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Florida Crop/Pest Management Profile: Limes, Pummelo, and Kumquat[1]

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Production Facts

- Lime in this crop profile refers to the 'Tahiti' lime (*Citrus latifolia*). Pest management practices of other members of the Rutaceae such as Key lime *(Citrus aurantifolia*), pummelo (*Citrus grandis*), and kumquat (*Fortunella* sp.) may also be described. All of these species of citrus are grown for the fresh market.
- The 2001–2002 average yield of limes in Florida was 11,880 pounds per acre. At a price of $6.19 (USD) per box, the Florida lime crop (150,000 boxes) for 2001–2002 was worth approximately $930,000 (1). (Lime production and value statistics were terminated in 2002.)
- In 2001–2002, 800 acres in Florida produced 13 million pounds of 'Tahiti' lime, a 75 percent decrease from lime production in Florida in 1999–2000, when 53 million pounds were recorded (1).
- Reductions in lime acreage have occurred due to citrus canker coupled with hurricanes. Twenty years of these events and foreign competition have decimated lime production from a peak of approximately 6,000 acres in 1990 to 500 bearing acres in 2007 (1,2).
- Pummelo acreage was reported to be 45 acres in 1995-1996. Twenty-five acres were young plantings, averaging about 10,000 pounds per acre, while the remainder was older, producing about 25,000 pounds per acre. Price at that time ($0.60 USD per pound) valued the crop at $435,000 (USD), of which 95 percent sold outside of Miami-Dade County (3).
- Kumquat acreage was reported to be about 40 bearing acres in 2007, up from 25 acres over the 1990s. In 1995–1996, yield averaged 8,300 pounds per acre. With a pack-out rate of 95 percent and average price approaching $1.50 per pound, the total crop value was reported to be $283,000 (2,3).

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Production Regions

Florida-grown citrus lime is grown exclusively in south Florida. In 2000, 98 percent of Florida's 'Tahiti' lime acreage was located in Miami-Dade County (1). Florida's Key lime, pummelo, and kumquat are also grown exclusively in southern Florida.

Production Practices

The 'Tahiti' lime tree is small (5 m), with dark green oval leaves that persist up to three years on the tree. Flowers are white and fragrant, and are borne in clusters of five to ten on the tip and several nodes back. The trees bloom continuously throughout the year, but peak in February through April, and fruit requires from 100 to 120 days to mature. Consequently, limes are available all year, but peak harvest is from June through August. Typically, acids run between five and six percent, sugars range from eight to ten percent, and juice by volume is 42–55 percent of the total volume (4).

With adequate budwood and rootstock, propagation can be performed by shield budding, chip budding, and air-layering. Rootstocks employed include rough lemon and *Citrus macrophylla*. Typical tree densities are between 90 and 200 trees per acre. Properly propagated and cultured trees may start to bear within three years, and quality groves will produce from 30,000 to 40,000 pounds of fruit per acre per year (4).

The 'Tahiti' lime is more cold hardy than the Key lime, but less so than grapefruit. The trees are moderately drought tolerant but irrigation is essential for commercial production. Soils must be well drained. Lime does not tolerate flooding or standing water, as this predisposes the tree to *Phytophthora* infection. The soils present in southern Florida generally fulfill this requirement (4).

With regard to pollination, research would seem to indicate that this crop is not greatly benefitted by pollinators. However, the same cannot be said for pummelo, which appears to require pollination (5).

Worker Activities

Lime trees are generally pruned mechanically once a year, usually in September, after the majority of limes are picked (from two to 16 pickings per year). The pruning process is the same for Key lime, which is harvested from June through September (picked two to five times). Kumquat is harvested October through February (picked two to three times), and mechanical pruning for this species is done every few years. Pummelo is picked from December through April. Besides picking, there is little direct contact of the worker with the trees of these species (6).

Insect/Mite Management

Insect/Mite Pests

The principal pests on lime in Florida are mites (broad mite, citrus rust mite, pink citrus rust mite, citrus red mite, Texas citrus mite, six-spotted mite), scale (snow, Florida red, purple, Glover's, chaff, brown soft, Caribbean black, Florida wax), root weevil, eastern subterranean termites, and citrus leafminer. Asian citrus psyllid has recently risen to primary pest status, as it vectors citrus greening disease. Minor and occasional pests include aphids, citrus black fly, orange dog, mealy bugs, white fly, flower midges, fire ants, crickets, grasshoppers, and plant bugs. Many of the scheduled treatments for the principal pests effectively manage the minor pests or the minor pests are effectively controlled biologically (7).

Mites (*Polyphagotarsonemus latus, Phyllocoptruta oleivora, Aculops pelekassi, Panonychus citri, Eutetranychus banksi, Eotetranychus sexmaculatus*)

The broad mite is an important pest of lime, with infestation usually occurring in spring and summer. The mites are generally amber, yellow, or green, and the female has a light median strip that forks near the back of the body. The two hind legs of the female are reduced to whip-like appendages. They are generally observed on new leaves and fruit (particularly the shaded side of the fruit in the inner canopy). Fruit feeding causes scurfing or russeting, which makes the fruit unmarketable but does not affect the juice. The

full cycle from egg to reproductive female takes only 4–5 days, so populations can build rapidly. In contrast to spring, broad mite presence in the summer will probably require control. Heavy infestations can lead to premature fruit drop (8).

In addition to the broad mite, citrus rust mite is another mite that requires management in commercial lime production because it inflicts the majority of damage during the summer months (9). This mite is lemon-colored and has a wedge-shaped body. Development from egg to reproductive female occurs within 5–7 days. As with broad mite, the scurfing and russeting that makes limes unmarketable but leaves the juice unaltered is a casualty indicative of the presence of citrus rust mite (10).

Spider mites that have the potential to be a problem in lime production include the citrus red mite, Texas citrus mite, and six-spotted mite. These are mostly leaf feeders unless under heavy infestation. The Texas mite is generally most prevalent. This mite is brownish-green and causes the same type of damage as the citrus red mite. Leaves are stippled and etched. Both of these species develop from egg to reproductive adult within ten to twelve days. Although the citrus red mite and Texas citrus mite both are more numerous during the spring months, the damage caused by them is more severe in winter, when they may cause mesophyll collapse and subsequent leaf dessication (firing). The six-spotted mite, yellow in color with two rows of three black spots on the abdomen, is a sporadic pest of citrus. Foliar feeding by this mite causes yellow spots along the midrib of the leaves (10,11,12,13).

Scale (*Coccus hesperidum, Chrysomphalus aonidium, Cornuaspis beckii, Lepidosaphes gloveri, Parlatoria pergandii, Unaspis citri, Saissetia neglecta, Ceroplastes floridensis*)

Soft and armored scales are plant-feeding insects, which are often well managed by natural and released parasites, predators, and pathogens. In cases when the natural balance of predation has been disrupted, scale populations may increase to levels requiring treatment. Since scale insects are relatively immobile and at least one month is required for the egg to reach the adult stage, an infestation builds up slowly (in comparison to mites or aphids) and may be hard to spot. It is important to verify that the scale insects attached to the plant are alive, as mummies accumulate on the plant over time. Economic thresholds for scale have not been determined. Most effective control is obtained when the scales are in nymphal stages, as egg and adult stages are recalcitrant to insecticide applications (7,13,14).

Citrus Root Weevils (*Diaprepes abbreviatus* and others)

There are at least eight species of root weevil that are known to attack citrus in Florida. The larvae of five of the species are important with regard to citrus culture, as they are capable of direct root damage and provide entry routes for fungal infection in the root tissue. Mature weevils cause only minimal damage from leaf feeding, which is apparent as "notches" on the leaf margins (15). *D. abbreviatus* is by far the most damaging of the weevils, and this pest is considered a major long-term threat to Florida agriculture. The pest has a large host range, which includes many woody plants. The larva move readily in sandy soils, and have been found at soil depths of 8–10 feet.

Most mature female root weevils place their eggs in clusters between two leaves on newly flushed foliage. After ten or twenty days, eggs hatch and larvae fall to the ground. The larvae begin feeding on the fibrous feeder roots. Successively larger larval instars feed on larger roots. For *D. abbreviatus*, the final larval stages (of at least eleven) proceed to the tap root and major lateral roots of the tree. Even if direct feeding does not girdle these roots, lesions provide entry to debilitating fungi such as *Phytophthora*. Adult weevils emerge over a three-month period which may begin as early as March. Larval development time ranges from nine to 18 months, which includes an inactive pupal stage of 1–3 months. Dry weather delays development and emergence. Two species of root weevil (*Artipus floridanus* and *Asynonychus godman*i) are flightless. Consequently, raising tree skirts and controlling weeds may reduce the numbers of these particular weevils (15).

Subterranean Termites (*Reticulitermes flavipes* and *Reticulitermes virginicus*)

These termites are native to the eastern United States, and provide useful conversion of wood to soil. The termites favor dead wood, but are known to attack live citrus trees. In these cases, the termites may be restricted from more favored feeding sites due to the water table, or there may be a lack of favored food. When feeding on live plants occurs, the trees are generally small (less than 5 inches in diameter). In addition, lime marcots are vulnerable because of the dead wood at their bases. Feeding commences below the soil line, and may therefore escape detection until death of the tree; trees may also demonstrate shock bloom, chlorosis, or leaf drop in response. Termites chew away bark and cambium, and lesions are characteristically clean and free of gumming. Grove managers may reduce potential termite damage by meticulously removing dead wood (especially pine) during grove establishment (16).

Citrus Leafminer (*Phyllocnistis citrella*)

This leaf-mining moth has become a serious pest of citrus and related plants of the Rutaceae. It is often found on grapefruit and pummelo. The adults are small (4 mm wingspan) with white, silvery scales on the forewings, and long fringe scales on the hind wing margins. They are active diurnally and in the evenings. Eggs are laid singly on the ventral leaf surface. After hatching, the greenish-yellow larva starts feeding and creates serpentine mines on the leaf. Feeding causes leaves (and sometimes shoots) to curl, which reduces the leaf area. After four instars, the insect pupates near the leaf margin under a slight curl of a leaf. In Florida, a new generation can occur every three weeks (17,18).

Leafminer populations decline to their lowest levels during the winter due to cool temperatures and the lack of flush for larval development. Populations of leafminer build rapidly on the spring flush, although their presence is not apparent until late spring as populations increase while the amount of new foliage decreases. Throughout the ensuing warm season, leafminer populations vary with the flushing cycles and subsequent flushes are often severely damaged. The summer period of high leafminer damage coincides with the rainy season when canker spread is most likely (17).

Citrus leafminer greatly exacerbates the severity of citrus canker caused by *Xanthomonas axonopodis* pv. *citri*. This insect is not a vector of the disease. Nevertheless, leafminer tunnels are susceptible to infection much longer than mechanical wounds. Tunnels infected by canker produce many times the amount of inoculum than in the absence of leafminer (17).

Even though chemical control may occasionally be needed, this organism is greatly reduced in number by *Ageneaspis citricola*, a parasitoid released in Florida in 1994-95. Economically damaging episodes of citrus leafminer occur on newly flushed leaves, especially when the flush comes at once. A scouting program should be initiated when 50 percent of the trees are producing flush. Pesticidal spraying should be considered only when the new flush is anticipated to constitute about 20 percent of the entire leaf area. Then, application should begin when about 30 percent of the flush leaves show active mines (17,19). Damage to 'Tahiti' limes by citrus leafminer ranged from 21 to 26 percent on newly flushed foliage (19).

Asian Citrus Psyllid (*Diaphorina citri*)

The Asian citrus psyllid (see the EDIS publication, "Biology and Management of the Asian Citrus Psyllid, *Diaphorina citri* Kwayama, in Florida Citrus," http://edis.ifas.ufl.edu/IN668) has become the most important insect pest of Florida citrus due to the presence of citrus greening disease, which is vectored by the psyllid. New flush is required for psyllid females to lay eggs as well as for subsequent development of the psyllid nymphs. Female psyllids lay their eggs in developing leaf buds and on feather-stage flush which has not yet unfurled. Once young leaves have begun to expand, they are no longer attractive to psyllids for egg laying. When suitable flush is not available for egg laying, psyllids may either remain on a tree feeding on the mature leaves until new flush is available for reproduction or they may leave the tree in search of other host plants on which to lay their eggs. These plants may be citrus trees within the same grove (particularly young

resets, which flush more often) or trees producing flush in neighboring groves (17).

Temperature is also closely linked to the abundance of psyllids in the field. The ideal temperature conditions for psyllids are between 68–86°F. At these temperatures, a single female psyllid can live for as much as 30–50 days and may lay as many as 300–750 eggs, according to laboratory studies. When the daily temperatures are above 90°F, the average lifespan of a female psyllid decreases to less than 30 days in the laboratory, with an average of fewer than 70 eggs produced per female at these higher temperatures. Thus, under Florida conditions, psyllid populations will be lower during the mid-summer months, compared to late spring and even early fall, due to both high temperatures, and a reduced amount of new flush available for egg laying (17).

Chemical Control

Seventy-eight percent of responding surveyed 'Tahiti' lime growers and 100 percent of pummelo, Key lime, and kumquat growers reported insecticide use. Those survey respondents that provided insect damage estimates indicated that from 25 to 90 percent of the 'Tahiti' lime crop would be lost to insect damage (n=5, mean of 70 percent). For pummelo, insect damage would also be 70 percent. Key lime growers only reported a five percent loss from insect damage (20).

Insecticides and miticides registered for use on Florida citrus (as well as kumquat) include azadirachtin, abamectin, acephate (non-bearing), acetamiprid, acequinocyl, aldicarb, azinphos, bifenthrin, *Bacillus thuringiensis*, bifenazate, buprofezin, cryolite, chlorpyrifos, carbaryl, dimethoate, dicofol, diflubenzuron, endosulfan (non-bearing), ethoprop (non-bearing), fenpropathrin, fenbutatin-oxide, fenpyroximate, hexythiazox, imidacloprid, malathion, methidathion, naled, insecticidal oil, oxamyl, phosmet, propargite, pyrethrin +/- rotenone, pyridaben, pyriproxyfen, insecticidal soap, spinosad, spinetoram, spirodiclofen, spirotetramat, sulfur, and zeta-cypermethrin. Methoprene and pyriproxyfen are available as ant baits and metaldehyde is labeled for slug and snail control (21).

Crop Oils

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 approximately $6 per gallon, and the approximate cost of a maximum labeled application (10 gal/A) is $60 (22). The restricted entry interval (REI) is 4 hours and there is no pre-harvest interval (PHI) (21).

Seventy-eight percent of surveyed 'Tahiti' lime growers, 100 percent of Key lime growers, and 25 percent of pummelo growers in Florida applied crop oil; of these, the number of applications reported were as follows: one (22 percent), two (11 percent), four (45 percent), five (11 percent), or six (11 percent) times, for an average use of 3.5 times per season. Kumquat growers did not report use of crop oil (20).

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 (21). Sulfur cannot be combined with oil, nor can it be applied within three weeks of any oil spray, as fruit burn/phytotoxicity will result. 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 averages $1 (USD) per pound, and the approximate cost of a maximum labeled application (15 lb/A) is $15 (22).

Thirty-three percent of surveyed 'Tahiti' lime growers in Florida applied sulfur either one (33 percent) or two (67 percent) times for an average use of 1.7 times per season. Key lime, pummelo, and kumquat growers did not report using sulfur (20).

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 averages $10 (USD) per pound of active ingredient, and the approximate cost of a maximum labeled application (3.5 lb ai/A) is $35 (22). The PHI is 28 days for soil application, 21 days for foliar application when using less than seven pints, 35 days for foliar application when using seven pints or more, and the REI is 120 hours (5 days). Chlorpyrifos can only be applied to the foliage twice per season (with a 30-day minimum interval between applications). Soil treatment is limited to three times per season and cannot exceed 10 pounds of active ingredient per acre per season (21).

Twenty-two percent of surveyed 'Tahiti' lime growers applied chlorpyrifos 2 times per season. Key lime growers did not report use of chlorpyrifos. Thirty-three percent of pummelo growers and 100 percent of kumquat growers used chlorpyrifos as a spot treatment (20).

Carbaryl

Carbaryl is a carbamate insecticide that interferes with nerve transmission. This compound is used to manage scales and adult root weevils (7). The median price of carbaryl is $7 per pound of active ingredient and the approximate cost per application is $21 per acre (22). The PHI is 5 days and the REI is 12 hours. The maximum amount of carbaryl that can be applied over a year is 20 pounds of active ingredient per acre (21).

Twenty-two percent of surveyed 'Tahiti' lime growers applied carbaryl either once (50 percent) or twice (50 percent) per season for an average use of 1.5 times per season. No pummelo, Key lime, or kumquat growers reported using carbaryl (20).

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 averages $4,570 (USD) per pound of active ingredient, and the approximate cost of a maximum labeled application (0.023 lb ai/A) is $107 (21,22). 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 REI is 12 hours and the PHI is seven days. There is a yearly maximum of three applications or 40 ounces of product per acre and minimum time between applications is 30 days. Abamectin must be applied in conjunction with a spray oil (23).

Thirty-three percent of surveyed 'Tahiti' lime and pummelo growers applied abamectin four (75 percent) or seven (25 percent) times for an average use rate of 4.8 times per season. Key lime and kumquat growers did not report use of abamectin (20)

Fenoxycarb

Fenoxycarb is a carbamate compound used as an insect growth regulator, which causes death in the last pupal stage. The bait product is used to manage ants (particularly the imported red fire ant). The price of fenoxycarb is $715 (USD) per pound of active ingredient and the approximate cost per application is $14 per acre (22).

Eleven percent of surveyed 'Tahiti' lime growers and 33 percent of pummelo growers applied fenoxycarb to their acreage once per season. Key lime and kumquat growers did not report use of fenoxycarb (20).

Methidathion

Methidathion is an organophosphate insecticide used to manage sucking insects. The price of methidathion averages $30 (USD) per pound of active ingredient and the approximate cost per application is $15 per acre (22). There is a maximum of two applications per year, which must be made at a minimum of 45 days apart. The PHI is 14 days and the REI is 48 hours (21).

Eleven percent of surveyed 'Tahiti' lime growers, 33 percent of pummelo growers, and 100 percent of Key lime growers applied methidathion to their acreage once (67 percent) or twice (33 percent) for an average use rate of 1.3 times per season. Methidathion was not used by kumquat growers (20).

Azadirachtin

Azadirachtin is a natural compound derived from the neem tree (*Azadirachta indica*) that has insect growth regulator as well as repellent activity. The compound is used to manage whiteflies, aphids, some scale insects, and caterpillars. The price of azadirachtin averages $2,100 (USD) per pound of active ingredient and the approximate cost per application is $90 per acre (22). The PHI for azadirachtin is 0 day and the REI is 4 hours (21).

Thirty-three percent of pummelo growers applied azadirachtin to their acreage five times per season. Growers of 'Tahiti' lime, Key lime, and kumquat did not report use of azadirachtin (20).

Cultural Control

Based on survey results of all tropical fruit growing respondents, 44 percent reported keeping records of pest problems, 50 percent adjusted applications (timing or rate) to protect beneficial insects and mites, and 52 percent alternated pesticides to reduce resistance. Sixty-two percent reported selecting the pesticide that is least toxic to beneficial insects and mites and 63 percent spot sprayed only infested plants or areas. Seventy percent reported selecting pesticides that are least toxic to the environment to make this the dominant form of cultural pest control (20).

Biological Control

Seven percent of the responding tropical fruit growers reported release of predatory wasps for control of lepidopteran pests. Additionally, 30 percent reported the use of biological-derived pesticides like B.t. (20).

Weed Management

Weed Pests

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 with the added benefit of minimizing the fire hazard during the dry winter and spring periods (24).

Of 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. Most of the current citrus acreage is under some form of integrated weed management program involving mainly chemical and mechanical control methods (25).

The current pattern of weed control follows one of two general schemes. In the first, and perhaps more historic scheme, pre-emergence 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 (25).

Chemical Control

Seventy-eight percent of surveyed 'Tahiti' lime growers and 100 percent of pummelo, Key lime, and kumquat growers reported herbicide use (20). There are about a dozen herbicides labeled for use on bearing lime (carfentrazone, diuron, bromacil, simazine, sethoxydim, glyphosate, norflurazon, paraquat, pendimethalin, oryzalin, trifluralin, MSMA, and DSMA). Fluazifop, EPTC, oxyfluorfen,

metolachlor, clethodim, and cacodylic acid can be used on non-bearing lime trees (21).

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.

Glyphosate

Glyphosate is a non-selective herbicide, and is applied using boom, wiping, or spot application equipment. 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 (24). The price of glyphosate averages $11 (USD) per pound of active ingredient, and the approximate cost of a maximum labeled application (5.0 lb ai/A) is $55 (22). Glyphosate has a REI from 4 to 12 hours and the PHI is 1 day (24).

Sixty-seven percent of surveyed 'Tahiti' lime growers in Florida applied glyphosate either four (17 percent), five (50 percent), or six (33 percent) times for an average use of 5.2 times per season. One hundred percent of pummelo growers applied glyphosate either four (25 percent), five (25 percent) or six (50 percent) times for an average use of 5.3 times per season. One hundred percent of Key lime and kumquat growers applied glyphosate five times per season (20).

Diuron/Bromacil

This mixture (Krovar®) is common in citrus weed management as it provides long-term control of a variety of grove weeds. It is generally applied to the soil once a year, but may be split between two applications. The median price of Krovar is $15 (USD) per pound of active ingredient and the approximate cost per application for a mature grove is $72 per acre (22,24). There is a limit of 8 pounds of Krovar per acre per year and if a second application is made, it must be made no sooner than 60 days after the first application. The material has some county restrictions and must be applied in a band, rather than trunk-to-trunk. The REI for this product is 12 hours (24). Based on survey results, 11 percent of lime growers in Florida applied Krovar to their acreage once per season (20).

Paraquat

Paraquat is a bipyridylium herbicide used for total vegetation control. Paraquat is applied in a directed manner to avoid foliage injury. The median price of paraquat is $12 (USD) per pound of active ingredient and the approximate cost per application is $11 per acre (22,24). The REI for paraquat is 24 hours. Based on survey results, 11 percent of lime growers in Florida applied paraquat once per season. Twenty-five percent of pummelo growers and 50 percent of kumquat growers reported using paraquat five times per season (20).

Disease Management

Disease Pathogens

The principal diseases affecting 'Tahiti' lime production in Florida include fungi and algae. Depending on soil conditions, *Phytophthora* foot rot may be a particular concern. Anthracnose (*Colletotrichum gloeosporioides*), melanose (*Diaporthe citri*), greasy spot (*Mycosphaerella citri*), scab (*Elsinoe fawcetti*), and postbloom fruit drop (*Colletotrichum acutatum*) are other fungal diseases which affect lime production. Algal spot (*Cephaleuros virescens*) may become apparent in summer and sooty mold is often present, though not considered a true disease of lime. The bacterial disease citrus canker (*Xanthomonas axonopodis* pv. *citri*), when detected, is controlled by eradicating infected trees and those in the immediate vicinity (26–28). This disease has had the greatest effect on Florida lime production, reducing acreage to the current levels. Other non-manageable diseases include the tristeza virus and the exocortis, xyloporosis, and psorosis viroids (7,29).

Foot Rot (caused by *Phytophthora* spp.)

Signs of lime foot rot include chlorosis (pale green leaves with yellow veins) and die-back as well as canker formation. Infected bark remains firm with small cracks through which abundant gum exudation occurs. Root rot may occur if conditions are conducive to fungal growth. Certain rootstocks are more susceptible to this fungus than others. However, trunk injury near the soil surface will allow infection even on resistant rootstock and grafted buds should be well above (10–12 inches) the ground when planted. Severe infection will kill the tree (26,30).

Anthracnose (caused by *Colletotrichum gloeosporioides*)

Key limes are particularly susceptible to anthracnose. The fungus attacks fruit, leaves, twigs, and blooms. On young rapidly growing fruit, the effect varies from shallow spots to deep, depressed cankers. The fruit may abscise or become misshapen. After the fruit is 75 percent formed, it becomes resistant to further attack. Diseased flower buds turn brown and fall before opening. Infected young shoots wilt and eventually die back several inches. Characteristic tan circular to oval spots develop on leaves. As the spots mature, the center falls out leaving a "shot hole" appearance (27).

Melanose (caused by *Diaporthe citri*)

Melanose can cause severe reductions in value by downgrading fruit to juice grade. Signs are distinctive. On leaves, melanose begins as small, dark brown to black sunken spots. Signs on young green twigs are similar to leaves, except that they are raised. On fruit, lesions begin as light brown, circular spots that later become brown to black raised vesicles. Heavy melanose infestations of the young fruit produce scar tissue, which may crack as the fruit enlarges producing the condition known as "mudcake melanose." Fruiting structures (pycnidia) only form on dead wood (31).

Greasy Spot (caused by Mycosphaerella citri)

Greasy spot can become a major disease of 'Tahiti' lime if not adequately controlled. The first signs of infection are orange to brown blisters on the underside of leaves, which have a corresponding yellow spot on the upper surface of the leaves. Eventually, the lesions turn dark brown to black, with a defined greasy look. Infection takes place during the summer, but signs do not appear until later in the year. The lime fruit is affected only occasionally, but the tree may suffer severe defoliation with subsequent loss of vigor (32).

Scab (caused by *Elsinoe fawcetti*)

Although 'Tahiti' lime is not affected by this disease as severely as other citrus, sporadic outbreaks can lead to economic losses. Trees grafted onto rough lemon rootstock are most susceptible to this fungus. On leaves, infections appear as light-colored raised areas, and the leaf may become distorted. Signs are similar on fruit, with prominent raised areas that drop the fruit out of grade (26).

Postbloom Fruit Drop (caused by *Colletotrichum acutatum*)

Postbloom fruit drop (PFD) was first observed on 'Tahiti' limes in south Florida in 1983. Since then it has traveled to other types of citrus. Production losses generally vary with the amount of rainfall that occurs during bloom, and total losses have been reported some years. The first signs of PFD are peach to reddish brown necrotic spots on open petals. Pinhead to half-grown flowers may also be attacked. Necrotic spots on petals often coalesce, producing a blight of the entire inflorescence. Affected petals become hard and dry, persisting for several days after the healthy flowers have experienced normal petal fall. After petal fall, young fruit show a slight yellow discoloration and generally fall off, leaving the calyx and floral disc intact. Those fruit that remain attached never develop (28).

Algal Spot (caused by *Cephaleuros virescens*)

Algal spot has a wide host range among tropical trees but is a particularly serious problem on 'Tahiti' lime trees. Lesions on leaves are roughly circular, raised, and greenish-gray in color. The alga will eventually produce rust-colored microscopic Aspores@ on the surface of the leaf spots, giving

them a reddish appearance. The alga may also spread to branches. If branch splitting occurs, these structures may become girdled and die. This organism seems to flourish in groves that are treated with the available organic fungicides rather than copper-based compounds (26).

Chemical Control

One-hundred percent of surveyed 'Tahiti' and Key lime growers, 75 percent of pummelo growers, and 50 percent of kumquat growers reported fungicide use. Those survey respondents that provided damage estimates indicated that from 25 to 100 percent of the 'Tahiti' lime crop would be lost to disease (n=6, mean of 70 percent). Key lime growers only reported a fifteen percent loss from disease (20). Fungicides registered for use on citrus (as well as kumquat) include azoxystrobin, pyraclostrobin, trifloxystrobin, bicarbonate, phosphourous acid, hydrogen dioxide, mefenoxam, fosetyl aluminum, copper, sulfur, and ferbam (lime only). A Section 18 registration for thiophanate to control PFD is often issued yearly (21).

Copper

Copper fungicides, which include basic copper sulfate, copper hydroxide, and copper oxychloride among others, are used to manage various citrus diseases including melanose, citrus scab, and greasy spot (31,32). The price of copper (hydroxide) is approximately $3.30 (USD) per pound of active ingredient, and the approximate cost of a maximum labeled application (4.9 lb ai/A) is $16 (22). The REI can be either 12, 24, or 48 hours, depending on the form of copper and there is no PHI. One-hundred percent of surveyed 'Tahiti' and Key lime growers, 75 percent of pummelo growers, and 50 percent of kumquat growers in Florida applied copper (in some form); of these, the number of applications reported were as follows: two (17 percent), three (25 percent), four (17 percent), five (17 percent), six (8 percent), eight (8 percent) or ten (8 percent) times for an average use of 4.5 times per season (20).

Ferbam

Ferbam is an iron-containing dithiocarbamate fungicide used to manage anthracnose, postbloom fruit drop, and scab (26,28). The median price of ferbam is $5 per pound of active ingredient and the approximate cost per application is $65 (USD) per acre (22,28). The PHI and REI for ferbam are both 24 hours (21).

Thirty-three percent of 'Tahiti' lime growers applied ferbam either one (33 percent), three (33 percent), or four (33 percent) times for an average use of 2.6 times per season. No ferbam use was reported by Key lime, pummelo, or kumquat growers (20).

Fosetyl-Aluminum

Fosetyl-aluminum (fosetyl-Al) is an aluminum ester of alkyl phosphonate that is used to manage *Phytophthora foot/root* rot (30). The median price of fosetyl-Al is $13 per pound of active ingredient and the approximate cost per application is $54 per acre (22,30). Restrictions include maximums of 4 applications/20 pounds of active ingredient per acre per year. The PHI and REI for fosetyl-Al are 30 days and 12 hours, respectively (21).

Based on survey results, 25 percent of pummelo growers in Florida applied fosetyl-Al to their acreage once per season. Use of fosetyl-Al was not reported by lime or kumquat growers (20).

Post-harvest Control

Careful handling during and after harvest, removal of infected fruit during grading, and adequate temperature maintenance can all aid in minimizing losses from post-harvest decays. In addition to the grade-affecting diseases already listed, green mold and stem-end rot are two post-harvest diseases which are managed with a pre-harvest treatment of thiophanate or a post-harvest treatment of thiabendazole (TBZ). TBZ is a benzimidazole fungicide used as a preventative (33).

Nematode Management

Nematode Pests

Plant-parasitic nematodes are microscopic roundworms, found in soils, which primarily attack plant roots. General signs of nematode damage include stunting, premature wilting, leaf yellowing,

root malformation, and related signs characteristic of nutrient deficiencies. Stunting and poor stand development tend to occur in patches throughout the field as a result of the irregular distribution of nematodes within the soil. Species of nematodes reported to be associated with affected citrus trees include the citrus nematode, *Tylenchulus semipenetrans*, and the burrowing nematode *Radopholus similis* (34). These two organisms are responsible for "slow-decline" and "spreading decline" of citrus, respectively. *Rotylenchulus reniformis* has also been shown to exist in ample numbers in soil samples taken from under lime tree canopies (35).

Chemical Control

The only nematicide actively registered for use on bearing lime trees in Florida is aldicarb (Temik®). Temik is available under a Special Local Needs registration (FL-88003). None of the surveyed lime (or pummelo or kumquat) growers reported the use of nematicides in Florida production (20).

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