (3.5 lb ai/A) is $37.10 (14,18). The label states that no more than 7.5 lb ai/A can be applied per acre per year and not to make more than two applications per year (minimum 30 days apart). The REI is 120 hours and the PHI is 21 days; however, applications generally take place as long as six months prior to harvest.

In 2005, Florida orange growers applied an average of 0.76 pound of chlorpyrifos per acre at each application to 12 percent of their acreage, an average of 2.1 times. Total usage was 102,100

pounds of active ingredient (13). During the years in which usage data have been collected, orange growers in Florida have applied chlorpyrifos at an average rate ranging from 0.57 to 1.08 pounds of active ingredient per acre at each application, to between 2 and 12 percent of their acreage. Growers have made an average number of applications ranging from 1.9 to 2.3 each year, totaling between 28,800 and 102,100 pounds of active ingredient annually (13,16).

During the years in which usage data have been collected, grapefruit growers in Florida have applied chlorpyrifos at an average rate ranging from 1.5 to 2.4 pounds of active ingredient per acre at each application, to between 2 and 19 percent of their acreage. Growers have made an average number of applications ranging from 1.1 to 2.0 times each year, totaling between 5,600 and 57,800 pounds of active ingredient annually (13,16).

DIFLUBENZURON. This insect growth regulator interferes with chitin biosynthesis in arthropods. It is used in the management of mites, citrus leafminer, and citrus root weevils. The price of diflubenzuron is $150 per pound of active ingredient, and the approximate cost of a maximum labeled application (0.31 lb ai/A) is $46.50 (9,14). The label states that no more than 0.94 lb ai/A can be applied in one year. The REI is 12 hours and the PHI is 21 days.

In 2005, Florida orange growers applied an average of 0.28 pound of diflubenzuron per acre at each application to 2 percent of their acreage, an average of 1.7 times. Total usage was 5,100 pounds of active ingredient (13). During the years in which usage data have been collected, orange growers in Florida have applied diflubenzuron at an average rate ranging from 0.19 to 0.37 pound of active ingredient per acre at each application, to between 2 and 10 percent of their acreage. Growers have made an average number of applications ranging from 1.0 to 1.7 times each year, totaling between 2,000 and 16,800 pounds of active ingredient annually (13,16).

In 2005, Florida grapefruit growers applied an average of 0.13 pound of diflubenzuron per acre at each application to 9 percent of their acreage, an average of 1 time. Total usage was 900 pounds of active ingredient (13). During the years in which usage data have been collected, grapefruit growers in Florida have applied diflubenzuron at an average rate ranging from 0.20 to 0.35 pound of active ingredient per acre at each application, to between 5 and 22 percent of their acreage. Growers have made an average number of applications ranging from 1.0 to 2.7 times each year, totaling between 900 and 8,400 pounds of active ingredient annually (13,16).

FENBUTATIN-OXIDE. Fenbutatin-oxide is an organotin miticide which has proven to be an excellent citrus miticide. It is chemically unique, has broad spectrum miticide activity, and is soft on beneficials (5). Mixing fenbutatin-oxide with oil or copper, however, results in reduced residual activity (9). The price of fenbutatin-oxide is $54.24 per pound of active ingredient, and the approximate cost of a maximum labeled application (1 lb ai/A) is $54.24 (9,14). The label indicates not to make more than two applications per year (minimum 60 days apart). The REI is 48 hours and the PHI is seven days.

In 2005, Florida orange growers applied an average of 0.8 pound of fenbutatin-oxide per acre at each application to 2 percent of their acreage, an average of 1 time. Total usage was 9,800 pounds of active ingredient (13). During the years in which usage data have been collected, orange growers in Florida have applied fenbutatin-oxide at an average rate ranging from 0.8 to 1.0 pound of active ingredient per acre at each application, to between 2 and 21 percent of their acreage. Growers have made an average number of applications ranging from 1.0 to 1.7 each year, totaling between 10,000 and 135,000 pounds of active ingredient annually (13,16).

In 2005, Florida grapefruit growers applied an average of 0.8 pound of fenbutatin-oxide per acre at each application to 29 percent of their acreage, an average of 1.3 times. Total usage was 22,100 pounds of active ingredient (13). During the years in which usage data have been collected, grapefruit growers in Florida have applied fenbutatin-oxide at an average rate ranging from 0.8 to 1.0 pound of active ingredient per acre at each application, to between 13 and 38 percent of their acreage. Growers have made an average number of applications ranging from 1.0 to 1.3 times each year, totaling between 20,100 and 44,400 pounds of active ingredient annually (13,16).

OIL. Oil is applied to help suppress citrus rust mites, spider mites, scales, and whiteflies as well as the disease greasy spot. It is the backbone of the integrated arthropod (and fungal) management system in Florida citrus. The price of oil is $6 per gallon, and the approximate cost of a maximum labeled application (10 gal./A) is $60 (9,19). The REI is 4 hours and there is no PHI.

In 2005, Florida orange growers applied an average of 36 pounds of oil per acre at each application to 80 percent of their acreage, an average of 2.5 times. Total usage was nearly 40 million pounds (13). During the years in which usage data have been collected, orange growers in Florida have applied oil at an average rate ranging from 29 to 37 pounds per acre at each application, to between 80 and 93 percent of their acreage. Growers have made an average number of applications ranging from 1.9 to 2.6 times each year, totaling between 39 and 42 million pounds annually (13,16).

In 2005, Florida grapefruit growers applied an average of 30 pounds of oil per acre at each application to 80 percent of their acreage, an average of 2.6 times. Total usage was approximately 4.4 million pounds (13). During the years in which usage data have been collected, grapefruit growers in Florida have applied oil at an average rate ranging from 28 to 36 pounds per acre at each application, to between 75 and 89 percent of their acreage. Growers have made an average number of applications ranging from 1.5 to 2.6 times each year, totaling between 4.4 and 9.0 million pounds annually (13,16).

PYRIDABEN. This miticide interferes with electron transport, leading to loss of metabolic integrity. It is used in the management of spider mites but is not recommended for citrus rust mite due to inconsistent performance. The price of pyridaben is $145 per pound of active ingredient, and the approximate cost of a maximum labeled application (0.5 lb ai/A) is $72.50 (9,14). The label states that no more than two applications can be applied in one season. The REI is 12 hours and the PHI is 7 days.

In 2005, Florida orange growers applied an average of 0.29 pound of pyridaben per acre at each application to 3 percent of their acreage, an average of 1.1 times. Total usage was 5,100 pounds of active ingredient (13). During the years in which usage data have been collected, orange growers in Florida have applied pyridaben at an average rate ranging from 0.27 to 0.30 pound of active ingredient per acre at each application, to between 3 and 5 percent of their acreage. Growers have made an average number of applications ranging from 1.0 to 1.1 times each year, totaling between 5,100 and 9,400 pounds of active ingredient annually (13,16).

In 2005, Florida grapefruit growers applied an average of 0.29 pound of pyridaben per acre at each application to 25 percent of their acreage, an average of 1.1 times. Total usage was 5,600 pounds of active ingredient (13). During the years in which usage data have been collected, grapefruit growers in Florida have applied pyridaben at an average rate ranging from 0.26 to 0.33 pound of active ingredient per acre at each application, to between 8 and 36 percent of their acreage. Growers have made an average number of applications ranging from 1.0 to 1.1 times each year, totaling between 2,300 and 12,600 pounds of active ingredient annually (13,16).

SULFUR. Sulfur is used to help suppress populations of citrus rust mites. It is recommended that sulfur applications be limited to about one application per season where supplemental rust mite management is needed. Sulfur may be legally applied on citrus up to and including the day of harvest (PHI = 0 days), but the restricted entry interval under the Worker Protection Standard for sulfur is 24 hours. Sulfur cannot be combined with oil, or applied within three weeks of an any oil spray, as fruit burn/phytotoxicity will result (9). Sulfur is the most persistent pesticide currently used on Florida citrus and multiple sulfur uses are disruptive to the established Integrated Pest Management program for mites. The price of sulfur is $1 per pound, and the approximate cost of a maximum labeled application (15 lb/A) is $15 (9,14).

In 2005, Florida orange growers applied an average of 9 pounds of sulfur per acre at each application to 6 percent of their acreage, an average of 1.6 times. Total usage was nearly a half million pounds (13). During the years in which usage data have been collected, orange growers in Florida have applied sulfur at an average rate ranging from 9 to 13

pounds per acre at each application, to between 6 and 19 percent of their acreage. Growers have made an average number of applications ranging from 1.0 to 1.6 times each year, totaling between 500,000 and 1.2 million pounds annually (13,16).

In 2005, Florida grapefruit growers applied an average of 13 pounds of sulfur per acre at each application to 46 percent of their acreage, an average of 1.7 times. Total usage was 719,000 pounds of active ingredient (13). During the years in which usage data have been collected, grapefruit growers in Florida have applied sulfur at an average rate ranging from 12 to 19 pounds per acre at each application, to between 35 and 58 percent of their acreage. Growers have made an average number of applications ranging from 1.0 to 1.9 times each year, totaling between 719,000 and 1.8 million pounds annually (13,16).

Nematode Pests

In Florida, the primary nematode species of major economic importance include the citrus nematode (causal agent of "slow decline" of citrus) and the burrowing nematode (causal agent of "spreading decline" of citrus). Other species of economic importance include the sting nematode and lesion nematode. Nematodes that are known pathogens of citrus seldom kill the tree, but can significantly reduce tree growth and grove productivity. Infested trees generally grow more slowly and ultimately are of smaller size and quality, have thinner canopies with little or no new foliar growth, produce less and smaller fruit, and have twig dieback within the upper tree canopy, symptoms that are often confused with stress brought on by drought or malnutrition. Symptoms increase with time and are more apparent during periods of environmental stress or when combined with other damaging soil pests such as root weevils and Phytophthora (9).

Controls

Non-Chemical

Preventative measures are the most effective and economic means of nonchemical nematode management. Site certification is a reliable method for production of nematode-free citrus nursery trees. Certified trees also reduce damage to young trees planted into old, previously infested groves. Cleaning equipment, and constructing buffer zones between infested and noninfested blocks of land, also help in excluding movement of burrowing nematodes. Proper grove management is critical to manage damage caused by plant parasitic nematodes. There is no value to managing nematodes if other problems such as poor soil drainage, insufficient irrigation, foot rot and feeder root rot, root weevils, improper fertilization, and poor disease control limit root function and/or reduce tree quality. With regard to resistant rootstocks, a large number of groves are currently growing well on nematode resistant rootstocks, partially in the presence of citrus nematodes. Grove infestations with sting nematodes, as well as several species of lesion nematode, can cause local isolated declines (9).

Chemical

Chemical control of established populations of citrus, burrowing, and sting nematodes has been difficult to achieve, and tree response to postplant chemical treatments often require a period of one to two years of repeated treatment for growth improvement and significant yield returns. The most effective treatment has been the "push and treat" method. With this method, infected trees are bulldozed out of the soil and burned. Methyl bromide or 1,3-dichloropropene are applied and the ground is left fallow for up to two years following treatment. Herbicides are simultaneously used to keep the area free of weeds, because clean fallow and a waiting period are very important in the push and treat program. Aldicarb and fenamiphos are the only postplant chemicals available for nematode management. Field research has shown, however, that repeated use of fenamiphos results in diminished efficacy in successive years due to accelerated microbial degradation of the active ingredient. This degradation process can be initiated after a single fenamiphos treatment without improvement to tree vigor and yield. In the event fumigant-type (methyl bromide, 1,3-dichloropropene) nematicides are no longer available for use, most growers will convert back to traditional methods of uprooting undesirable trees and to delay citrus tree replanting. In the event aldicarb is no longer available for use in Florida,

citrus production losses are estimated to be in the range of 5 to 10 percent. This estimate reflects production losses that are attributable to many factors other than just nematode (20). The use of aldicarb, the only nematicide seriously employed in Florida citrus, is discussed above in the insect/mite section.

Diseases

Primary disease problems on Florida orange and grapefruit include canker, Phytophthora crown/foot/root rots, brown rot, greasy spot, melanose, postbloom fruit drop, and citrus scab. Although not currently a primary disease problem, citrus greening may easily enter this category within the near future (9).

Citrus Canker. The bacterium that causes canker affects numerous species, cultivars, and hybrids of citrus and citrus relatives. Grapefruit, limes and certain early oranges are highly susceptible; Navel, Pineapple, and Hamlin sweet oranges are moderately susceptible; Valencia orange, tangors, tangelos, and mandarin hybrids are susceptible, and tangerines are moderately tolerant. When new flushes of leaves are occurring and wind and high moisture are prevalent (such as during/after hurricanes), the bacterium is easily spread. Galleries of citrus leafminer serve as excellent reservoirs of the bacterium. Canker is generally just a leaf and fruit spotting disease, but when conditions are highly favorable for infection, it causes defoliation, shoot die-back, and fruit drop. Young lesions are raised on both surfaces of the leaf, but particularly on the lower leaf surface. The pustules later become corky and crater-like with a raised margin, sunken center and are surrounded by a yellow halo. Fruit lesions vary in size because the rind is susceptible for a longer time, and more than one infection cycle can occur on the fruit (9).

The current canker episode in Florida, which began in 1995, was being managed by the Florida Department of Agriculture and Consumer Services with federal funding. However, due to the hurricanes of 2004 and 2005, canker has spread to approximately two-thirds of all Florida citrus. Consequently, the eradication plan has been discontinued, and fresh fruit shipments to other citrus states may be affected. Growers are still trying to manage the disease culturally, through windbreaks and grove decontamination stations. The disease has brought about the question of whether commercial citrus has much future in the state.

Phytophthora Foot, Crown and Root Rots. Phytophthora foot rot results from infection of the scion near the ground level. Crown rot results from infection of the bark below the soil line. Root rot occurs when the cortex of fibrous roots is infected. Fibrous roots slough their cortex leaving only white thread-like stele, rendering them ineffective for nutrient and moisture uptake, or carbohydrate storage (9).

Brown Rot. Management of brown rot is needed on both processing and fresh market fruit. Brown rot (also caused by a Phytophthora organism) is a problem usually associated with restricted air and/or water drainage, appearing after periods of extended high rainfall. Beginning stages of infection are very difficult to detect before the fruit are colored and showing typical symptoms. Infected fruit may not show symptoms when inspected and graded in the packinghouse, and are packed with sound fruit where the disease may spread in containers during transit and storage. This may be particularly disastrous in oversea grapefruit shipments (9).

Greasy Spot. Like brown rot, management of greasy spot must be considered in groves intended for processing or for fresh market fruit. Greasy spot affects both leaves and fruit. Infected leaves often drop before the lesions develop a dark greasy appearance, especially if infection occurs close to the abscission zones on or near the leaf petiole. Leaf drop associated with greasy spot typically follows a seasonal pattern. Relatively few leaves drop during the summer and fall. Beginning in the winter, leaf drop proceeds at an increasingly rapid rate, leading to maximum accumulation of leaf litter on the grove floor by May or June. Infection on fruit results in pinpoint black specks which occur between the oil gland cells on the fruit surface. On grapefruit, larger and coalescent specks are sometimes produced giving rise to a symptom called greasy spot rind blotch (pink pitting). Another serious aspect of greasy spot rind infection is that living cells adjacent to the specks

often retain a green color for much longer than normal. Ethylene degreening treatment usually fails to color up the affected areas satisfactorily, making fruit aesthetically undesirable for fresh fruit sales (9).

Melanose. Management of melanose is necessary where fruit is intended for the fresh market, particularly if recently killed twigs and wood are present as a result of freezes or other causes. Fruit blemishes result in downgrading of fruit to juice production. Distinct melanose symptoms occur on leaves, green wood, and fruit. On leaves, melanose lesions begin as small, dark brown to black sunken spots. As the leaf tissue ages, the spots may become raised. Symptoms on young, green twigs are quite similar to those on leaves except that they tend to be distinctly raised. On fruit, lesions begin as light brown, circular spots that later become brown to black raised pimples, imparting a sandpaperfeel to the fruit. If infections become numerous, symptoms appear as large areas of dark, rough scar tissue on the rind (9).

Post Bloom Fruit Drop. Post bloom fruit drop (PFD) must be controlled on processing and fresh market fruit. PFD affects all species and cultivars of citrus, but severity on a given cultivar may vary according to the time of bloom in relation to rainfall. Most spores of this fungus are produced directly on the surface of infected petals. Spores are splashed by rains to healthy flowers where they infect within 24 hours and produce symptoms in 4 to 5 days. The fungus survives between bloom periods as resistant structures on the surface of leaves, buttons and twigs. A model has been developed to assist growers in determining the need and timing of fungicide applications. The model is based on the amount of inoculum of the fungus present (i.e. the number of diseased flowers per tree) and the rainfall for the last 5 days and predicts the percentage of diseased flowers 4 days in advance. The removal of declining trees, where off-season blooms may provide a site for fungal spore buildup, and a reduction in overhead irrigation during the bloom period, helps to reduce disease severity (9).

Citrus Scab. Scab lesions appear as wart-like growths or as flat scars on the fruit of susceptible varieties. Scab can be a serious problem in the nursery, but there is no need to control citrus scab on processing fruit. Reduction or elimination of overhead irrigation on susceptible varieties during the active growth period of the fruit can help decrease disease severity. Spores of this fungus are produced directly on scab pustules on leaves and fruit. Spores are dispersed to healthy tissues by water splash. Fruit usually becomes resistant to scab by some time in May, about 2 months after petal fall (9).

Citrus Greening. Although the insect that vectors citrus greening (citrus psyllid) has been in Florida since the late 1990s, the disease itself has only been identified in the state in the latter part of 2005. Since surveying for greening began, it has been found in more than 650 locations in twelve Florida counties. Most of these trees were private (85 percent), rather than commercial citrus. The fastidious bacterium that causes citrus greening invades the vascular tissue of the tree. Initial or early symptoms on leaves are vein yellowing and a variegated chlorosis referred to as blotchy mottle. Leaves may be small with signs of nutrient deficiencies. Often some of the leaves may be totally devoid of green or with only islands of green spots. The early symptoms may also be manifest as a yellowed deformed shoot. Fruit are often sour and bitter tasting (9).

Controls

Non-Chemical

Cultural practices, such as planting stock certified to be free of viral disease, planting disease resistant/tolerant varieties, selecting favorable grove locations not previously planted with citrus, planting trees with the bud union well above the soil line, maintaining proper placement of herbicide strips, skirting of trees to reduce inoculum on the ground from contacting the canopy, reducing or eliminating overhead irrigation, and proper drainage and irrigation management are non-chemical pest management tactics implemented whenever possible to mitigate disease impacts.

Chemical

Fungicides used to manage disease on Florida citrus are primarily limited to the coppers, petroleum

oil (reviewed in the insect/mite section), strobilurin fungicides (azoxystrobin, pyraclostrobin, trifloxystrobin), and mefenoxam. Fenbuconazole (for greasy spot) and thiophanate (for post bloom fruit drop and stem end rot) have been under Section 18 emergency exemption for citrus for the last seven and three years, respectively. In 2005, 61 percent of oranges and 91 percent of grapefruit were treated with some type of fungicide (13).

Under state law, fresh market citrus must be treated with some type of fungicide, primarily to control green mold. The three most widely used fungicides for Florida citrus include sodium phenylphenate, thiabendazole, and imazalil (21).

COPPERS. Copper fungicides, which include basic copper sulfate, copper hydroxide, and copper oxychloride among others, are used to manage various citrus diseases including brown rot, melanose, citrus scab, and greasy spot (9). The price of copper (hydroxide) is approximately $3.30 per pound of active ingredient, and the approximate cost of a maximum labeled application (4.9 lb ai/A) is $16.17 (19,22). The REI can be either 12, 24, or 48 hours, depending on the form of copper, and there is no PHI.

In 2005, orange growers in Florida have applied copper (all forms) to between 1 and 36 percent of their acreage between 1.3 and 2.3 times. Rates ranged between 1.0 and 2.5 lb ai/A, and total usage was estimated at 650,000 pounds (13). This total use figure is approximately half of the amount of copper used historically in Florida. In the years in which data have been collected, orange growers applied copper at an average rate ranging from 1.0 to 4.0 pounds of active ingredient per acre at each application, to between 1 and 57 percent of their acreage. Growers have made an average number of applications ranging from 1.1 to 2.8 each year, totaling between 650,000 and 1,417,900 pounds of active ingredient annually (13,16).

In 2005, grapefruit growers in Florida have applied copper (all forms) to between 8 and 83 percent of their acreage between 1.2 and 4.2 times. Rates ranged between 1.2 and 2.8 lb ai/A, and total usage was estimated at 440,700 pounds (13). In the years in which data have been collected, grapefruit growers applied copper at an average rate ranging from 0.8 to 5.1 pounds of active ingredient per acre at each application, to between 6 and 83 percent of their acreage. Growers have made an average number of applications ranging from 1.2 to 4.2 each year, totaling between 250,400 and 827,800 pounds of active ingredient annually (13,16).

STROBILURINS. Strobilurin fungicides act by inhibiting respiration in fungi. They are used to control greasy spot, melanose, scab, and post bloom fruit drop. The price of these materials is approximately $115 per pound of active ingredient, and the approximate cost of a maximum labeled application (from 0.12 to 0.25 lb ai/A) ranges from $14 to $30 (19,22). The REI can be either 4 (azoxystrobin) or 12 (pyraclostrobin, trifloxystrobin) hours, and the PHI can be zero (azoxystrobin, pyraclostrobin), or 30 (trifloxystrobin) days (9). There are limits for seasonal applications for all three fungicides.

In 2005, orange growers in Florida have applied strobilurins (all forms) to between 5 and 14 percent of their acreage between 1.2 and 1.9 times. Rates ranged between 0.06 and 0.19 lb ai/A, and total usage was estimated at 36,300 pounds (13). In the years in which data have been collected, orange growers applied strobilurins at an average rate ranging from 0.06 to 0.19 pounds of active ingredient per acre at each application, to between 2 and 14 percent of their acreage. Growers have made an average number of applications ranging from 1.0 to 1.9 each year, totaling between 500 and 36,300 pounds of active ingredient annually (13,16).

In 2005, grapefruit growers in Florida have applied strobilurins (all forms) to between 8 and 29 percent of their acreage between 1.4 and 1.7 times. Rates ranged between 0.08 and 0.20 lb ai/A, and total usage was estimated at 10,500 pounds (13). In the years in which data have been collected, grapefruit growers applied strobilurins at an average rate ranging from 0.08 to 0.24 pounds of active ingredient per acre at each application, to between 3 and 34 percent of their acreage. Growers have made an average number of applications ranging from 1.0 to 1.5 each year, totaling between 3,800 and 15,000 pounds of active ingredient annually (13,16).

FENBUCONAZOLE. Fenbuconazole is a triazole fungicide which inhibits the formation of sterols. It has been under Section 18 emergency exemption for Florida grapefruit since 1999 for the control of greasy spot (in those cases where oil and copper sprays are less effective than desired). The price of fenbuconazole is $108 per pound of active ingredient, and the approximate cost of a maximum labeled application (0.13 lb ai/A) is $14 (14,23). The label states that no more than 0.38 lb ai/A (or three applications) can be applied in one year. The REI is 12 hours and the PHI is 2 days.

In 2005, Florida grapefruit growers applied an average of 0.12 pound of fenbuconazole per acre at each application to 25 percent of their acreage, an average of 1.5 times. Total usage was 3,300 pounds of active ingredient (13). During the years in which usage data have been collected, grapefruit growers in Florida have applied fenbuconazole at an average rate ranging from 0.12 to 0.14 pound of active ingredient per acre at each application, to between 25 and 39 percent of their acreage. Growers have made an average number of applications ranging from 1.1 to 1.5 times each year, totaling between 3,300 and 20,300 pounds of active ingredient annually (13,16,24).

MEFANOXAM. Mefenoxam is an acylamine which is used to control organisms such as Phytophthora. The price of mefenoxam is $157 per pound of active ingredient, and the approximate cost of a maximum labeled application (1.0 lb ai/A) is $157 (9,14). The label states that two or three applications should be made to increase the efficacy of the product and no more 6 lb ai/A can be applied in one year. The REI is 48 hours and there is no PHI.

In 2005, Florida orange growers applied an average of 0.4 pound of mefenoxam per acre at each application to 10 percent of their acreage, an average of 1.0 time. Total usage was 21,200 pounds of active ingredient (13). During the years in which usage data have been collected, orange growers in Florida have applied mefenoxam at an average rate ranging from 0.4 to 0.9 pound of active ingredient per acre at each application, to between 2 and 10 percent of their acreage. Growers have made an average number of applications ranging from 1.0 to 1.5 times each year, totaling between 12,800 and 39,100 pounds of active ingredient annually (13,16).

In 2005, Florida grapefruit growers applied an average of 1.3 pounds of mefenoxam per acre at each application to 5 percent of their acreage, an average of 1.1 times. Total usage was 4,700 pounds of active ingredient (13). During the years in which usage data have been collected, grapefruit growers in Florida have applied mefenoxam at an average rate ranging from 0.3 to 1.3 pounds of active ingredient per acre at each application, to between 4 and 15 percent of their acreage. Growers have made an average number of applications ranging from 1.1 to 1.7 times each year, totaling between 4,700 and 6,300 pounds of active ingredient annually (13,16).

THIOPHANATE. Thiophanate replaced benomyl as a management tool for post bloom fruit drop. It has been under Section 18 emergency exemption for Florida citrus since 2003. The price of thiophanate is $22 per pound of active ingredient, and the approximate cost of a maximum labeled application (1.4 lb ai/A) is $31 (14,25). The label states that no more than 2.8 lb ai/A can be applied in one year. The REI and PHI are both 48 hours (25).

In 2005, Florida growers treated 13,500 acres of citrus (orange and grapefruit combined) with thiophanate. Total use was 28,000 pounds of active ingredient. In the years for which data have been collected, between 10,000 and 13,500 acres of citrus were treated with thiophanate, at a rate ranging from 1.1 to 2.1 pounds of active ingredient per acre. Total use ranged between 10,500 and 28,000 pounds annually (24).

SODIUM PHENYLPHENATE. This fungicide, known widely as OPP, is a disinfectant and fungicide with protectant action. It is the most widely used of the post harvest fungicides. In 2003-04, navel oranges were treated with 6,600 pounds of OPP. For Valencia oranges in 2003-04, 8,200 pounds of OPP were used to treat the fruit (21).

THIABENDAZOLE. This fungicide, known widely as TBZ, is a benzimidazole fungicide with curative and protective action. It is the second most widely used of the post harvest fungicides. In 2003-04, navel oranges were treated with 1,500

pounds of TBZ. For Valencia oranges in 2003-04, 1,400 pounds of TBZ were used to treat the fruit (21).

IMAZALIL. Imazalil is seldom used in citrus packing. It is an azole fungicide with curative and protective action. In 2003-04, navel oranges were treated with 300 pounds of imazalil. For Valencia oranges in 2003-04, 300 pounds of imazalil were used to treat the fruit (21).

Weeds

In the Florida citrus production system's weed management program, total acreage treated with herbicides often account for over 25 percent of total production costs (26). Lost revenues because of poor weed control result from reduced efficiency of production and harvesting operations, direct competitive effects of the weeds, and other impacts less readily documented. Proper weed management programs also positively manipulate grove temperatures during freeze events, and minimize the fire hazard during the dry winter and spring periods.

It has been estimated that of the more than 100 weed species commonly occurring in Florida groves, only about 30 are considered very undesirable. Of these, perhaps 20 are capable of becoming or have become serious pests. Some of these include milkweed, balsam apple, morningglory, Virginia creeper, briar, lantana, goatweed, saltbush, teaweed, torpedograss, vaseygrass, guineagrass, peppervine, air potato, wild grape, and phasey bean. This reflects a mixture of grasses and broadleaf weeds, as well as annuals, biennials, and perennials. It is recognized that most of the current citrus acreage is under some form of integrated weed management program involving mainly chemical and mechanical control methods (3,5).

The current pattern of weed control follows one of two general schemes. In the first, and perhaps more historic scheme, preemergence herbicides are applied at the beginning of the season and then post-emergent herbicides are used on an as-needed basis later in the season. In the second scheme, post-emergent herbicides are used throughout the year, usually two to four times. Areas under tree canopies are kept weed-free, and row middles are often left vegetated. Florida citrus growers reported using mowing for weed control for 84 percent of the citrus acreage (16).

Controls

Non-Chemical

An integrated vegetation management program involves the consideration of all options over time including cultural, mechanical, and biological methods. The choice of which combination to use depends on grove location, planting system, tree row vs. tree middle, vegetation species and cost constraints. Cultural methods include:

- Exclusion and sanitation practices to minimize species introduction, establishment and spread;
- Modification of other grove practices that may promote the establishment and spread of undesirable vegetation;
- Early shading of grove floor surface by tree canopy; and,
- Leguminous cover crops that can supply nitrogen and require less annual maintenance.

Mechanical cultivation kills annual weeds efficiently. Each crop of weeds must be killed in order to prevent production of seeds. Each cultivation, however, also brings seeds to the soil surface where they can germinate. Infrequent cultivation provides temporary control, it also spreads and invigorates perennial weeds by increasing the number of buried seeds and distributing rhizome and stolon cuttings, tubers, and bulbs. Constant cultivation also results in the destruction of citrus fibrous roots that normally would grow in the undisturbed portion of the soil. Mowing is practiced between the tree rows, but mowing has a high energy demand and high equipment costs. Weeds can also be spread by seeds during mowing operations. Mowing operations need to be performed before seedhead formation to reduce seed dissemination and reinfestation.

Chemical

Herbicides are applied on an as needed basis under the tree's drip line within the row, and in some

instances to the row middles, ditchbanks and certain aquatic areas to manage grass, broadleaf, woody, vine, and sedge weed pests. In most cases, the preemergent herbicides are applied only under the row's drip line and not in the row middles, whereas some of the postemergent herbicides may be applied under the drip line and between the rows. Care is taken to prevent any herbicide drift from contacting any portion of the tree or its fruit. Contact herbicides that are commonly used include glyphosate, 2,4-D, and paraquat, while residual herbicides commonly used include diuron, bromacil, simazine, and norflurazon (16). To a limited degree, sethoxydim, oryzalin, pendimethalin, and thiazopyr are other herbicides that are used for weed management in Florida citrus groves (9).

It should be noted that unlike insecticides/miticides and fungicides, herbicides are used in different areas of the grove. The costs for full labeled treatments presented below are for an acre which is entirely treated. Since the areas of treatment (under the trees, or in row middles) are only a portion of the total acreage, the application must be tailored accordingly, depending on tree maturity. For example, one treated acre may represent enough herbicide to treat approximately three grove acres (26).

GLYPHOSATE. Glyphosate is a non-selective herbicide, and is applied using boom, wiping, or spot application equipment. It is also mixed with 2,4-D in a shielded manner. Glyphosate is used to manage weeds within the drip line under the trees, and within the row middles as a chemical mowing agent. It is also selectively applied within row middles by wiping to remove tall growing and difficult to control weed species, and as a spot treatment. The price of glyphosate is $10.95 per pound of active ingredient, and the approximate cost of a maximum labeled application (5.0 lb ai/A) is $54.75 (9,14). Glyphosate has a REI from 4 to 12 hours and the PHI is 1 day (9).

In 2005, Florida orange growers applied an average of 1.2 pounds of glyphosate per acre at each application to 86 percent of their acreage, an average of 2.6 times. Total usage was 1,453,500 pounds of active ingredient (13). During the years in which usage data have been collected, orange growers in Florida have applied glyphosate at an average rate ranging from 0.74 to 1.2 pounds of active ingredient per acre at each application, to between 60 and 88 percent of their acreage. Growers have made an average number of applications ranging from 2.0 to 2.9 times each year, totaling between 791,900 and 1,453,500 pounds of active ingredient annually (13,16).

In 2005, Florida grapefruit growers applied an average of 1.0 pounds of glyphosate per acre at each application to 72 percent of their acreage, an average of 2.4 times. Total usage was 125,300 pounds of active ingredient (13). During the years in which usage data have been collected, grapefruit growers in Florida have applied glyphosate at an average rate ranging from 0.8 to 1.2 pounds of active ingredient per acre at each application, to between 60 and 91 percent of their acreage. Growers have made an average number of applications ranging from 2.2 to 2.8 times each year, totaling between 125,300 and 267,800 pounds of active ingredient annually (13,16).

DIURON. Diuron is a preemergent herbicide used for annual broadleaf and annual grass management. It is not applied to row middles. The price of diuron is $5.50 per pound of active ingredient, and the approximate cost of a maximum labeled application (3.2 lb ai/A) is $17.60 (14,22). There are application limits depending on soil type. Diuron has a REI of 12 hours and the PHI is 0 day (9).

In 2005, Florida orange growers applied an average of 1.4 pounds of diuron per acre at each application to 51 percent of their acreage, an average of 1.7 times. Total usage was 657,400 pounds of active ingredient (13). During the years in which usage data have been collected, orange growers in Florida have applied diuron at an average rate ranging from 0.83 to 1.4 pounds of active ingredient per acre at each application, to between 32 and 61 percent of their acreage. Growers have made an average number of applications ranging from 1.6 to 1.9 times each year, totaling between 428,100 and 756,600 pounds of active ingredient annually (13,16).

In 2005, Florida grapefruit growers applied an average of 1.2 pounds of diuron per acre at each application to 43 percent of their acreage, an average of 1.7 times. Total usage was 63,000 pounds of active ingredient (13). During the years in which usage data have been collected, grapefruit growers in Florida have applied diuron at an average rate ranging from 0.87 to 1.4 pounds of active ingredient per acre at each application, to between 26 and 53 percent of their acreage. Growers have made an average number of applications ranging from 1.3 to 1.7 times each year, totaling between 36,600 and 108,500 pounds of active ingredient annually (13,16).

BROMACIL. Bromacil is a preemergent/limited postemergent herbicide used to manage annual broadleaf, and annual and perennial grass weeds. It cannot be used on Florida's sandy ridge-type soils. The price of bromacil is $27.65 per pound of active ingredient, and the approximate cost of a maximum labeled application (3.2 lb ai/A) is $88.48 (14,22). Bromacil has a REI of 12 hours and the PHI is 0 day (9).

In 2005, Florida orange growers applied an average of 0.89 pounds of bromacil per acre at each application to 15 percent of their acreage, an average of 1.8 times. Total usage was 126,900 pounds of active ingredient (13). During the years in which usage data have been collected, orange growers in Florida have applied bromacil at an average rate ranging from 0.72 to 1.3 pounds of active ingredient per acre at each application, to between 15 and 45 percent of their acreage. Growers have made an average number of applications ranging from 1.5 to 2.0 times each year, totaling between 122,900 and 314,600 pounds of active ingredient annually (13,16).

In 2005, Florida grapefruit growers applied an average of 0.71 pounds of bromacil per acre at each application to 21 percent of their acreage, an average of 1.7 times. Total usage was 18,500 pounds of active ingredient (13). During the years in which usage data have been collected, grapefruit growers in Florida have applied bromacil at an average rate ranging from 0.71 to 0.88 pounds of active ingredient per acre at each application, to between 20 and 30 percent of their acreage. Growers have made an average number of applications ranging from 1.3 to 1.7 times each year, totaling between 18,500 and 45,400 pounds of active ingredient annually (13,16).

SIMAZINE. Simazine is a preemergent herbicide used to manage broadleaf weeds, annual vines, and annual grasses. The price of simazine is $4.50 per pound of active ingredient, and the approximate cost of a maximum labeled application (9.5 lb ai/A) is $42.93 (9,14). There are annual application limitations ranging from 8 to 9.5 lb ai/A. Simazine has a REI of 12 hours and the PHI is 0 day (9).

In 2005, Florida orange growers applied an average of 2.4 pounds of simazine per acre at each application to 31 percent of their acreage, an average of 1.4 times. Total usage was 574,500 pounds of active ingredient (13). During the years in which usage data have been collected, orange growers in Florida have applied simazine at an average rate ranging from 1.4 to 2.4 pounds of active ingredient per acre at each application, to between 23 and 40 percent of their acreage. Growers have made an average number of applications ranging from 1.3 to 2.0 times each year, totaling between 320,300 and 728,700 pounds of active ingredient annually (13,16).

In 2005, Florida grapefruit growers applied an average of 2.0 pounds of simazine per acre at each application to 23 percent of their acreage, an average of 1.6 times. Total usage was 53,800 pounds of active ingredient (13). During the years in which usage data have been collected, grapefruit growers in Florida have applied simazine at an average rate ranging from 1.2 to 2.3 pounds of active ingredient per acre at each application, to between 12 and 48 percent of their acreage. Growers have made an average number of applications ranging from 1.3 to 2.5 times each year, totaling between 51,200 and 80,100 pounds of active ingredient annually (13,16).

NORFLURAZON. Norflurazon is a preemergent herbicide used to manage annual broadleaf, and annual and perennial grasses. It can be used as a directed spray under the trees, in chemigation through low volume sub-canopy irrigation systems or in chemigation through high volume overhead systems (in field nurseries only).

The price of norflurazon is $25.50 per pound of active ingredient, and the approximate cost of a maximum labeled application (4 lb ai/A) is $102 (9,14). The label limits the amount used to 8 lb ai/A every year. Norflurazon has a REI of 12 hours and the PHI is 30 days (9).

In 2005, Florida orange growers applied an average of 1.4 pounds of norflurazon per acre at each application to 16 percent of their acreage, an average of 2.2 times. Total usage was 260,500 pounds of active ingredient (13). During the years in which usage data have been collected, orange growers in Florida have applied norflurazon at an average rate ranging from 1.0 to 1.5 pounds of active ingredient per acre at each application, to between 13 and 25 percent of their acreage. Growers have made an average number of applications ranging from 1.5 to 2.2 times each year, totaling between 198,900 and 324,000 pounds of active ingredient annually (13,16).

In 2005, Florida grapefruit growers applied an average of 1.5 pounds of norflurazon per acre at each application to 16 percent of their acreage, an average of 1.8 times. Total usage was 31,100 pounds of active ingredient (13). During the years in which usage data have been collected, grapefruit growers in Florida have applied norflurazon at an average rate ranging from 1.0 to 1.5 pounds of active ingredient per acre at each application, to between 16 and 26 percent of their acreage. Growers have made an average number of applications ranging from 1.3 to 1.9 times each year, totaling between 20,700 and 69,300 pounds of active ingredient annually (13,16).

PARAQUAT. Paraquat is a non-selective herbicide that destroys all green tissue contacted. The price of paraquat is $12.00 per pound of active ingredient, and the approximate cost of a maximum labeled application (1.0 lb ai/A) is $12.00 (9,14). The annual application limitation is 5 lb ai/A. Paraquat has a REI of 12 hours and the PHI is 0 day (9).

In 2005, Florida orange growers applied an average of 0.37 pound of paraquat per acre at each application to 9 percent of their acreage, an average of 1.3 times. Total usage was 23,800 pounds of active ingredient (13). During the years in which usage data have been collected, orange growers in Florida have applied paraquat at an average rate ranging from 0.28 to 0.45 pound of active ingredient per acre at each application, to between 6 and 13 percent of their acreage. Growers have made an average number of applications ranging from 1.0 to 2.2 times each year, totaling between 15,700 and 52,500 pounds of active ingredient annually (13,16).

In 2005, Florida grapefruit growers applied an average of 0.44 pound of paraquat per acre at each application to 1 percent of their acreage, an average of 1.5 times. Total usage was 700 pounds of active ingredient (13). During the years in which usage data have been collected, grapefruit growers in Florida have applied paraquat at an average rate ranging from 0.38 to 0.45 pound of active ingredient per acre at each application, to between 1 and 3 percent of their acreage. Growers have made an average number of applications ranging from 1.1 to 1.5 times each year, totaling between 700 and 2,200 pounds of active ingredient annually (13,16).

2,4-D. The auxin mimic 2,4-D is used in combination with glyphosate in about a third of the acreage sprayed with glyphosate under a special local needs registration. A very small amount is used as a growth regulator in pineapple oranges. The price of 2,4-D is $3.00 per pound of active ingredient, and the approximate cost of a maximum labeled application (3.8 lb ai/A) is $11.40 (14,23). The annual application limitation is 3.8 lb ai/A and records must be kept of wind directions when using the mixture. 2,4-D has a REI of 48 hours and the PHI is 7 days (9).

In 2005, Florida orange growers applied an average of 0.27 pound of 2,4-D per acre at each application to 26 percent of their acreage, an average of 1.9 times. Total usage was 75,400 pounds of active ingredient (13). During the years in which usage data have been collected, orange growers in Florida have applied 2,4-D at an average rate ranging from 0.19 to 0.27 pound of active ingredient per acre at each application, to between 3 and 26 percent of their acreage. Growers have made an average number of applications ranging from 1.5 to 2.3 times each year, totaling between 6,100 and 75,400 pounds of active ingredient annually (13,16).

In 2005, Florida grapefruit growers applied an average of 0.25 pound of 2,4-D per acre at each application to 18 percent of their acreage, an average of 1.5 times. Total usage was 4,800 pounds of active ingredient (13). During the years in which usage data have been collected, grapefruit growers in Florida have applied 2,4-D at an average rate ranging from 0.24 to 0.25 pound of active ingredient per acre at each application, to between 8 and 18 percent of their acreage. Growers have made 1.5 applications per year, totaling between 2,700 and 4,800 pounds of active ingredient annually (13,16).

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