



Florida Crop/Pest Management Profiles: Cucumbers¹

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Production Regions

Approximately 29 percent of the state's cucumber producing farms are in the west-central region, with 25 percent in the northern region, 14 percent in the southeastern region, and 8 percent in the southwestern region (4). During the 1997-98 production season, the west-central production region (Hillsborough, Manatee, and Hardee counties) produced 42.4 percent of the state's fresh-market cucumber crop on 34.4 percent of the harvested acreage. The southeastern region (southeast Palm Beach County, together with Miami-Dade and Martin counties) produced 28.3 percent of the crop on 30.7 percent of the harvested acreage, while 17.3 percent of production came from 22.9 percent of harvested acreage in the southwestern region (Lee, Hendry, and Collier counties). Finally, the north and northwestern regions produced 12.0 percent of the crop on 12.0 percent of the harvested acreage (2).

Production Practices

There are three types of cucumbers produced in Florida. Slicing cucumbers are usually used uncooked in salads, although younger fruits may occasionally be pickled. Approximately 98 percent or more of the slicing type of cucumbers are produced for the fresh market. Fruit of pickling cultivars are generally shorter and stouter than those of slicing cultivars and are not as dark green in color. Most pickling cucumbers are sold on contract and are shipped out-of-state to pickling processors, although a significant amount of the crop may be sold on the fresh market. Pickling cultivars sold fresh are becoming more common in grocery stores, but fresh-market sales of pickling cucumbers remains a minor portion of total sales. Fresh-market sales of pickling cultivars depend in part on market price. Early spring or winter crops bring higher prices for pickling cucumbers sold on the fresh market. Some growers produce for both the fresh market and for pickling, while others produce only for pickling. The third type of cucumbers produced in Florida,

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European burpless greenhouse cucumbers, are all sold fresh, marketed as a premium product in grocery stores in Florida and the eastern states (3,6-10).

Greenhouse production of cucumbers in Florida continues from approximately September to June. High heat and humidity during the summer months in Florida make greenhouse vegetable production difficult. In north Florida, most greenhouse production is in family-run operations, using single greenhouses. In contrast, most greenhouse vegetable production in southern Florida is part of much larger operations, covering larger acreages (11).

All greenhouse cucumbers are European burpless, a seedless type that does not require pollination. Nearly all greenhouse production of cucumbers in Florida uses bag culture with perlite as the medium. The use of artificial medium greatly reduces soil-borne pest problems (12). Rockwool may also be used as an alternative medium, and it produces the same results as perlite in terms of cucumber yield (13).

Field grown cucumbers are planted in north Florida from February to April and from August to September. In central Florida, growers plant from January to March and in September. South Florida growers plant cucumbers anytime from September to April. Typical planting distances for slicing cucumbers are 48 to 60 inches (102 to 152 cm) between rows and 6 to 12 inches (15 to 30 cm) between plants. Pickling cucumbers are typically planted at 36 to 48 inches (91 to 122 cm) between rows and 2 to 4 inches (5 to 10 cm) between plants. When grown under plastic mulch, slicing cucumbers are planted in one or two rows per bed, with 10 to 18 inches (30 to 46 cm) between the rows on the bed, 48 to 72 inches (102 to 183 cm) between beds, and 8 to 12 inches (20 to 30 cm) between holes with one or two plants per hole. Pickling cucumbers are planted at a distance of 3 to 4 inches (7.6 to 10 cm) between plants. At the closest spacing, the plant population is 21,780 per acre. Seeds are set at a depth of 0.5 to 0.75 inches (1.3 to 1.9 cm). Between 35 and 65 days are required from seeding to the first picking (7,14,15).

Cucumbers can be grown on most soil types, although the crop can be produced earlier on sandy soils, which also make fruits easier to clean. Optimum

soil pH for cucumbers is 6.0 to 6.5. Germination and growth is best at soil temperatures between 70 and 80°F (21 to 27°C) and air temperatures between 70 and 85°F (21 to 29°C). Most cucumbers in Florida are produced on raised beds with plastic mulch, either as the primary crop or, more commonly, in a double-cropping system following tomato, eggplant, or bell pepper. Double-cropping involves producing a second crop by using the inputs of the first crop, thereby spreading out the costs of fumigation, fertilization, plastic mulch, and in some cases, microirrigation tubing, over two crops. Cucurbits such as cucumber are preferred as second crops following solanaceous crops such as tomato. In addition to having relatively low production costs, cucurbits have different disease problems than solanaceous crops, avoiding pathogen buildup (7,14,16-20).

When cucumber is planted as a second crop in the winter following a fall crop of tomato, pepper, or eggplant, the plastic mulch may be painted black before planting cucumbers. However, if cucumbers are planted in March or April, growers will leave the plastic mulch white. On winter cucumber grown as a second crop, some growers use herbicides to kill the first crop, leaving the debris to protect the second crop from cold and winds. When cucumbers are planted after tomatoes, about 20 percent of the growers leave the stakes and string as a trellis for the cucumber plants to climb (21). More commonly in southwest Florida, some growers planting on new plastic run a single string from short stakes approximately two to three inches above the plastic. This provides anchorage for the young plants and helps prevent twisting and stem damage in windy weather (22,23).

In Palm Beach County, a pepper and cucumber double-cropping system is common. After the pepper crop is produced, using fumigated full-bed plastic mulch with seepage irrigation, the same plastic mulch is used for the cucumber crop, provided that it is in satisfactory condition. Vacuum seeders, which cut through the plastic and place the seed in the hole mechanically, are more commonly used by large growers. In smaller operations (approximately 10 percent of total), laborers manually place seeds in holes punched through the plastic. Hand seeders are

made to wear gloves because seed is always treated. After emergence, the rows are inspected for multiple plants and for missed holes. In this case, there is one person thinning each row, and one person with gloves seeding for every two rows. In a double-cropping system, methyl bromide is applied to the first crop, but not to the second crop (17). Manatee County growers also commonly grow cucumber in a double-crop, following pepper or tomato. As a result, many of the cucumbers are produced with drip irrigation (10). In the northern regions of the state, about three-quarters of the cucumber crop is grown on open ground.

Critical periods for adequate soil moisture in cucumber include seed germination, flowering, and the fruiting period. Throughout the season, the crop requires approximately one to 1.5 inches (2.5 to 3.8 cm) of water per week, from rain or irrigation. More water is needed during the fruiting period than earlier in the season. Cucumbers in Florida are produced using several types of irrigation systems. In mulched production, drip, overhead, and seepage irrigation are used. By raising the water table, seepage irrigation restricts root growth to the bed area. Water is maintained approximately 15 to 18 inches (38 to 46 cm) below the soil surface, allowing seepage into the root zone. The plastic mulch plays an important role in maintaining moisture in the soil, which permits the banded nitrogen and potassium fertilizer to diffuse into the soil, avoiding leaching from heavy rains (7,14,17).

On cucumber grown without polyethylene mulch, up to one-half of the nitrogen and potassium fertilizer are applied at planting, with the remainder banded in split applications early in the season. On a first crop of mulched cucumber, fertilizer timing and placement depend on the type of irrigation system used. When drip irrigation is used with mulch production, between 20 and 40 percent of the nitrogen and potassium fertilizer, and 100 percent of the phosphorus and micronutrients are applied prior to planting, with additional nitrogen and potassium applied through the drip irrigation as needed. With overhead irrigation, all of the fertilizer is incorporated into the bed before the mulch is applied. Finally, with the use of seepage irrigation, all of the phosphorus and micronutrients and 10 to 15 percent of the

nitrogen and potassium are incorporated into the bed, with the remaining nitrogen and potassium banded on the bed surface before the mulch is laid down (14). In double-cropping situations, when additional nitrogen and potassium are needed, the fertilizer is applied as a liquid with fertilizer injection wheels at 30 pounds per acre per application (16).

Crop nutrient requirements for cucumbers in Florida have been determined based on studies conducted by researchers at the University of Florida, Institute of Food and Agricultural Sciences (UF/IFAS). The cucumber crop requires 90 pounds per acre of nitrogen and 120 pounds per acre each of phosphate and potassium. When needed, as after leaching rainfall, up to three supplemental applications of 30 pounds per acre of nitrogen and 20 pounds per acre of potassium are recommended (24).

During the years in which usage data have been collected, 88 to 100 percent of fresh-market cucumber acreage in Florida has received an average of 1.7 to 4.0 applications of nitrogen annually. An average range of 28 to 93 pounds of nitrogen per acre has been used at each application, with a statewide annual total ranging from 816,000 to 3,113,000 pounds. An average range of 23 to 95 pounds per acre of phosphate has been applied an average of 1.6 to 4.7 times annually to between 12 and 71 percent of the fresh-market cucumber acreage, with total annual usage ranging from 120,000 to 1,665,000 pounds. Potash has also been applied an average of 1.7 to 4.0 times per year to between 88 and 100 percent of the fresh-market cucumber acreage. An average range of 30 to 164 pounds of potash per acre have been used at each application, and a total of 979,000 to 4,376,000 pounds has been used annually (26-30).

For pickling cucumbers in Florida, 100 percent of the acreage has received an average of 2.6 to 3.3 applications of nitrogen annually, during the years in which usage data have been collected. An average range of 19 to 73 pounds of nitrogen per acre has been used at each application, with a statewide annual total ranging from 206,000 to 583,000 pounds. An average range of 15 to 93 pounds per acre of phosphate has been applied an average of 1.0 to 5.8 times annually to between 42 and 99 percent of the

processed cucumber acreage, with total annual usage ranging from 82,000 to 400,000 pounds. Potash has also been applied an average of 1.9 to 3.6 times per year to 100 percent of the processed cucumber acreage. An average range of 48 to 103 pounds of potash per acre have been used at each application, and a total of 241,000 to 930,000 pounds has been used annually (26-30).

Except for greenhouse varieties, cucumbers require insect pollination for fruit development to occur. Honeybees must be present in sufficient populations to ensure adequate pollination. Growers usually rent honeybee hives for placement in and around their fields during the flowering period. Adequate pollination is generally achieved by the placement of two strong hives for every two acres, and colonies are left in the field until about a week before the harvest is complete. Cucurbit flowers are open from just after sunrise until mid afternoon, and honeybee activity is greatest during that time. While hives are in the field, growers schedule insecticide applications for dusk or later, to avoid harming bee populations (14,15).

All cucumbers in Florida are harvested by hand several times. Pickling cucumbers must be harvested every three to four days, or they will be oversized. For slicing cucumbers, the number of pickings is largely determined by market price. Once the price falls below a certain level, continued harvesting becomes uneconomical. Cucumber crops planted in south Florida in early spring may be harvested eight to ten times, but crops planted in the late spring may only be harvested three to four times before the price drops enough to make further harvest uneconomical. The most common picking container is a plastic bucket or pail holding about one-half bushel. Harvesters generally empty the plastic pails into truck beds with conveyor floors or pallet boxes for transport to the packinghouse. Hand-harvesting of cucumbers requires approximately 150 man-hours per acre for the season (8,20). Picking is usually the first task of the day when plants are producing, taking from three to six hours of a nine-hour day. Pickers wear cotton gloves to reduce abrasion to hands and fruit.

After reaching the packinghouse, the cucumbers are washed in a dump tank and lifted from there into the packinghouse to be sorted and graded. The price of pickling cucumbers is related to the fruit size; higher prices are received for smaller cucumbers. After sorting and grading, pickling cucumbers are then placed into pallet bins for shipment to the processor. Less commonly, they are boxed. Since cucumbers are highly susceptible to dessication, those destined for the fresh market are waxed prior to packing. Waxing is done primarily to reduce water loss, but it also reduces mechanical injury on the skin. Most greenhouse cucumbers are shrink-wrapped with polyethylene film. The most common packing container for cucumbers is a bushel or 1 and 1/9 bushel (7,8).

Cucumbers in Florida are hydrocooled and shipped under refrigeration. Cucumbers can be stored for 10 to 14 days at 50 to 55°F (10 to 13°C). They are very susceptible to shriveling, and maintaining high relative humidity, waxing, or applying film wraps help to limit water loss. At temperatures below 50°F, chilling injury occurs after two days. Water-soaked spots, pitting, or tissue collapse are symptoms of chilling injury. When the temperature on chilled cucumbers is increased, substantial decay occurs. Cucumbers can be stored with eggplant, grapefruit, limes, potatoes, pumpkins, squash, and watermelons, but should not be exposed to ethylene-producing crops such as apples or tomatoes (8,32).

Pest Management

Insect pests generally do not inflict very serious damage to cucumbers in Florida, but they are a serious concern for the grower because the very low tolerance for insect damage in the crop makes strict insect control necessary, particularly for pickling cucumbers. Entire loads can be rejected for slight damage or the presence of as few as 20 pickleworm holes found (33). Diseases on Florida cucumbers are less significant than on other vegetable crops, principally because of the availability of resistant cultivars. Weeds also do not present a significant problem, because most cucumbers are grown as second crops on plastic mulch. Cucumbers are highly susceptible to nematodes, which may cause more

problems for cucumber growers in the absence of effective alternatives to methyl bromide (9,16,17,31).

Use of Methyl Bromide and Chloropicrin in Florida Cucumber Production

Methyl bromide is a broad-spectrum soil fumigant that has played a key role in the production of several Florida vegetables since its adoption as part of the full-bed plastic mulch production system several decades ago (17). As a Class I ozone depleting compound, methyl bromide is currently scheduled to be banned in the United States by the year 2005, and its present use is under restriction.

Use of methyl bromide on fresh-market cucumbers in Florida was reported in 1994, 1992, and 1990. During those years, growers applied methyl bromide one time to each crop at an average rate ranging from 173 to 188 pounds of active ingredient per acre, to between 10 and 20 percent of their fresh-market cucumber acreage. Total annual usage ranged from 258,700 to 509,800 pounds of active ingredient (28-30).

Since cucumber is often grown as a second crop following tomato, eggplant, or pepper, using full-bed plastic mulch production, much of Florida's cucumber crop has received the effects of methyl bromide applied to the first crop. Although there is no residual methyl bromide in the soil, the substantial reduction in populations of soil-borne nematodes, disease pathogens, and weeds during the first crop usually permits cucumber production to be completed before soil pest populations increase enough to become a problem. Diseases such as damping-off and Fusarium wilt are therefore likely to increase on Florida cucumbers with the impending phase-out of methyl bromide (17).

A model analyzing the impact of the loss of methyl bromide on Florida vegetable production predicts that overall, cucumber production in Florida will decline by 46 percent. All production in Palm Beach County is expected to end once methyl bromide is no longer available. Southwest Florida production of cucumbers double-cropped with tomatoes is expected to increase (17).

Chloropicrin is a preplant soil fumigant used to control soil-borne fungi, diseases and nematodes. It is also used as a warning agent for methyl bromide because of its sharp odor. The last reported use of chloropicrin on fresh-market cucumbers in Florida was in 1990, when growers applied an average of 51 pounds of active ingredient per acre one time, to 7 percent of their processed cucumber acreage. Total usage on fresh-market cucumbers in that year was 51,800 pounds of active ingredient (30).

Alternatives to Methyl Bromide

Development of non-chemical alternatives to methyl bromide is in the research stage, and efforts in Florida have been concentrated on higher use crops, particularly tomato. The alternative management practices currently under evaluation include the use of cover crops, organic amendments, biological control agents, crop rotation, hot water/steam treatment, paper, plastic, and living mulches, pest resistant crop varieties, solarization, natural product pesticides, supplemental fertilization, and fallowing. Several of these options have been cited as being impractical under Florida conditions. For example, steam/hot water treatment is costly under present technology, and flooding can only be used by growers in certain parts of the state (17,34-36).

Soil solarization is less effective on well-drained, sandy soils, and the hottest part of the year in Florida coincides with a time of heavy rainfall, resulting in water accumulation above the plastic that impedes soil heating (35,36). Nevertheless, the practice has shown some promise in certain situations. Solarization was compared to use of methyl bromide in southeast Florida (Palm Beach County) on a double-crop of bell peppers and cucumber. Clear polyethylene mulch was applied to field plots for 51 days, after which the clear mulch was sprayed with a white latex paint and peppers were transplanted. Results were promising for the first crop of bell peppers, with no difference between the solarized and methyl bromide treated plots in terms of yield, average fruit size, or disease or weed incidence. However, when a second crop of cucumbers was planted after the peppers, the effects of the solarization did not carry over as well as did the effects of methyl bromide in comparative plots.

Cucumber yields in solarized plots were lower than yields in plots treated with methyl bromide, and greater damage from root-knot nematodes was seen under the solarization treatment. For solarization to be effective on double-cropped vegetables in Florida, it would have to be combined with additional management tactics, such as the use of Telone C-17 in years following nematode buildup after solarization. Additionally, for solarization to effectively reduce pest population levels, high soil moisture is required. During the field test described above, with subsurface irrigation, the water table had to be raised higher than is normally done before transplanting (36).

Several of the proposed alternatives to methyl bromide show promise as part of a comprehensive Integrated Pest Management (IPM) program. However, the conditions under which specific combinations of tactics will be most effective must still be worked out. Furthermore, since research on alternatives to methyl bromide in Florida has been concentrated on high-use crops, applicability of any appropriate alternatives to the cucumber crop will have to be determined.

Insect/Mite Management

Insect/Mite Pests

Management of insect pests is vital in cucumber production, since shipments can be rejected if small amounts of insect damage are found, particularly from pickleworm. Most pickle contracts require complete insect control. In north Florida, fall plantings of cucumbers generally suffer greater insect attack than spring plantings, while in south Florida, insect problems are usually greater in the spring. The most troublesome insect pest on cucumbers in Florida is the pickleworm. Melonworm and silverleaf whitefly are other major insect pests. Minor arthropod pests on cucumber include melon thrips, leafminers, banded cucumber beetle, aphids, armyworms, mole crickets, and cutworms. Flea beetles, mites, stink bugs, wireworms, grasshoppers, leafhoppers, squash bug, squash vine borer, and loopers may occasionally damage cucumber but are generally not a concern for the commercial grower (6,7,16,20,37-40). In greenhouse production of

cucumbers in Florida, whiteflies are the principal insect pest. Aphids and spider mites occasionally affect the crop in the greenhouse (3). In field production, wireworms may increase in importance when methyl bromide is no longer in use (17).

Pickleworm (*Diaphania nitidalis*). Pickleworm, although well managed by Florida's cucumber growers, is one of the most important insect pests, because of the low tolerance for feeding damage on the crop. Processors of pickling cucumbers reject entire loads when very low numbers are detected. The pest is first seen in north-central Florida between April and June and can be devastating in years when it arrives early. Its abundance in the spring appears to be related to the weather during the preceding winter. It is unknown if pickleworm moves up from south Florida every year or enters central and north Florida from other areas (31).

Female moths can lay up to 300 or more eggs throughout their life, generally depositing them on foliage when the plants are young and on the underside of fruits once they have formed. After three or four days, the eggs hatch, and larvae may feed on stems, flowers, or foliage. Older larvae bore into fruits, usually entering close to the ground and feeding on the inside. Masses of green waste can be seen in the entrance holes. In addition to the direct damage inflicted, the entrance holes may also serve as points of entry for decay organisms. Therefore, as a result of pickleworm feeding, fruit rot may occur. After approximately two weeks, the insect pupates within a dried leaf or other shelter, and the moth emerges a week to ten days later. Up to five generations of pickleworm may occur per season in Florida (38,40).

While potentially a devastating pest, cucumber growers in Florida are presently able to maintain good control of pickleworm and other lepidopterous larvae. *Bacillus thuringiensis* and methomyl are the insecticides most frequently used for pickleworm control, although increasingly less methomyl is used, because of its harmful effects on beneficial insects (16).

Melonworm (*Diaphania hyalinata*). Melonworm is closely related to the pickleworm. Although it is similar in appearance to the

pickleworm at a number of life stages, the melonworm feeds to a greater extent on the foliage of the plant. Eggs are primarily laid on young leaves. Melonworm is mainly a problem in the southern part of the state and is not as damaging to cucumber as pickleworm. In addition to cucumber, preferred plants include cantaloupe, squash, and pumpkin (40).

Silverleaf Whitefly (*Bemisia argentifolii*).

Silverleaf whitefly, previously known as strain B of sweetpotato whitefly (*Bemisia tabaci*), has become a major pest of many vegetable crops in south and central Florida. Since the first outbreak on poinsettia in south-central Florida in 1986, the pest has caused extensive losses, particularly on tomato and squash. Silverleaf whitefly can be found on plants in over 500 species and 74 families, but not all can support high populations. In addition to tomato, squash and cucumber, high populations can be found on cotton, cabbage and other cole crops, melons, eggplant, okra, sesame, soybean, peanut, and many ornamental plants (41-43).

The adult usually lays eggs on the underside of young leaves, with each female laying an average of 160 eggs. Upon hatching from the egg, the first instar or crawler stage whitefly moves on the leaf and settles, where the insect remains while passing through three more immature (nymphal) stages. The young whiteflies appear like flat, oval, and nearly transparent scales. At the end of the fourth instar, the insect enters the pupal stage, just before the adult stage. Pupae have a deeper yellow color and distinct red eye spots. The whitefly molts at the end of each stage, leaving behind cast skins, which are a sign of whitefly presence. Under very warm conditions, the whitefly may develop from egg to adult in as few as two weeks. Larger nymphs are often found on older leaves, while adults are more commonly found on younger leaves, where they lay their eggs. In severe infestations, adults congregating on the underside of host plant leaves rise up in white clouds when disturbed (43,44).

Whiteflies damage cucumber plants by removing plant sap with their needle-like, piercing-sucking mouthparts, depleting the plant of needed nutrients and resulting in poor growth. Yellowing and loss of foliage may result, and plant death may occur under

severe infestations. In cucumber, plant growth is completely stunted by an average whitefly population density of 30 nymphs per square inch of leaf. In addition, as a result of feeding, whiteflies excrete a sugary solution known as honeydew. Honeydew on leaf surfaces contributes to the growth of sooty mold, a black fungus that can cover the leaves and inhibit photosynthesis (42-44).

Whitefly populations commonly peak on the state's crops at the time of harvest, as the whitefly migrates from crop to crop throughout the year. Fall and winter crops in Florida tend to generate high populations of whiteflies. In south Florida, whiteflies can move to spring crops from fall vegetables, particularly tomato, where they build up high populations. In south-central Florida, winter cabbage serves as a source of spring populations of silverleaf whitefly. Weeds serve only as intermediate hosts, supporting low populations of whiteflies during fallow periods. They may also harbor natural enemies that reduce populations further (41,43,44).

Thrips [tobacco thrips (*Frankliniella fusca*) and melon thrips (*Thrips palmi*)]. Thrips are occasionally a major pest on cucumbers in Florida, particularly in south Florida. Tobacco thrips are rarely found in south Florida but are more of a problem in central and north Florida. Melon thrips are found only in south Florida, where it is a relatively new pest, having been first reported in early 1991 in the Homestead area (Miami-Dade County). Since then, it has caused large economic losses in several vegetable crops in south Florida, particularly in cucumber, snap beans, peppers, eggplant, winter melon, and squash. In addition to those crops, melon thrips feeds on cantaloupe, watermelon, potato, tobacco, soybean, broad bean, cowpea, sweet potato, spinach, and amaranth. A number of weeds are also attacked (45-47).

Both adult and immature thrips feed in groups, removing sap with their rasping-sucking mouthparts. They rasp the surface of the plant tissue and suck up the sap. Their feeding can leave scars and deformities and can eventually kill the plant. Under heavy infestations, silvery scars are present and leaves have a bronzed appearance. On cucumber plants, adult thrips are usually found on mature leaves, flowers,

and young fruits. Several species of thrips may be present at any time. Some species do not damage cucumber but help to keep out melon thrips, which is one of the most damaging species. Identification of the thrips species present is important, and many cucumber growers in Florida rely on scouts for the identification of thrips. The mean generation time of melon thrips on cucumber leaves has been determined to be 54 days at 15°C, 25 days at 26°C, and 17 days at 32°C. Populations are generally higher in the winter and spring and lower in the summer in Florida. Use of broad-spectrum insecticides may increase thrips populations by killing off natural enemies (16,38,45,47,48).

Leafminers [vegetable leafminer (*Liriomyza sativae*) and American serpentine leafminer (*Liriomyza trifolii*)]. Leafminers are another minor pest of cucumber in Florida. Although present throughout the growing season, they are more of a problem during the warmer periods of early fall and late spring and are generally more of a problem on young plants. They also commonly attack other cucurbits, bean, pea, celery, carrot, crucifers, okra, potato, and tomato (16,48).

The adult female, an agromyzid fly, punctures the upper leaf surface to feed on sap and lay eggs in the puncture holes. In addition to directly damaging the plants by feeding, leafminers leave them more susceptible to disease, since the punctures in the leaf surface provide access for the entrance of disease pathogens. The larvae (maggots) feed on the tissue between the upper and lower leaf surfaces. Each larva creates a winding tunnel that becomes larger as the maggot grows. When larval development is complete, after about two weeks, the maggot cuts through the leaf surface to exit the tunnel, dropping to the soil to pupate. Where cucumber is grown on plastic mulched beds, leafminer pupae can be seen on the surface of the plastic (48).

Leafminer populations can increase rapidly in Florida, where the life cycle can be as short as 18 to 21 days. Chemical control of leafminers is difficult, because the larvae are protected in their tunnels. Leafminers have developed resistance to many insecticides used against them. In addition, the use of broad-spectrum materials has in some cases wiped out

the beneficial insects that play an important role in natural management of leafminer populations (38,48).

Cucumber Beetles [banded cucumber beetle (*Diabrotica balteata*), striped cucumber beetle (*Acalymma vittatum*), and spotted cucumber beetle (*D. undecimpunctata howardi*)]. Cucumber beetles, mainly banded and occasionally spotted and striped, are minor pests on cucumbers in Florida. Banded cucumber beetle is more common in south Florida, while spotted cucumber beetle is more common in the northern regions of the state. Striped cucumber beetle is seen only occasionally, primarily in western and northern Florida. Cucumber beetles feed on foliage and flowers, and the larvae may feed on roots, tunneling into them (40,49).

Banded cucumber beetle prefers beans and soybeans, but in addition to cucumbers also damages squash, beets, peas, sweet potatoes, okra, corn, lettuce, onion, and cabbage, among other vegetables, as well as many weeds. Many generations may occur each year, and the life cycle may be completed in 45 days under appropriate conditions. Adult females each lay up to 850 eggs, in two to 15 masses, each containing up to 100 eggs. Eggs are deposited in soil cracks. After hatching five to nine days later, larvae emerge and feed exclusively on plant roots, passing through three instars (stages) in 11 to 17 days. After a four to six day period of pupation in the soil, the adult emerges and feeds on above-ground plant parts (49).

Aphids (Family *Aphididae*). Several species of aphids colonize cucumber, including melon aphid (*Aphis gossypii*), spirea aphid (*Aphis spiraeicola*), cowpea aphid (*Aphis fabae*), green peach aphid (*Myzus persicae*), and potato aphid (*Macrosiphum euphorbiae*). Melon aphid is one of the most common on cucumber, but is not as serious a problem as in melon crops (50,51). In addition to being a major pest of cucurbits and cotton, melon aphid feeds on a wide range of plants, including eggplant, peppers, potatoes, citrus, okra, ornamentals, and many weeds (33).

Aphids feed by inserting their piercing-sucking mouthparts (stylets) into plant tissue, withdrawing the sap. Younger leaves and vine tips are most commonly attacked. During feeding, aphids may

inject toxins into the plant, resulting in leaves being curled or crumpled. To receive sufficient nutrients, aphids must take in large amounts of sap, and they excrete the excess water and sugars as honeydew, which favors sooty mold development. Aphid populations can increase rapidly, particularly at warmer temperatures, with most rapid development at 78 to 80°F (25.6 to 26.7°C). In Florida, only females are produced, and they give birth to live young instead of laying eggs. Within a week to ten days, the next generation is able to reproduce. Although colonizing aphids have wings, populations increase by producing wingless aphids (33,48).

In addition to direct feeding, some aphids cause damage to cucumber plants by transmitting potyviruses that affect cucumbers in Florida, especially the watermelon strain of papaya ringspot virus (PRSV-W) and watermelon mosaic virus 2 (WMV-2). Aphids transmit these viruses in a stylet-borne, nonpersistent manner, meaning that once an aphid picks up virus particles on its mouthparts (stylet) from an infected plant, the virus particles remain on the stylet. For a short period of time, these particles can be transferred to a healthy plant. These viruses can be transmitted by aphids that do not feed on the plant but only land on it momentarily to probe, or test the plant's suitability as a food source. Therefore, aphid vectors that do not feed on cucumber may move from plant to plant within a field, probing each one and spreading the virus. Aphids that do feed and reproduce on cucumber may also move from one plant to another within the field under crowded conditions, when winged individuals are produced. Due to the ability of aphids to spread a virus within seconds, insecticides are not able to prevent non-colonizing aphids from spreading the viruses, and may actually cause them to move more often within the field. Virus spread can be delayed by application every four to five days of mineral oil (stylet oil), which interferes with virus transmission (48,52).

Granulate Cutworm (*Feltia subterranea*). Cutworms, the most common of which on cucumber in Florida is the granulate cutworm, are stout caterpillars with a dark, greasy appearance. They are a problem during the seedling stage and can cut seedlings off at the base of the stem. They may also

feed on plant foliage. Cutworms are active at night, hiding during the day in the soil near the plant base. Cutworms are often controlled by baits, which are applied in the late afternoon (38).

Armyworms [Southern armyworm (*Spodoptera eridania*), beet armyworm (*Spodoptera exigua*), and fall armyworm (*Spodoptera frugiperda*)]. Armyworms are caterpillars that feed on a wide range of plants. Some (fall armyworms) can be recognized by the inverted "Y" on the front of their head. Armyworms mainly attack foliage and can cause extensive damage. On cucumbers, they are a minor and occasional pest. Beet armyworm is the most difficult of the armyworms to control (31).

Armyworms feed during the day in protected parts of the plant. Most spend two to three weeks in the larval stage, consuming greater amounts of plant material as they grow. When mature, they pupate in the soil, and after one to two weeks, they emerge as adults. The life cycle of armyworms averages 28 to 30 days and ranges from 24 to 36 days, depending on the species and the temperature. Many generations may occur each year in Florida, and populations usually peak from June to September (31,53).

Mole Crickets (*Scapteriscus spp*). Mole crickets are a minor pest on cucumbers in Florida, principally affecting seedlings. The main damage to cucumber plants from mole crickets is from the tunnels made around the root system. Some feeding on roots may occur as well. In several vegetable crops, mole crickets have been observed to feed directly on above-ground plant parts or girdle the stems at the base. Mole crickets are active at night and are rarely seen during the day. They are typically controlled with preplant baits applied late in the afternoon. Mole cricket baits are most effective when soils are moist and evening temperatures are warm (31,54).

Mole crickets overseason as adults or older nymphs, often a foot or more below the soil surface. Adults deposit their eggs in chambers they make in the soil, usually four to twelve inches below the surface. Nymphs hatch after about three weeks, and they feed for many weeks before reaching the adult stage. Although mole crickets may attack many vegetable crops, they prefer pasture and grass, where

they are generally found in large numbers in Florida (54,55).

Chemical Control

In 2000, Florida growers applied insecticides totaling 15,500 pounds of active ingredient to 97 percent of the state's fresh-market cucumber acreage. During the years in which usage data have been collected, between 94 and 97 percent of fresh-market cucumber acreage has been treated with insecticides each year, with total annual usage ranging from 9,800 to 66,100 pounds of active ingredient. On processed cucumbers, Florida growers applied insecticides to 100 percent of their acreage in 2000 (historic range of 98 to 100 percent), with total usage of 16,400 pounds of active ingredient (historic range of 16,400 to 40,600 pounds) (25-30).

The most commonly applied insecticides on Florida fresh-market cucumbers are *Bacillus thuringiensis*, methomyl (Lannate®), and endosulfan. Although use numbers were not reported in 2000, growers in Florida employed abamectin (Agri-Mek®), carbaryl, diazinon, dimethoate, esfenvalerate (Asana®), imidacloprid (Admire®/Provado®), malathion, neem oil (azadirachtin), soaps, Oxamyl (Vydate®), permethrin, petroleum oil, and spinosad (Spintor®). On processed cucumbers in Florida, use of methomyl is reported most frequently, with occasional reports of use of *Bacillus thuringiensis*, cyromazine (Trigard®), diazinon, imidacloprid, malathion, and spinosad. Other insecticides and miticides registered for use on cucumbers in Florida in 2002 include azinphos-methyl, buprofezin (Applaud®), cryolite, dicofol (Kelthane®), ethoprop (Mocap®), kaolin (Surround®), pymetrozine (Fulfill®), thiamethoxam (Platinum®/ Actara®), bifenthrin (Capture®), fenpropathrin (Danitol®), oxydemeton-methyl (Metasystox-R®), *Beauveria bassiana*, polyhedrosis virus for corn earworm/beet armyworm (Gemstar®/Spod-X®), pyrethrins, pyrethrins + rotenone (Pyrellin®), and sulfur. The beet armyworm pheromone Isomate® was registered for use in cucumber, but it was not available in Florida in 2002.

Bacillus Thuringiensis. The biological insecticide *Bacillus thuringiensis* (*B.t.*) is one of the most important insecticides for Florida cucumber growers, who use it every year, primarily in the management of pickleworm and melonworm. It can also be used for armyworms, cutworms, and loopers (56,57). *B.t.* is a naturally occurring soil bacterium that produces spores and crystalline bodies acting as a stomach poison to the insects that consume it. It is highly specific for lepidopterous larvae (caterpillars) and therefore does not harm beneficial organisms. It is most effective against smaller larvae. The median price of *B.t.* is \$160.00 per pound of active ingredient (58). *B.t.* may be applied up to the day of harvest (PHI=0 days), and the restricted entry interval (REI) under the Worker Protection Standard is 4 hours (56).

In 2000, Florida growers applied *B.t.* to 48 percent of their fresh-market cucumber acreage, an average of 4.7 times. During the years in which usage data have been collected, growers in Florida have applied *B.t.* to between 15 and 82 percent of their fresh-market cucumber acreage, each making an average of 3.9 to 9.1 applications per year. On processed cucumbers in Florida, last reported use was in 1990, when growers applied *B.t.* to 41 percent of their processed cucumber acreage, making an average of 2.7 applications (25-30).

Methomyl (Lannate®). Florida cucumber growers also rely annually on methomyl, a broad-spectrum, carbamate insecticide and acaricide. They use it primarily in the management of pickleworm, melonworm, and cucumber beetle, although it can also be used for aphids, armyworms, cutworms, flea beetles, loopers, and tobacco budworms (56). The median price of methomyl is \$25.12 per pound of active ingredient, and the cost per maximum labeled application (0.9 lb ai/A) in 2001 was \$22.61 per acre (58,59). Methomyl may be applied up to 1 day before harvest (PHI=1 day) when 0.75 to 1.5 pints per acre are used, or up to 3 days before harvest (PHI=3 days) when over 1.5 pints per acre are used. The restricted entry interval (REI) under the Worker Protection Standard is 48 hours. No more than 12 applications may be made to the crop and the material limit is 5.4 lb ai/acre/crop (59).

In 2000, Florida growers applied an average of 1.03 pounds of active ingredient of methomyl per application to 16 percent of their fresh-market cucumber acreage, an average of 3.9 times. Total usage was 6,500 pounds of active ingredient. During the years in which usage data have been collected, growers of fresh-market cucumbers in Florida have applied methomyl at an average rate ranging from 0.40 to 1.03 pounds of active ingredient per acre at each application, to between 9 and 79 percent of their fresh-market cucumber acreage. Growers have made an average number of applications ranging from 3.2 to 6.3 each year, totaling between 200 and 26,800 pounds of active ingredient annually (25-30).

In 2000, Florida growers applied an average of 0.45 pounds of active ingredient of methomyl per application to 100 percent of their processed cucumber acreage, an average of 3.0 times. Total usage was 8,900 pounds of active ingredient. During the years in which usage data have been collected, growers of processed cucumbers in Florida have applied methomyl at an average rate ranging from 0.42 to 0.65 pounds of active ingredient per acre at each application, to between 63 and 100 percent of their processed cucumber acreage. Growers have made an average number of applications ranging from 2.5 to 5.1 each year, totaling between 2,400 and 8,900 pounds of active ingredient annually (25-30).

Endosulfan. Endosulfan, a cyclodiene chlorinated hydrocarbon insecticide and acaricide, is the third primary insecticide used by Florida cucumber growers each year. They apply it mainly in the management of pickleworm, melonworm, cucumber beetle, and silverleaf whitefly. It can also be used for aphids, cabbage loopers, flea beetles, leafrollers, squash beetles, squash bugs, and squash vine borers (56). The median price of endosulfan is \$15.02 per pound of active ingredient, and the approximate cost per maximum labeled application (1.0 lb ai/A) in 2001 was \$15.02 per acre (55,60). Endosulfan may be applied up to 2 days before harvest (PHI=2 days), and the restricted entry interval (REI) under the Worker Protection Standard is 24 hours. No more than six applications and 3.0 pounds of active ingredient per acre per year may be utilized (60).

In 2000, Florida growers applied an average of 0.51 pounds of active ingredient of endosulfan per application to 39 percent of their fresh-market cucumber acreage, an average of 1.1 times. Total usage was 2,200 pounds of active ingredient. During the years in which usage data have been collected, growers of fresh-market cucumber in Florida have applied endosulfan at an average rate ranging from 0.51 to 0.84 pounds of active ingredient per acre at each application, to between 5 and 39 percent of their fresh-market cucumber acreage. Growers have made an average number of applications ranging from 1.1 to 2.8 each year, totaling between 1,000 and 6,900 pounds of active ingredient annually (25-30).

On processed cucumbers in Florida, last reported use was in 1990, when growers applied an average of 1.93 pounds of active ingredient of endosulfan per acre at each application, an average of 2.0 times, to 29 percent of their processed cucumber acreage. Total usage on processed cucumbers in that year was 2,800 pounds of active ingredient (30).

Chemical Alternatives

A number of new insecticides have been introduced for cucumber. Due to cost and selectivity, grower acceptance is slow. However, the materials are gradually being incorporated into IPM programs that target key pests.

Cultural Control

A crop-free period is recommended for the management of silverleaf whitefly. In south Florida, the continuous cropping of diverse vegetables makes winter separation of fall and spring crops unfeasible. Destruction of crop residues during summer fallow is more practical. Consequently, after initial outbreaks of the whitefly, once growers in south-west Florida instituted a crop-free period during the summer, including the removal of crop residues, whitefly populations have been reduced on fall vegetable crops (44). Additional cultural controls for whiteflies include the use of reflective mulches, adjustment of planting dates, and field selection to avoid proximity to crops with high infestations (33).

Cucumber growers in Florida commonly kill the pests from a first crop of tomato or eggplant and wait

as long as possible before planting cucumbers. Some are able to do that to a greater extent than others. Growers also control weeds, which helps to cut down on insect problems. Finally, crop rotation is practiced by most cucumber growers in Florida. Within any given year, cucumbers are rotated with fruiting vegetables such as tomato, pepper, and eggplant (16).

Early planting of spring cucumber crops aids in avoiding buildup of melonworm and pickleworm populations, since their numbers increase throughout the season. In the past, trap crops of crookneck squash have been used to reduce damage from pickleworm and melonworm. Squash is highly preferable to the moths, who will lay their eggs on the squash plants instead of on cucumber. Planting four to eight rows of squash per acre of cucumber is recommended, with several successive plantings to provide a continuous supply of squash fruit to the moths. The pests must be destroyed on the trap crop before they become fully grown or their food supply is depleted and they move onto the cucumber plants (39).

Biological Control

In the absence of broad-spectrum insecticide use, whitefly populations are naturally managed by numerous predators, parasites, and pathogens (43). Common predators include green lacewing larvae and ladybird beetles, such as *Nephaspis oculatus*, introduced from Central America and found preying on several species of whiteflies in Florida (61). *Delphastus* spp. beetles have been studied in Florida for their ability to manage whiteflies, and they are now available from insectaries, mainly for greenhouse release (62).

Whiteflies are also killed by parasitic wasps such as *Encarsia* spp. and *Eretmocerus* spp. In Florida, *Encarsia pergandiella* was found to be the most abundant parasitoid reared from silverleaf whiteflies collected on field crops and wild host plants over a two year period in central and southern Florida (63). *Eretmocerus* wasps are available commercially, and some greenhouse growers have begun to use them (62). Florida's Biological Control Quarantine Laboratory, Division of Plant Industry has studied the potential of introduced parasites to manage

whitefly populations. Between 1990 and 1994, fifteen parasites of the silverleaf whitefly were imported, with subsequent field releases of seven, including releases of *Amitus bennetti*, three species of *Eretmocerus*, and two species of *Encarsia*. Most were recovered several weeks after their release, having suppressed silverleaf whitefly populations in various areas throughout the state. Some parasites were observed several months after their release, but permanent establishment was not confirmed. Biological control specialists at the Division of Plant Industry have continued to study additional parasites as potential biological controls for silverleaf whitefly in Florida (64).

Insect pathogens for management of silverleaf whitefly are currently being studied under field and greenhouse conditions. Silverleaf whitefly is attacked by several disease-causing fungi, such as *Beauveria*, *Paecilomyces* and *Verticillium*, which can be applied in spray treatments. A commercial formulation of *Beauveria bassiana* is available for greenhouse and field use. In greenhouse tests, the fungus *Paecilomyces fumosoroseus*, a native strain of which was found to be highly effective in managing whiteflies and other pests, killed more than 70 percent of whitefly nymphs on several host plants, including cucumber. A commercial formulation of this fungus is currently sold in Europe for use in greenhouse production, and EPA registration is pending. Research is under way in several states to determine with which fungicides and beneficial insects the whitefly-attacking fungi may be compatible (33,42,62,65,66).

Beneficial organisms also naturally control some of the other pests of cucumber in Florida. For example, the protozoan *Microsporidium* sp. has been found infecting granulate cutworm, and many parasitic wasps and tachinid flies attack beet armyworm. Natural enemies such as pirate bugs (*Orius* spp.) also play an important role in the management of melon thrips populations (33). Two strains of the parasitic wasp *Ceranisus menes* were introduced into Florida from Japan and Thailand to study their potential as biological control agents of melon thrips. Temperature was determined not to be a limiting factor for field establishment of the wasps in south Florida. While the wasp is considered a good

candidate for biological control, the project is still in the research stage (67). The pathogens *B. bassiana* (strain BbH and BbHa) and *P. fumosoroseus* (strain 97) have also been evaluated as biological control agents of melon thrips in greenhouse tests. *B. bassiana* BbHa contributed to highest mortality of thrips and showed greatest potential under appropriate conditions. The pupal stage, which is found in the soil, is most susceptible to fungal infection, because of the high relative humidity needed for fungal germination (68).

Disease Management

Disease Pests

There are many diseases that can affect cucumbers grown in Florida, and disease problems can sometimes be serious. However, diseases on cucumbers in Florida are generally well managed with resistant varieties and a combination of other tactics. Diseases tend to affect fall cucumber crops in the state to a greater extent than spring plantings. Common diseases affecting cucumbers in Florida include target spot (caused by *Corynespora cassiicola*), downy mildew (caused by *Pseudoperonospora cubensis*), powdery mildew (caused by *Sphaerotheca fuliginea* and *Erysiphe cichoracearum*), gummy stem blight (caused by *Mycosphaerella citrullina*), Phytophthora blight (caused by *Phytophthora capsici*), watermelon mosaic viruses, belly rot (caused by *Rhizoctonia solani*), angular leaf spot (caused by *Pseudomonas syringae* pv *lachrymans*), anthracnose (caused by *Colletotrichum lagenarium/ Glomerella cingulata*), and cottony leak (caused by *Pythium aphanidermatum*). Diseases that present a problem less commonly on cucumbers in the state include damping-off (caused by *Pythium* spp. and *Rhizoctonia* spp.), fusarium wilt (caused by *Fusarium oxysporum* f.sp. *cucumerinum*), scab (caused by *Cladosporium cucumerinum*), Alternaria leaf blight (caused by *Alternaria cucumerina*), Cercospora leaf spot (caused by *Cercospora* sp.), and wet rot or blossom blight (caused by *Choanephora cucurbitarum*) (6,7,9,16,20,31,69-72).

In greenhouse production, soil-borne pests are less of a problem than in the field, since plants are

grown in an artificial medium. Gummy stem blight commonly affects cucumbers in greenhouse production to a greater extent than in field production. Additionally, Botrytis blight (caused by *Botrytis cinerea*) can be a problem in greenhouse cucumber production, as can Pythium root rot (caused by *Pythium aphanidermatum*), damping-off, sclerotinia stem rot (caused by *Sclerotinia sclerotiorum*), cucumber mosaic virus, and downy mildew (3,12).

Target Spot (caused by *Corynespora cassiicola*). Target spot is the most important disease for cucumber growers in Florida. It is potentially a problem every year, and it can seriously damage the cucumber crop. No resistant cultivars, biological, or cultural controls are available, making it difficult for growers to manage. The disease affects approximately 20 percent of the cucumber acreage in Florida and probably causes up to 10 percent yield loss. It is most prevalent from about the middle of November to the middle of March, being more common when the weather is cooler (69).

Target spot was first reported in Florida in 1967, on cucumber in the Immokalee area. Symptoms can appear similar to those of downy mildew or angular leafspot. The disease is first apparent on cucumber leaves as small, yellow flecks, which later become angular and tan to light brown in color, surrounded by darker brown edges. Concentric rings may sometimes be observed in the lesions, from which the disease derives its name. As the lesions grow, they merge and form large areas of dry, dead tissue (70,73).

The disease is most severe when the temperature is approximately 28°C (82°F). The fungus, which can survive up to two years in crop debris, is spread through the field by air-borne spores that are released mainly in the midmorning. It survives well in part because of its wide host range (73).

Downy Mildew (caused by *Pseudoperonospora cubensis*). Downy mildew occurs on cucumbers every year throughout Florida, but it does not seriously affect production, due to the availability of resistant varieties. In south Florida, it is more severe on cucumbers planted in the fall and spring than on those planted in the winter, and it may affect fall and spring planted cucumber as early as the first true leaf stage. In north Florida, spring

epidemics are often delayed until flowering, due to the cooler nighttime temperatures (74).

Downy mildew is a foliar disease that can reduce yield and quality of fruit and can kill susceptible plants if infected early. Initial symptoms include yellow spots on the upper leaf surface, accompanied by a whitish-gray to light blue growth on the lower leaf surface of each lesion under moist conditions. This downy growth is the principal site of spore production. Affected leaves usually turn from yellow to brown and die. (31,70,74).

Once it appears on the crop, downy mildew can spread rapidly. Spores are readily dispersed by wind, mainly from late morning to midday. Within four to seven days of a spore landing on a leaf, germinating, and penetrating the leaf tissue, new lesions appear. Wet weather, heavy dews, and fog favor disease development. Optimum conditions for disease development include nighttime temperatures between 55 and 75°F (12.8 to 23.9°C) and relative humidity above 90 percent (31,70,74).

Powdery Mildew (caused by *Sphaerotheca fuliginea* and *Erysiphe cichoracearum*). Powdery mildew is also commonly seen on cucumbers, but it is a minor problem for Florida growers, because cultivars with good resistance are available (68). In addition to cucumbers, powdery mildew caused by several species of fungus attacks beans, southern pea, okra, squash, muskmelon, honeydew, pumpkin, strawberry, and watermelon in Florida. The disease affects both leaves and stems, and symptoms are found primarily on older tissue. Severe infestations can cause leaves to become first yellow, and then brown and dry. Yields are reduced as a result of foliage loss (70,75).

Early symptoms of powdery mildew are small, round, white spots on the lower surface of leaves and sometimes on stems. As the spots enlarge and merge, they can be seen on the upper leaf surface as a white, powdery growth, comprised principally of spores. The spores are carried on the wind to nearby plants. The fungus is capable of reproducing under relatively dry conditions, but increased humidity heightens the severity of the disease. While downy mildew requires moist conditions for disease development, powdery

mildew can become severe when rainfall is low during the winter and spring months in Florida (70,75).

Gummy Stem Blight (caused by *Mycosphaerella citrullina*). Gummy stem blight frequently infects cucumbers in Florida (76). In greenhouse production of cucumbers, it poses a greater problem than in outdoor production (3). The disease also affects cantaloupe, chayote, pumpkin, squash, watermelon, gourds, balsam pear, and opuntia, among others. Gummy stem blight can survive on crop and weed hosts, and it can be seed-borne (70,76).

Gummy stem blight symptoms can occur at any plant stage and on any above-ground plant part. Symptoms usually appear first at the crown, with brown lesions that eventually become white. On leaves, lesions are round or irregular in shape and brownish in color. The fungus that causes gummy stem blight can survive in host plant debris. It produces two types of spores, with the sexually produced spore (ascospore) capable of moving long distances on the wind and therefore usually serving as primary inoculum. Sources of primary inoculum include infested seed, debris from previous cucurbit crops, and weed hosts such as wild citron, balsam pear, or volunteer cucurbits. The asexually produced spores (pycnidiospores) play an important role in secondary spread, moving primarily in splashing water. Moisture is necessary for spores to germinate, and the optimum temperature for infection is 61 to 75°F (16 to 24°C). Under optimal temperature conditions, symptoms can appear on host tissue within seven to 12 days of germination and penetration by the fungus. The fungus is not able to grow at temperatures below 45°F (7°C) (31,70,76).

Phytophthora Blight (caused by *Phytophthora capsici*). Phytophthora blight appears to be linked to periods of high rainfall, such as El Niño years. Although sporadic, it can be devastating, striking rapidly and causing substantial losses (72). It is closely correlated with excessive rainfall and flooded field conditions (77). *P. capsici* has a wide host range, including eggplant, pepper, tomato, summer squash, watermelon, cantaloupe, chayote, pumpkin, marigold, papaya, and macadamia, as well as many others (78).

Phytophthora blight can affect roots, foliage, and fruits of host plants. On cucumber, it produces angular, water-soaked lesions and a rapidly developing fruit rot that becomes covered with a white fungal mat (78). In 1998, the disease was widespread and severe on several vegetable crops in Florida. In Manatee County, 41 percent of cucumber plants in some surveyed fields were found to have the disease (77).

The fungus produces thick-walled spores (oospores), through which it survives on seed or in the soil on debris of host plants for up to one year. It is able to spread from plant to plant through the production of another type of spore (zoospores) which move in water or wind. For the zoospores to infect new host tissue, adequate surface moisture is required. Disease development is therefore most rapid during warm weather (75 to 90°F or 24 to 32°C) and in low, waterlogged areas of the field or during excessive rainfall. During the 1998 epidemic, disease development continued rapidly even after rainfall had ceased, suggesting that moisture on leaf surfaces from dew and fog is sufficient for spread of spores. When ideal conditions are present, symptoms of Phytophthora blight may be observed within three to four days after infection (78,79).

Mosaic Viruses (Papaya ringspot virus - type W, watermelon mosaic virus 2, cucumber mosaic virus, and zucchini yellow mosaic virus). Viruses are less of a problem on cucumber in Florida than on watermelon and squash. Cucumber mosaic virus and zucchini yellow mosaic virus are considered minor diseases on cucumber in the state. Virus infection results in mosaic, distortion, and stunting of leaves and possibly mottling and deformation of fruits. The viruses that affect cucumber in Florida are transmitted by aphids, which can acquire them from a number of crop and weed hosts. For example, cantaloupe, squash, watermelon, balsam pear (*Momordica* sp.), bur cucumber (*Sicyos* sp.), citron (*Citrullus vulgaris* var. *citroides*), creeping cucumber (*Melothria* sp.), plantain (*Plantago* major), Sesbania sp., showy croton (*Crotalaria spectabilis*), sweet clover (*Melilotus indicus*), and alyceclover (*Alysicarpus* sp.) may each serve as a host to at least one of the viruses that affect cucumbers in the state. However, papaya ringspot virus - type W and zucchini yellow mosaic

virus are much more restricted in their host ranges than watermelon mosaic virus 2 and cucumber mosaic virus (16,31,33,70).

Belly Rot (caused by *Rhizoctonia solani*). Belly rot is caused by a soil-borne fungus that affects the underside of fruits. Initial symptoms include a yellowish-brown discoloration on fruits, which later develops into a sunken lesion on the underside, accompanied by large areas of water-soaked decay. Development of the disease is favored by high humidity and temperatures above 82°F (28°C). Under those conditions, fruit lesions can develop a light brown mold growth (31,70). The widespread use of plastic mulch has been instrumental in reducing losses from this disease (69).

Angular Leaf Spot (caused by *Pseudomonas syringae* pv. *lachrymans*). Angular leaf spot occurs occasionally on cucumber in Florida, appearing approximately once every four years. It affects leaves, stems, and fruits. The disease is more severe when the winter and spring months are very wet. Although sporadic, it is difficult to control when it does appear (69,70).

Initial symptoms of angular leaf spot include angular, water-soaked lesions on leaves. The lesions become dry, and the dead tissue in the center may fall out, leaving angular holes in the leaves. On fruits, the tissue beneath the small, circular lesions turns brown. The internal discoloration reaches to the seed layer and may be found in the whole length of the fruit. Older lesions on fruit turn white, and the tissue cracks. The bacterium that causes angular leaf spot can survive in crop debris (31,70).

Anthracnose (caused by *Colletotrichum lagenarium*/*Glomerella cingulata*). Anthracnose is a fungal disease that produces small, water-soaked spots on leaves and sunken, water-soaked spots on fruits. Lesions on both leaves and fruits darken over time, and the dead tissue in leaf lesions may fall out. Fruit lesions turn from dark green to brown, and the center may appear pink under wet conditions due to spore production. Elongate, brown to black lesions may also appear on stems. Temperatures between 70 and 80°F (21 to 27°C) and high moisture favor rapid development of the disease. The fungus, which also attacks cantaloupe, watermelon, bottle-gourd (*Lagenaria* sp.), balsam pear (*Momordica* sp.),

chayote (*Sechium* sp.), and mock cucumber (*Echinocystis* sp.), can survive on weed hosts and in crop debris (31,70).

Cottony Leak (caused by *Pythium aphanidermatum*). Cottony leak was a major problem on Florida cucumber in the past. Its incidence has declined with the increased use of plastic mulch, which provides a physical barrier between the soil and the fruit (68). The causal fungus primarily produces a fruit rot, but in very wet conditions can also cause seedling damping-off or vine canker. It enters the fruit from the soil or in old flowers and produces dark green, water-soaked lesions. As a result, the tissue of the fruit rapidly becomes soft. Under wet conditions, the fruit may be entirely covered with a white, cottony mass of mycelium (the body of the fungus). Cottony leak may also develop as a post-harvest disease while cucumbers are in transit, in which case it can spread easily from fruit to fruit (70).

Pythium Root Rot (caused by *Pythium* spp.). The same and similar fungi that cause cottony leak on field grown cucumbers also causes *Pythium* root rot on greenhouse grown cucumbers. The fungus is spread in water. *Pythium* root rot results in a decay of the root system with discolored areas and progressive wilt symptoms, as well as overall reduced vigor of the plant. The disease can kill young plants within two weeks (12).

Botrytis Blight (caused by *Botrytis cinerea*). Botrytis blight, or gray mold, primarily affects cucumbers in greenhouse production. The disease affects all above-ground plant parts, causing withering of leaves and young fruit. Old diseased tissue develops a gray or brownish covering of fungal body and spores. Disease development is most rapid during cool, moist conditions, and optimum growth of the fungus occurs at 68 to 72°F (20 to 22°C), declining sharply above 77°F (25°C). Spores can be spread throughout the greenhouse by condensation splash or wind currents (12,80).

Chemical Control

In 2000, Florida growers applied fungicides totaling 66,000 pounds of active ingredient to 95 percent of the state's fresh-market cucumber acreage.

During the years in which usage data have been collected, between 89 and 98 percent of fresh-market cucumber acreage has been treated with fungicides each year, with total annual usage ranging from 53,400 to 170,600 pounds of active ingredient. On processed cucumbers, Florida growers applied fungicides to 100 percent of their acreage in 2000 (historic range of 74 to 100 percent), with total usage of 24,200 pounds of active ingredient (historic range of (9,200 to 45,500 pounds) (25-30).

The most commonly applied fungicides on Florida fresh-market cucumbers are chlorothalonil, copper hydroxide, mancozeb, and maneb. Although use numbers were not reported in 2000, growers in Florida employed azoxystrobin (Abound®), mefenoxam (Ridomil Gold®), thiophanate-methyl (Topsin®), and sulfur. On processed cucumbers, use of chlorothalonil, copper hydroxide, mancozeb, and mefenoxam was reported in 2000, but exact usage figures were not published. Other fungicides registered for use on cucumber in Florida in 2002 include other forms of copper, fosetyl-Al (Aliette®), triadimefon (Bayleton®), trifloxystrobin (Flint®), carbonic acid (Armicarb®), zoxamide + mancozeb (Gavel®), and the biological organisms *Streptomyces griseoviridis* (Mycostop®) *Gliocladium virens*, and *Trichoderma harzianum* (T-22). Fludioxonil (Maxim®), captan, and thiram are registered for cucumber seed treatment, and sodium phenylphenate (Freshgard®) and peroxyacetic acid (Victory®), are registered for post-harvest fungus control. Triflumizole, myclobutanil, *Bacillus subtilis*, *Gliocladium catenulatum*, and *Pseudomonas chlororaphis* were registered for use in cucumber, but no products that contained these ingredients were available in Florida in 2002.

Chlorothalonil. The broad-spectrum chloronitrile fungicide chlorothalonil is the fungicide most frequently used by Florida cucumber growers, who utilize it in the management of anthracnose, belly rot, downy mildew, gummy stem blight, powdery mildew, scab, and target spot (70). The median price of chlorothalonil is \$10.32 per pound of active ingredient, and the approximate cost per maximum labeled application (1.5 lb ai/A) in 2001 was \$15.48 per acre (55,81). There is a 7-day minimum retreatment interval and a season maximum

of 15.75 lb ai/A. The restricted entry interval (REI) of chlorothalonil under the Worker Protection Standard is 12 hours (81).

In 2000, Florida growers applied an average of 1.56 pounds of active ingredient of chlorothalonil per application to 62 percent of their fresh-market cucumber acreage, an average of 3.1 times. Total usage was 30,900 pounds of active ingredient. During the years in which usage data have been collected, fresh-market cucumber growers in Florida have applied chlorothalonil at an average rate ranging from 1.13 to 1.56 pounds of active ingredient per acre at each application, to between 58 and 83 percent of their fresh-market cucumber acreage. Growers have made an average number of applications ranging from 3.0 to 12.7 each year, totaling between 30,900 and 82,700 pounds of active ingredient annually (25-30).

Although used on processed cucumbers in Florida, detailed chlorothalonil data are available only for 1994, 1992, and 1990. During those years, growers applied chlorothalonil at an average rate ranging from 2.19 to 3.32 pounds of active ingredient per acre at each application, to between 59 and 74 percent of their processed cucumber acreage. Growers made an average number of applications ranging from 2.4 to 3.9 each year, totaling between 8,400 and 20,400 pounds of active ingredient annually (28-30).

Mancozeb. Mancozeb is a broad-spectrum ethylene(bis) dithiocarbamate (EBDC) fungicide used every year as a protectant, in the management of anthracnose, cottony leak, downy mildew, gummy stem blight, and scab (70). The median price of mancozeb is \$4.80 per pound of active ingredient, and the approximate cost per maximum labeled application (2.4 lb ai/A) in 2001 was \$11.52 per acre (55,82). No more than 19.2 pounds of active ingredient per acre may be applied per crop. Mancozeb may be applied up to 5 days before harvest (PHI=5 days), and the restricted entry interval (REI) under the Worker Protection Standard is 24 hours (82).

In 2001, Florida growers applied an average of 0.59 pounds of active ingredient of mancozeb per application to 11 percent of their fresh-market cucumber acreage, an average of 6.1 times. Total

usage was 4,100 pounds of active ingredient. During the years in which usage data have been collected, fresh-market cucumber growers in Florida have applied mancozeb at an average rate ranging from 0.59 to 1.78 pounds of active ingredient per acre at each application, to between 11 and 56 percent of their fresh-market cucumber acreage. Growers have made an average number of applications ranging from 2.8 to 6.1 each year, totaling between 4,100 and 61,100 pounds of active ingredient annually (25-30).

Although used on processed cucumbers in Florida, detailed mancozeb data are available only for 1990, when growers applied an average of 1.08 pounds of active ingredient of mancozeb per acre at each application, an average of 4.9 times each, to 52 percent of their processed cucumber acreage. Total usage on processed cucumbers in that year was 6,700 pounds of active ingredient (30).

Copper Hydroxide. Copper hydroxide (or other copper-containing compounds) is used every year in Florida cucumber production, in the management of angular leaf spot, anthracnose, downy mildew, and gummy stem blight (70). The median price of copper hydroxide is \$2.11 per pound of active ingredient, and the approximate cost per maximum labeled application (1.54 lb ai/A) in 2001 was \$3.25 per acre (55,83). The restricted entry interval (REI) of copper hydroxide under the Worker Protection Standard is 24 hours (83).

In 2000, Florida growers applied an average of 0.62 pounds of active ingredient per application to 43 percent of their fresh-market cucumber acreage, an average of 4.5 times. Total usage was 12,100 pounds of active ingredient. During the years in which usage data have been collected, fresh-market cucumber growers in Florida have applied copper hydroxide at an average rate ranging from 0.53 to 0.98 pounds of active ingredient per acre at each application, to between 8 and 43 percent of their fresh-market cucumber acreage. Growers have made an average number of applications ranging from 1.5 to 4.5 each year, totaling between 2,200 and 12,100 pounds of active ingredient annually (25-30).

Although used on processed cucumbers in Florida, detailed copper hydroxide data are available only for 1990, when growers applied an average of

0.38 pounds of active ingredient of copper hydroxide per acre at each application, an average of 1.4 times, to 36 percent of their processed cucumber acreage. Total usage on processed cucumbers in that year was 500 pounds of active ingredient (30).

Maneb. Maneb is another ethylene(bis) dithiocarbamate (EBDC) fungicide used every year as a protectant in Florida cucumber production. Growers apply it in the management of anthracnose, cottony leak, downy mildew, and target spot (70). The median price of maneb is \$3.67 per pound of active ingredient, and the approximate cost per maximum labeled application (1.5 lb ai/A) in 2001 was \$5.51 per acre (55,84). Maneb may be applied up to 5 days before harvest (PHI=5 days), and the restricted entry interval (REI) under the Worker Protection Standard is 24 hours. No more than 12.8 pounds of active ingredient per acre may be applied during each season (84).

In 2000, Florida growers applied an average of 0.79 pounds of active ingredient per application to 26 percent of their fresh-market cucumber acreage, an average of 7.9 times. Total usage was 16,400 pounds of active ingredient. During the years in which usage data have been collected, fresh-market cucumber growers in Florida have applied maneb at an average rate ranging from 0.79 to 1.21 pounds of active ingredient per acre at each application, to between 9 and 26 percent of their fresh-market cucumber acreage. Growers have made an average number of applications ranging from 3.4 to 7.9 each year, totaling between 2,500 and 20,800 pounds of active ingredient annually. Use of maneb on processed cucumber in Florida has not been reported (25-30).

Chemical Alternatives

A few new fungicides have been introduced for cucumber. Due to cost and selectivity, grower acceptance is slow. However, the materials are gradually being incorporated into IPM programs that target key diseases.

Cultural Control

Cucumber growers in Florida are managing diseases well, with an integration of several important tactics. The development of resistant

cultivars has been the most important component of disease management on Florida cucumbers. Cultivars with resistance to downy mildew, gummy stem blight, and anthracnose are currently available and commonly used (9). Cultivars with resistance to powdery mildew, angular leaf spot, bacterial wilt, mosaic virus, and scab have also been developed (6).

In addition to the use of resistant cultivars, cucumber growers in Florida make an effort to use clean seed, particularly to avoid angular leaf spot. Gummy stem blight can also be managed in part by using disease-free seed. In addition, most growers utilize plastic mulch, which acts as a physical barrier.

For example, the use of full-bed plastic mulch has been found to reduce incidence of belly rot. Water management is another important component of diseases management in cucumbers. Most growers in Florida avoid watering the plants from above with overhead irrigation, instead utilizing seepage or drip irrigation. Avoiding the handling of wet plants aids in reducing the spread of downy mildew, target spot, angular leaf spot, and anthracnose (17,31,69,70,75).

Additional recommendations for cucumber disease management include the removal of crop and weed residues for the management of belly rot and gummy stem blight, the removal of weeds around cucumber fields to reduce virus incidence, and crop rotation. A rotation of at least two years is recommended for belly rot, while a rotation of at least five years with non-susceptible crops such as crucifers, legumes, or solanaceous plants is recommended for the management of Fusarium wilt. Finally, the maintenance of healthy, vigorous plants can delay the development of diseases such as powdery mildew (17,31,69,70,75).

Cultural tactics for management of cucumber diseases in the greenhouse include the use of pathogen-free transplants, which reduces Pythium root rot. Additionally, Botrytis blight in greenhouse production can be managed by controlling the temperature and humidity to avoid favorable conditions for the fungus, maximizing air circulation by pruning the lower canopy, and sanitizing infected plant tissue (12).

Post-harvest Diseases and Their Management

Post-harvest diseases are occasionally a problem in cucumber production in Florida, particularly soft rot and cottony leak (85). Hand harvesting when vines are dry aids in avoiding spread of foliar diseases. Proper sanitation of harvesting containers and washing in chlorinated water are also important in managing post-harvest disease (7). However, the most important step in reducing post-harvest decay is adequate cooling. Cucumbers in Florida are room cooled or hydrocooled and shipped under refrigeration, which minimizes post-harvest loss (32).

Nematode Management

Nematode Pests

The nematodes that attack plants are microscopic roundworms that live in the soil and feed principally on roots. Typical above-ground symptoms of nematode feeding include stunting, premature wilting, leaf yellowing, and related symptoms characteristic of nutrient deficiencies (86). Stunting and poor stand development tend to occur in patches throughout the field as a result of nonuniform or irregular distribution of nematodes within the field. Damage and yield loss are related to the population level of nematodes in soil prior to planting. Cucumbers, like other cucurbits, are highly susceptible to root-knot nematodes and can also be severely damaged by sting nematodes (87,88).

Root-knot Nematodes (*Meloidogyne* spp.).

Root-knot nematodes are the principal nematode pest of cucumbers in Florida. The nematodes enter the host plant root as juveniles and settle close to the vascular system to feed. During establishment of a feeding site, secretions from the juveniles cause the surrounding plant cells to enlarge and multiply, producing the characteristic galls associated with root-knot attack. Galls from root-knot nematodes attacking cucumbers are approximately 1/8 to 1/4 inch (0.3 to 0.6 cm) in diameter. As more nematodes enter the root and feeding continues, the galls fuse to form large tumors on the roots, which interfere with plant uptake and internal transport of water and nutrients. Resulting symptoms induced by root attack

include stunting, wilting, chlorosis and yield loss. In addition to expending the plant's resources, the gall tissue is more susceptible to secondary infections such as root rot and wilt pathogens. Within the root, the female molts several times before developing into a swollen, pear-shaped adult. The adult may live in the host plant for up to several months, laying hundreds to several thousand eggs. Most eggs are extruded in a gelatinous matrix on the root surface, while others are laid directly within root tissue. Many eggs hatch within days, releasing juveniles into the soil to initiate a new wave of root invasion. Low temperatures or very dry soil conditions can cause eggs to hatch more slowly (31,88-91).

Sting Nematodes (*Belonolaimus*

longicaudatus). Sting nematodes are ectoparasites, remaining outside the plant root and feeding superficially at or near the root tip by penetrating the root deeply with their long stylets (mouthparts). Affected root tips turn yellow and later necrotic, with cavities forming and the root tip swelling slightly. Damage from sting nematode feeding inhibits root elongation and causes roots to form tight mats and appear swollen, resulting in "stubby root" or "coarse root" appearance (31,88,89,92,93).

Sting nematodes are especially damaging to seedlings. In north Florida, they are most abundant in April and May. Sting nematodes prefer sandy soils (with 84 to 94 percent sand) and are most abundant in the upper 12 inches (30 cm). Optimum soil temperature for this nematode is between 77 and 90°F (25 and 32°C), and optimum soil moisture is about 7 percent (88,89,92,93).

Chemical Control

Oxamyl (Vydate®) is the most frequently reported nematicide used on cucumber in Florida, in addition to combinations of dichloropropene (Telone®), methyl bromide, and chloropicrin, which when applied to the first crop in a double-cropping system controls nematodes in the following cucumber crop. Additional nematicides registered for use on cucumber in 2002 include the non-fumigant nematicides carbofuran (Furadan®) and ethoprop (Mocap®) (25-30,87). There is also the biological material, fermentation solids from *Myrothecium verrucaria*. Metam sodium (Vapam®), applied as a

chemigation treatment, is sometimes used as a preplant treatment in double cropped cucumbers when drip irrigation delivery is feasible (91).

Oxamyl (Vydate®). Oxamyl is a broad-spectrum carbamate nematocide, insecticide, and acaricide occasionally used by Florida cucumber growers in the management of sting and root-knot nematodes. It is broadcast or banded preplant or at planting, followed by foliar treatment(s). The median price of oxamyl is \$35.23 per pound of active ingredient, and the approximate cost per maximum labeled application (4.0 lb ai/A) was \$140.92 per acre (55,59). Oxamyl may be applied up to 1 day before harvest (PHI=1 day), but the restricted entry interval (REI) under the Worker Protection Standard is 48 hours. Maximum usage of 6.0 pounds of active ingredient per acre is permitted on cucumber each season (59).

Although used in 2000 in Florida, detailed oxamyl data are available for only 3 of the 6 years in which usage data have been collected. At these times, growers of fresh-market cucumbers in Florida have applied oxamyl at an average rate ranging from 0.37 to 0.48 pounds of active ingredient per acre at each application, to between 13 and 43 percent of their fresh-market cucumber acreage. Growers have made an average number of applications ranging from 2.6 to 3.7 during those years, totaling between 2,700 and 9,500 pounds of active ingredient annually (25-30).

On processed cucumbers in Florida, use of oxamyl has been reported only for 1994, when growers applied an average of 0.53 pounds of active ingredient of oxamyl per acre at each application, an average of 4.2 times each, to 35 percent of their processed cucumber acreage. Total usage on processed cucumber in that year was 1,600 pounds of active ingredient (28).

Chemical Alternatives

In double-cropping production systems, resurgence of root-knot nematodes late in the cucumber season can be a problem, even with the use of methyl bromide. Research on the effect of various alternative fumigants showed that fumigation with metam sodium, chloropicrin, or 1,3-dichloropropene plus chloropicrin produced more vigorous plants with larger, apparently healthier, root systems able to

withstand higher nematode populations as compared to non-fumigated plants. Consequently, there was less root galling and yields were higher than in plants not fumigated. However, none of the alternative fumigants was as effective as methyl bromide in terms of cucumber plant vigor, root galling, and yield (19).

Cultural Control

Nematode populations on double-cropped cucumbers have been found to be reduced when the cucumber crop is preceded by a nematode-resistant tomato cultivar (86). There are no nematode-resistant cucumber cultivars available commercially. Additional cultural controls that may be of some benefit when incorporated into the overall nematode management program include clean fallow during the off-season, soil solarization, flooding, and rapid destruction of crop roots after harvest. The use of various soil amendments, including municipal solid composted waste, has been studied recently in Florida. Further research is needed to clarify the effects of soil amendments for management of nematode populations (88).

Biological Control

There are presently no commercially available biological controls that can be used effectively to manage nematodes under field conditions (88).

Weed Management

Weed Pests

Weeds compete with cucumber plants for light, moisture, and nutrients, and can interfere with harvest operations. The most critical time for weed control is early in the season (94). Cucumber plants grow slowly during the early part of the season, and their low vining habit precludes the use of mechanical cultivation after three to four weeks (95).

Common weeds in Florida cucumber production include nutsedges, crabgrass, goosegrass, Texas panicum, lambs-quarters, bristly starbur, Florida pusley, and purslane (17,18). Since most cucumbers in Florida are grown as a second crop with plastic mulch, weeds are not presently a major problem in double-cropped cucumber. Growers

generally apply herbicides to alleyways between beds, once to kill weeds from the prior crop and usually once more during the season (16).

Nutsedges **Yellow nutsedge** (*Cyperus esculentus*) and purple nutsedge (*C. rotundus*) are significant weeds for Florida cucumber growers. Both of these perennial sedges are found in disturbed habitats throughout Florida and the southeast U.S. Yellow nutsedge may produce some seed but reproduces primarily by rhizomes and tubers. The first plant develops rhizomes, which end in bulbs or tubers that produce new plants. Tuber production is favored by low nitrogen levels and high temperatures (80 to 91°F, or 27 to 33°C). The plant is tolerant of high soil moisture but is intolerant of shade. Purple nutsedge is also able to reproduce from tubers when conditions are harsh, making it difficult to control. Unlike the rhizomes of yellow nutsedge, purple nutsedge rhizomes growing off the first plant produce new plants in a series ("tuber-chains"). The plant also reproduces by seed to a limited degree. Although purple nutsedge is also intolerant of shade, it is able to survive a wide range of environmental conditions, growing well in nearly all soil types and over a range of soil moisture, soil pH, and elevation. Purple nutsedge is also able to survive extremely high temperatures (96,97).

Crabgrass (*Digitaria* spp.). Crabgrasses are annual grass plants that reproduce mainly by seed, but also by spreading and rooting of stems at the base. They germinate during the summer, flowering from June or July to October and quickly establish clumps. The plant thrives in moist soil (96,98).

Goosegrass (*Eleusine indica*). Goosegrass is similar in appearance to crabgrass, but grows more densely. It is also a summer annual, and it prefers sunny, moist conditions. Reproducing by seed, it flowers from July to October (96,98).

Texas Panicum (*Panicum texanum*). Texas panicum is primarily a problem in south Florida (18). A summer annual with erect stems, the plant produces large seeds and also roots at the nodes (96).

Lambs-quarters (*Chenopodium album*). Lambs-quarters is a summer annual broadleaf that grows well in all soil types and over a range of soil

pH conditions. The plant has a taproot and grows to a maximum of 2 meters in length. Reproduction is by seed (97).

Bristly Starbur (*Acanthospermum hispidum*). Bristly starbur, a highly competitive weed, is currently present only in the northern part of the state, although it appears to be spreading southward. Bristly starbur received its common name because of the bristly appearance of the flat, triangular fruits, several of which are clumped at each head. Fruits, stems, and leaves are all densely covered with hairs. A member of the daisy or sunflower family (Compositae), bristly starbur produces abundant seed until the plant freezes in the fall. Deep plowing is thought to aid in reducing its population, because seeds buried below 3 inches (7.5 cm) in the soil have been found to lose viability after three years (18,97).

Florida Pusley (*Richardia scabra*). Florida pusley is a loosely branched annual that stands erect or lies flat on the ground. Its hairy stems and oppositely arranged leaves are often rough in texture, particularly along the main veins. The plant is only found in central and north Florida and is often mixed with Brazilian pusley (*R. brasiliensis*). Florida pusley reproduces by seed and blooms in any month in the absence of frost (97).

Purslane (*Portulaca oleracea*). Purslane is a broadleaf summer annual with a single taproot from which arise multiple branched, purplish-red stems that often form large mats. Clusters of small leaves are found at the end of its branches. The plant reproduces by seed, flowering from August to October. Being resistant to drought, it is difficult to kill. However, it is susceptible to frost injury (96,98,99).

Chemical Control

Cucumbers have limited tolerance to most herbicides, and most herbicide applications are therefore made preplant or preemergence (31). In 2000, Florida growers applied herbicides totaling 200 pounds of active ingredient to 5 percent of the state's fresh-market cucumber acreage. During the years in which usage data have been collected, between 5 and 60 percent of fresh-market cucumber acreage has been treated with herbicides each year,

with total annual usage ranging from 200 to 134,400 pounds of active ingredient. On processed cucumbers, Florida growers applied herbicides to 40 percent of their acreage in 1994, with total usage of 800 pounds of active ingredient in that year (25-30).

Paraquat (Gramoxone®) is the herbicide most frequently reported in cucumber production in Florida. Use of glyphosate (Roundup®) and diquat has been less common. Other herbicides registered for use on cucumber in Florida in 2002 include bensulide (Prefar®), diquat, naptalam (Alanap®), DCPA (Dacthal®), trifluralin, ethalfluralin (Curbit®), clomazone (Command®), pelargonic acid (Scythe®), halosulfuron (Sanda®), and sethoxydim (Poast®). Clethodim was registered for use in cucumber, but no product that contained this ingredient were available in Florida in 2002.

Paraquat (Gramoxone®). Paraquat is a quaternary nitrogen contact herbicide applied preplant or prior to crop emergence to control a broad range of annual weeds. Paraquat is typically used to control any weeds from a first crop of tomato, pepper, or eggplant, when cucumbers are planted as the second crop in a double-cropping system. The median price of paraquat is \$12.07 per pound of active ingredient, and the approximate cost per maximum labeled application (0.94 lb ai/A) in 2001 was \$11.35 per acre (55,81). The restricted entry interval (REI) of paraquat under the Worker Protection Standard is 12 hours (81).

In 2000, Florida growers applied an average of 0.54 pounds of active ingredient per application to 5 percent of their fresh-market cucumber acreage once per season. Total usage was 200 pounds of active ingredient. During 5 of the 6 years in which usage data have been collected, fresh-market cucumber growers in Florida have applied paraquat at an average rate ranging from 0.36 to 0.67 pounds of active ingredient per treated acre at each application, to between 5 and 46 percent of their fresh-market cucumber acreage. Growers made an average number of applications ranging from 1.0 to 1.7 each year, totaling between 200 and 6,200 pounds of active ingredient annually (25-30).

On processed cucumbers in Florida, last reported use of paraquat was in 1990, when growers applied an average of 0.60 pounds of active ingredient per treated acre at each application, an average of 1.3 times each, to 41 percent of their processed cucumber acreage. Total paraquat usage on processed cucumbers in that year was 800 pounds of active ingredient (30).

Glyphosate (Roundup®). Glyphosate is a broad-spectrum phosphoric acid herbicide used rarely by Florida cucumber growers to remove weeds before planting. Like paraquat, it is typically used to control weeds from a first crop prior to planting cucumber on mulched beds. The median price of glyphosate is \$10.95 per pound of active ingredient, and the approximate cost per maximum labeled application (1.0 lb ai/A) in 2001 was \$10.95 per acre (55,100). The restricted entry interval (REI) of glyphosate under the Worker Protection Standard is 4 hours (100).

Use of glyphosate on fresh-market cucumbers in Florida was last reported in 1990, when growers applied an average of 1.90 pounds of active ingredient per treated acre an average of 1.1 time each, to 18 percent of their fresh-market cucumber acreage. Total glyphosate use on fresh-market cucumbers in that year was 5,400 pounds of active ingredient (30).

On processed cucumbers in Florida, last reported use was also in 1990, when growers applied an average of 0.50 pounds of active ingredient per treated acre at each application, an average of 1.5 times each, to 29 percent of their processed cucumber acreage. Total glyphosate usage on processed cucumbers in that year was 500 pounds of active ingredient (30).

Chemical Alternatives

Nutsedge is the only weed able to grow through the polyethylene mulch commonly used in cucumber production in Florida. Consequently, when methyl bromide is no longer available, nutsedge is expected to present greater problems for growers. Researchers in Florida have been evaluating alternatives that can control nutsedge and have found that the herbicide halosulfuron-methyl is able to control nutsedge at

specific times during the production of cucumber and all other cucurbits except squash (18). This herbicide was registered for use in Florida in 2002.

Cultural Control

A combination of cultural tactics is recommended for adequate weed management in cucumber production. Mechanical control, including preplant plowing or disking of the field and cultivation during the season, is an important component of weed management for Florida's cucumber producers. However, after planting, most growers do not cultivate between the rows because of the narrow row spacing in cucumbers. Polyethylene mulch, used by most cucumber growers, acts as a barrier to the growth of weeds, inhibiting the development of all weeds except nutsedge. In addition, good management practices, including optimum spacing, fertility, and water control, aid in producing a healthy crop that can outcompete weed species (18,94).

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