

Crop Profile for Peppers (Bell) in Florida

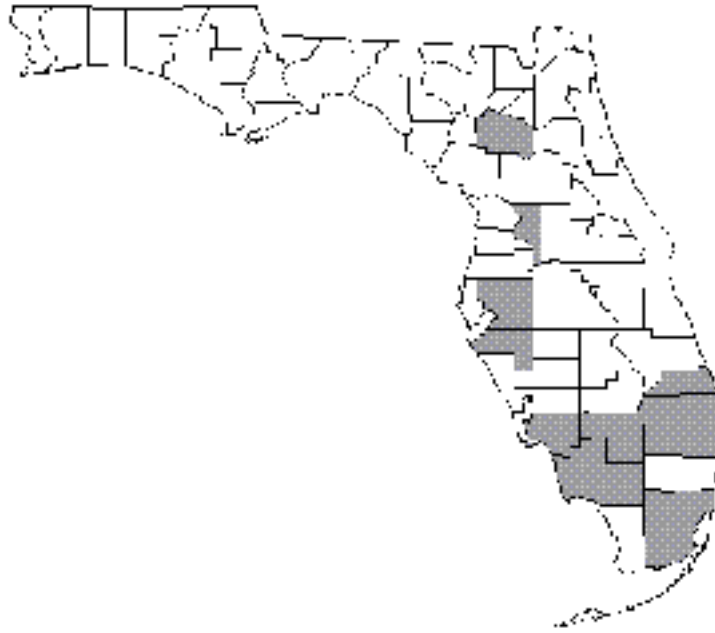
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General Production Information

- In 2004, Florida ranked second nationally in the acreage, production, and value of bell pepper (1).
- In 2004, Florida produced and harvested 34 percent of the national bell pepper acreage and earned 38 percent of the cash receipts for this crop (1).
- In 2004, Florida produced over one-half billion pounds of bell pepper on over 18,000 acres, valued at over 200 million dollars, equating to an average price of \$0.39 per pound (1).
- Bell peppers comprised approximately 15 percent of Florida fresh market vegetable cash receipts in 2004 (2).
- Florida bell peppers account for most of the U.S. grown bell peppers eaten by Americans from October through June (2).
- Total production cost for an acre of peppers ranges from approximately \$8,000 to \$9,000 (3).

Production Regions



The principal region of pepper production includes southern Florida as well as areas near Tampa Bay. Some production extends as far as north central Florida, but the majority is planted in frost free areas for winter cultivation (3).

Cultural Practices

Production practices vary considerably among the major production areas, although almost all of the state's pepper crop is grown in double rows on polyethylene-mulched raised beds, using drip or seep irrigation (3). Even with the advent of the methyl bromide phase out, methyl bromide in combination with chloropicrin is applied to more than 70 percent of Florida's bell pepper acreage (4). A single application of the mixture is injected into the soil during construction of the raised-beds (row middles are not treated in Florida), and the raised beds are immediately covered with the plastic mulch. Methyl bromide is applied at least two weeks prior to planting transplants for management of soil insects, pathogens, nematodes and weeds (especially nutsedges), all of which are major pests in pepper production. Historic methyl bromide usage on Florida peppers has ranged from 2,126,000 to 3,477,400 pounds of active ingredient annually (5). It is important to note that a tremendous amount of preventative pest management occurs before transplantation by producing high-quality plants. Certain commercial pepper varieties are resistant to *Tobacco mosaic virus*, *Potato virus Y*, *Tobacco etch virus*, and/or bacterial spot (3).

Pepper transplants with the growing medium still attached to the roots are set in the mulched raised beds from August through March, depending on the specific production regions and whether the crop is destined for the fall or spring market. The transplants are set in the early or late part of the day to reduce stem scald. Approximately a third of the growers use stakes and twine around the bed perimeter to

construct “corrals” which contain the plants (6). Peppers grow in some part of the state during all times of the year. Standard spacing allows for approximately six feet between bed centers, with plants typically planted 10 inches apart. Maximum plant density per acre is approximately 17,500 plants per acre (3). A total of 65-75 days elapses from transplanting to harvest. The most active harvest period extends from November through June. Peppers are usually hand harvested at least twice, and southern grown pepper plants may be picked up to five times.

Chemical and Non-chemical Control Alternatives to Methyl Bromide

Experts have maintained that no one single management strategy can be relied upon for effects currently obtained by methyl bromide, with the exception of methyl iodide. Where double cropping is practiced, data show that pest densities are higher when using alternatives than compared with using methyl bromide. This suggests that it will be more difficult to economically produce second crops if methyl bromide is not used.

The breadth and focus of the methyl bromide alternatives research program in Florida is not limited exclusively to evaluation of chemical combination treatment regimes. The Florida program also encompasses an evaluation of a diversity of nonchemical tactics. Some of the nonchemical alternatives evaluated include:

1. Cover crops
2. Organic Amendments
3. Biological Control Agents
4. Crop Rotation (Strip Tillage)
5. Super Heated Water and Steam
6. Paper and Plastic Mulch Technologies and Emissions Reduction
7. Pest Resistant Crop Varieties
8. Solarization
9. Natural Product Pesticides
10. Supplemental Fertilization
11. Fallowing

Studies conducted through the methyl bromide replacement program in Florida show that no single, equivalent replacement (chemical or nonchemical) currently exists that exactly matches the broad spectrum efficacy of methyl bromide. A summary of chemical alternatives research suggests that a chemical cocktail of different fumigants (i.e., 1,3-dichloropropene with chloropicrin) and a separate, but complementary herbicide treatment will be required to achieve satisfactory pepper crop yield response. The future success for development of alternatives for effective soilborne pest and disease control in Florida will require an integrated approach involving combinations of multiple tactics since none of the nonchemical tactics are considered single, stand alone replacement strategies for methyl bromide soil fumigation at this time. As a result, new field studies evaluating combinations of tactics have been proposed or are in progress to establish cumulative impacts on soilborne pest control and crop yields.

Worker Activities

Pepper production in Florida is labor intensive. In-field activities commence with fumigation. Ten to 15 people are required to help seal bed ends and cut shovel ditches in the mulch. After several weeks, transplanting crews (approximately 14 people) set transplants using a setting aid. These workers can cover about ten to 15 acres a day. Several weeks after transplanting, stakes (if used) are set in the field and the twine strung around the bed border. Ten to eleven weeks after transplanting comes the beginning of harvesting. Twelve to 100 people may be in a field for harvest, depending on field size. The plant may be picked two to five times at ten to 14 day intervals. Workers then pull the stakes and string (if used) prior to crop destruction or setting a second crop (6).

Insect/Mite Pests

A number of arthropod pests have the potential of seriously reducing both yields and the market value of bell peppers. Peppers must be essentially blemish free to qualify as sellable. Insect/mite pests inflict a negative impact on yield and quality by directly feeding on the plant and/or its fruit, and by vectoring destructive agents such as fungi and viruses, especially *Tobacco etch* and *Tomato spotted wilt virus*. Insect pests are presented in order of importance according to producers.

Caterpillar-type pests (fall armyworm, beet armyworm, southern armyworm, yellowstriped armyworm, cutworms, and loopers). Caterpillar-type pests cause damage by their feeding on foliage and fruiting structures. Young larvae feed generously on under surfaces of leaflets, which leaves the upper epidermis intact ("windowpane" effect). Older larvae, which for some species can grow to 3 inches in length, consume foliage and eat large holes anywhere on the fruit's surface, which can also lead to secondary rots becoming established. The beet armyworm is one of the major pests of bell pepper in Florida. Cutworm larvae do most of their damage at night when they climb the plants and feed on the foliage, or they cut seedlings and transplants off at the soil surface (3).

Worm pests are responsible for the majority of insecticides used in Florida production. As much as possible, these pests are managed with *B.t.* materials when they are in the first several larval instars, and it may be applied every three to four days during peak hatching times. Older larvae, traditionally controlled by methomyl or chlorpyrifos, are now more often treated with spinosad, tebufenozide, or indoxacarb.

Pepper Weevil. Pepper weevils are shiny, brownishblack or grey colored snout beetles, about one-eighth of an inch long. Adults use the mandibles at the end of their proboscis to feed on leaf and flower buds. Females also use their mandibles to bore a small hole in developing fruit or flower buds. The

hole is plugged with fecal matter (frass) after an egg is deposited. A tiny, legless grub hatches from the egg and eats its way toward the core of the fruit where it feeds on seeds and pulp. Both adult and larval feeding causes bud/fruit drop. The stem of pods infested by larvae turn yellow, and the pod may turn yellow or red prematurely. Punctures in the fruit allow fungal colonization and destruction of the tissue. Damaged fruit become contaminated by insect parts, frass and rotted tissue, and eventually fall from the plant. The adults are long-lived and there may be three to five generations per year. Black nightshade management is important as this weed can serve as a secondary host to pepper weevil during fallow periods.

Pepper weevil populations are monitored visually and with sticky yellow card traps. The action threshold for this pest is one adult per 400 terminal buds or one percent of buds infested (7). Late planted pepper crops require more insecticides for weevils than worms and often these tend to be more non-selective materials such as oxamyl or pyrethroids.

Broad mite. Broad mite adults are tiny, white mites and are usually most numerous on the underside of young, emergent foliage. Generation time may be as short as eight days, depending on temperature. Broad mite feeding distorts plant tissue, causing leaves to become thickened and narrow, giving them a “strappy” appearance. Heavy feeding causes flower abortion and dark, smooth russetting of fruit. Infestations are often spotty, but may become more generalized, especially in late fall.

Broad mite may be more of a problem than pepper weevil on the eastern coast of Florida. These mites are mostly early or late season pests and are often managed with only sulfur.

Aphids. Adults are delicate, pear or spindle-shaped insects with a posterior pair of tubes (cornicles), which project upward and backward from the dorsal surface of the abdomen that are used for excreting a defensive fluid. Winged and nonwinged forms are all female and give birth to living young (nymphs). Nymphs are smaller but otherwise similar in appearance to wingless adults, which they become in 7 to 10 days. Heavy aphid infestations may result in plant debilitation, sooty mold growth on honeydew and leaf distortion. Aphids also spread plant viruses such as *Tobacco etch*. Acquisition and transmission of these viruses is rapid but the virus does not persist in the aphid for more than several minutes. Most transmission results from winged aphids probing, feeding/rejecting, flying to another plant and probing again, rather than by colonized aphid feeding. Aphids are generally managed with neonicotinoids. Pymetrozine use has also been reported (5).

Melon Thrips. Melon thrips is a key pest in the Homestead production area. Melon thrips injury to pepper plants is caused by both nymphs and adults that rasp the bud, flower, and/or leaf tissues, and then suck the exuding sap. Infestations cause feeding injury (scarification) to leaves, stems, flowers, and fruits. When present in high numbers, melon thrips produce silvering, yellowing and bronzing of affected areas. Leaves may crinkle and die; growing tips may become stunted, discolored and deformed, and fruits may abort or develop scar tissue. The overall effect is a loss of plant vigor and a reduction in marketable produce. Adults are quite mobile and can move into new plantings quickly from old fields. Therefore, new fields should not be planted adjacent to or near old fields. In addition to infestations of

pepper, melon thrips can easily increase on subsequent plantings of eggplant, cucumber, potato, beans, and watermelon, which are also susceptible to damage from this pest. Most conventional insecticides seem to stimulate melon thrips populations (8).

Western Flower Thrips. Western flower thrips and other members of the genus *Frankliniella* cause flower abortion and poor fruit set because the adult female inserts an egg in flower parts and very small fruit. The larvae then feed on these tissues after hatching. This pest is also a vector of *Tomato spotted wilt* virus (8).

Thrips are early season pests and populations decline greatly in the summer and fall as natural enemies become important factors controlling their abundance. Pepper flowers can tolerate up to 15 thrips per flower for short periods with little damage. Many growers in northern Florida have adopted a biological control program integrating pirate bug predation and the repellency of reflective mulch to control this pest and *Tomato spotted wilt* occurrence (8).

Leafminers. Adult leafminers are small flies, approximately 3/32 inch long, with black heads which are yellow between the eyes and black thorax. Females have a tubelike ovipositor at the end of the abdomen used to puncture the upper leaf surface for egg laying. The white, oval egg is inserted in the leaf tissue, but many punctures (called stipples) are used by the adult for feeding and do not contain eggs. The larva, a yellow maggot with black, sickleshaped mouth hooks, feeds between the upper and lower leaf surface for approximately seven days, leaving a serpentine mine containing a black string of frass. The mature larva exits from the mine and falls to the ground (or plastic mulch) where it pupates, from which the adult emerges in 7 to 14 days. Serpentine mines in leaves reduce photosynthetic area and may provide entry points for foliar pathogens. Heavily damaged leaves become necrotic, predisposing fruit to sunscald.

Controls

Insect pest management tactics for Florida peppers are ever changing in order to incorporate new technologies and to adapt to new pests introduced into Florida.

Non-chemical

Florida pepper producers traditionally practice a variety of nonchemical pest management practices to control insect pests. These practices include pest population monitoring, ditchbank weed control, and immediate crop residue destruction. Other nonchemical measures include using certified pest-free plants and sanitation. All Florida pepper producers do some type of scouting for pests in their fields, and they typically do it more than once a week.

Chemical

Insecticides are applied to 100 percent of Florida's pepper acreage (4). Chemical insecticide/miticide

products reportedly used on Florida peppers include acephate, dicofol, endosulfan, esfenvalerate, imidacloprid, methomyl, oxamyl, permethrin, and spinosad (5). A full listing of insecticides/miticides and their affect on beneficial insects can be found in Table 1.

ACEPHATE. This organophosphate insecticide was used in Florida production (and is still widely used in northern states), but its use has decreased in recent years as neonicotinoids replace organophosphates for aphid control. Acephate is also used to manage all caterpillar-type pests. The price of acephate is \$16.47 per pound of active ingredient, and the approximate cost of a maximum labeled application (1.0 lb ai/A) is \$16.47 (9,10). The label states that no more than 2.0 lb ai/A can be applied per season. The restricted entry interval (REI) is 24 hours and the pre-harvest interval (PHI) is seven days.

Although acephate use in Florida bell pepper production was reported in 2004, the values were not enumerated. Between 1992 and 1998, Florida growers have applied acephate at an average rate ranging from 0.56 to 0.76 pound of active ingredient per acre at each application, to between 15 and 29 percent of their acreage. Growers have made an average number of applications ranging from 3.0 to 4.5 each year, totaling between 7,500 and 14,600 pounds of active ingredient annually (5)

DICOFOL. This organochlorine miticide's use in Florida production has decreased in recent years as newer materials have become registered. Dicofol is used to manage broad mites and two-spotted spider mites. The price of dicofol is \$27.14 per pound of active ingredient, and the approximate cost of a maximum labeled application (0.75 lb ai/A) is \$20.36 (9,11). The label states that no more than 0.8 lb ai/A or two applications can be applied per year. The restricted entry interval (REI) is 12 hours and the pre-harvest interval (PHI) is two days.

Although dicofol use in Florida bell pepper production was reported in 2004, the values were not enumerated. Between 1994 and 1996, Florida growers have applied dicofol at an average rate ranging from 0.29 to 0.43 pound of active ingredient per acre at each application, to between 25 and 39 percent of their acreage. Growers have made an average number of applications ranging from 1.4 to 2.0 each year, totaling between 3,600 and 4,400 pounds of active ingredient annually (5).

ENDOSULFAN. Endosulfan is a cyclodiene organochlorine insecticide used by pepper producers to manage aphids, whiteflies, armyworms and other caterpillar-type pests. The price of endosulfan is approximately \$10 per pound of active ingredient, which is also the maximum labeled application rate (i. e., \$10/acre). The label states that no more than 2.0 lb ai/A can be applied per year in two applications. The REI is 48 hours and the PHI is four days (9,12).

In 2004, Florida growers applied an average of 0.44 pound of endosulfan per acre at each application to three percent of their pepper acreage, an average of 1.4 times. Total usage was 400 pounds of active ingredient. During the years in which usage data have been collected, pepper growers in Florida have applied endosulfan at an average rate ranging from 0.44 to 0.72 pound of active ingredient per acre at each application, to between three and 39 percent of their acreage. Growers have made an average

number of applications ranging from 1.4 to 6.1 each year, totaling between 400 and 16,500 pounds of active ingredient annually (5). Total endosulfan usage on peppers has dropped by over 95 percent when values from 2004 are compared to the year of peak use (1994).

ESFENVALERATE. Esfenvalerate is a synthetic pyrethroid insecticide commonly used to manage pepper weevil and armyworms and other caterpillar-type pests. The price of esfenvalerate is \$164 per pound of active ingredient, and the approximate cost of a maximum labeled application (0.05 lb ai/A) is \$8.20 (9,13). The label states that no more than 0.35 lb ai/A can be applied in any one season. The REI is 12 hours and the PHI is seven days.

In 2000, Florida growers applied an average of 0.03 pound of esfenvalerate per acre at each application to 31 percent of their pepper acreage, an average of 1.2 times. Total usage was 200 pounds of active ingredient (5).

IMIDACLOPRID. Imidacloprid is a chloronicotinyl compound used for whitefly and more importantly aphid management on Florida peppers. The price of imidacloprid is \$281 per pound of active ingredient, and the approximate cost of a maximum labeled application (0.50 lb ai/A) is \$141 (9,14). Foliar applications of imidacloprid may be applied up to and including the day of harvest (PHI = 0) for crops not previously treated with imidacloprid, but the restricted entry interval for imidacloprid under the Worker Protection Standard is 12 hours. Soil applications of imidacloprid have a preharvest interval of 21 days.

In 2002, Florida growers applied an average of 0.15 pound of imidacloprid per acre at each application to 21 percent of their pepper acreage, an average of 1.6 times. Total usage was 900 pounds of active ingredient. During the years in which usage data have been collected, pepper growers in Florida have applied imidacloprid at an average rate ranging from 0.15 to 0.44 pound of active ingredient per acre at each application, to between 17 and 62 percent of their acreage. Growers have made an average number of applications ranging from 1.1 to 1.6 each year, totaling between 900 and 2,000 pounds of active ingredient annually (5).

METHOMYL. Methomyl is a carbamate insecticide pepper growers utilize in their broad spectrum insect pest management programs which are more typical toward the season's end. It is used to manage aphids and armyworms and other caterpillar-type pests. The price of methomyl is \$25 per pound of active ingredient, and the approximate cost of a maximum labeled application (0.9 lb ai/A) is \$22.50 (9,13). The label states that no more than 4.5 lb ai/A can be applied to any one crop and not to make more than 10 applications. The REI is 48 hours and the PHI is three days.

In 2004, Florida growers applied an average of 0.41 pound of methomyl per acre at each application to 70 percent of their pepper acreage, an average of 5.6 times. Total usage was 29,900 pounds of active ingredient. During the years in which usage data have been collected, pepper growers in Florida have applied methomyl at an average rate ranging from 0.33 to 0.56 pound of active ingredient per acre at each application, to between 35 and 87 percent of their acreage. Growers have made an average number

of applications ranging from 2.5 to 7.9 each year, totaling between 15,800 and 58,100 pounds of active ingredient annually. Current use has averaged less than half from the peak of 58,100 pounds of annual use in 1992 (5).

OXAMYL. Oxamyl is a carbamate insecticide that is mainly used to manage pepper weevil, but it also aids in suppression of nematodes, leafminers, thrips, and aphids. The price of oxamyl is \$35 per pound of active ingredient, and the approximate cost of a maximum labeled foliar application (1.0 lb ai/A) is \$35 (9,13). The label states that no more than 6 lb ai/A can be applied per season. The REI is 48 hours and the PHI is seven days.

In 2004, Florida growers applied an average of 0.50 pound of oxamyl per acre at each application to 10 percent of their pepper acreage, an average of 6.3 times. Total usage was 5,500 pounds of active ingredient. During the years in which usage data have been collected, pepper growers in Florida have applied oxamyl at an average rate ranging from 0.50 to 0.70 pound of active ingredient per acre at each application, to between 9 and 76 percent of their acreage. Growers have made an average number of applications ranging from 2.4 to 6.3 each year totaling between 5,500 and 20,700 pounds of active ingredient annually (5).

PERMETHRIN. Permethrin is a synthetic pyrethroid insecticide that is commonly used to manage primarily leafminer and pepper weevil. The price of permethrin is \$67 per pound of active ingredient, and the approximate cost of a maximum labeled application (0.2 lb ai/A) is \$13.40 (9,15). The label states that no more than 1.6 lb ai/A can be applied during the season. The REI is 12 hours and the PHI is three days.

In 2000, Florida growers applied an average of 0.09 pound of permethrin per acre at each application to 31 percent of their pepper acreage, an average of 2.1 times. Total usage was 1,200 pounds of active ingredient. During the years in which usage data have been collected, pepper growers in Florida have applied permethrin at an average rate ranging from 0.09 to 0.14 pound of active ingredient per acre at each application, to between 8 and 65 percent of their acreage. Growers have made an average number of applications ranging from 2.1 to 7.0 each year, totaling between 500 and 11,500 pounds of active ingredient annually. Use of this material has decreased steadily (90 percent reduction as of 2000) since the peak use year of 1992 (5).

SPINOSAD. Spinosad is a microbial fermentation product that is toxic to select insects, and as such, has negligible effects on populations of certain beneficial arthropods. Growers use it to manage mainly lepidopteran larvae, thrips, and leafminers. The price of spinosad is \$263 per pound of active ingredient, and the approximate cost of a maximum labeled application (0.125 lb ai/A) is \$32.88 (9,11). The label states that no more than 0.45 lb ai/A can be applied to any one crop and not to make more than three applications in a 21-day period. The label also forbids transplant treatment. The REI is 4 hours and the PHI is one day.

In 2004, Florida growers applied an average of 0.09 pound of spinosad per acre at each application to 35

percent of their pepper acreage, an average of 3.0 times. Total usage was 1,700 pounds of active ingredient. During the years in which usage data have been collected, pepper growers in Florida have applied spinosad at an average rate ranging from 0.06 to 0.1 pound of active ingredient per acre at each application, to between 35 and 85 percent of their acreage. Growers have made an average number of applications ranging from 2.5 to 4.1 each year, totaling between 1,700 and 3,800 pounds of active ingredient annually (5).

Biological

The preponderant use of biological arthropod control in Florida pepper production is the use of *Bacillus thuringiensis* (B.t.) to control lepidoptera larvae (caterpillars).

***Bacillus thuringiensis* (B.t.)**. B.t. is used by growers when scouting reports indicate low densities of armyworms or other caterpillar-type pests, or when larvae present are still small in size. If worms become larger and more mature, alternatives such as spinosad, tebufenozide, or indoxacarb are then used. The price of B.t. is approximately \$10 per pound (11), which is often the maximum labeled rate (i. e., \$10/acre). The REI is 4 hours.

In 2004, Florida growers applied B.t. an average of 9.6 times to 58 percent of their pepper acreage. During the years in which usage data have been collected, pepper growers in Florida have applied B.t. to between 58 and 97 percent of their acreage and made an average number of applications ranging from 5.4 to 14.1 (5). Adoption of B.t. is currently very high among Florida growers.

Nematodes

Plant parasitic nematodes are small microscopic roundworms that live in the soil and attack the roots of plants. Pepper crop production problems induced by nematodes therefore generally occur as a result of root dysfunction, reducing rooting volume and utilization efficiency of water and nutrients. In many cases a mixed community of plant parasitic nematodes is present in a field, rather than a single species. In general, the most widespread and economically important nematode species include the root-knot nematode (*Meloidogyne spp.*), stubby root nematodes (*Paratrichodorus* and *Trichodorus spp.*), and sting nematode (*Belonolaimus longicaudatus*). The host range of these nematodes, except stubby root which are problematic more in muck soils, includes most of the state. In addition to the direct crop damage caused by nematodes, many of these species have also been shown to predispose plants to infection by fungal or bacterial pathogens, which contributes to additional yield reductions (16).

Typical symptoms of nematode injury to pepper can involve both above ground and below ground plant parts. Foliar symptoms of nematode infestation of roots generally involve stunting and general unthriftiness, premature wilting and slow recovery to improved soil moisture conditions, leaf chlorosis (yellowing) and other symptoms characteristic of nutrient deficiency. An increased rate of ethylene

production, thought to be largely responsible for symptom expression, has been shown to be closely associated with root-knot nematode root infection and gall formation. Although stunting may not be observed immediately when plants are grown within nematode infested soils, pepper plants may also flower poorly, and ultimately produce small fruit. Plants exhibiting stunted, chlorotic, or decline symptoms usually occur in patches of nonuniform growth rather than as an overall decline of plants within an entire field (16).

The time in which symptoms of plant injury occur is related to nematode population density, crop susceptibility, and prevailing environmental conditions. Under heavy nematode infestation, crop seedlings or transplants may fail to develop, maintaining a stunted condition, or die, causing poor or patchy stand development. Under less severe infestation levels, symptom expression may be delayed until later in the crop season after a number of nematode reproductive cycles have been completed. With time and reduction in root system size and function, symptoms become more pronounced and diagnostic, particularly in such long season crops as pepper (16).

Root symptoms induced by sting or root knot nematodes can oftentimes be as specific as above ground symptoms. Sting nematode can be very injurious, causing infected plants to develop a small root system. Roots may form a mat of short roots, oftentimes assuming a swollen appearance. New roots generally are killed by heavy infestations of the sting nematode, causing a symptom reminiscent of fertilizer salt burn. Root symptoms induced by rootknot nematodes cause swollen areas (galls) on the roots of infected pepper plants. Gall size may range from a few spherical swellings to extensive areas of elongated, convoluted, hyperplastic swellings that result from exposure to multiple and repeated infections. Results from field observations within Florida have also demonstrated that commercial pepper varieties can exhibit a wide range of galling reactions to the southern rootknot nematode. Symptoms of any pepper root galling can, however, provide positive diagnostic confirmation of nematode presence, infection severity, and potential for crop damage (16).

For most crop and nematode combinations the damage caused by nematodes has not been accurately determined. In peppers, plant symptoms and yield reductions are directly related to preplant infestation levels in soil and to other environmental stresses imposed upon the plant during crop growth. As infestation levels increase so then does the amount of damage and yield loss. Pepper plant growth and yield have been shown to be greatly reduced in sandy soils by root-knot nematode soil population levels as low as 50 eggs or juveniles per 100 cc of soil. In general, the mere presence of root-knot or sting nematodes suggests a potentially serious problem, particularly on sandy ground during the fall when soil temperatures favor high levels of nematode activity. At very high levels, typical of those that might occur under double cropping, plants may be killed (16).

Although somewhat variable in response, all of the commercial pepper varieties produced in Florida are highly susceptible to sting and root-knot nematode, particularly *Meloidogyne incognita*. Fruit size and numbers per plant can be greatly reduced, and yield losses of 30 to 80 percent are not unusual in heavily infested soils indicating the extreme sensitivity of peppers to *M. incognita*. In recent Florida field trials, pepper yields were nearly doubled in response to nematode and weed control provided by methyl bromide soil fumigation. In these studies, pepper plants that did not grow normally or attain large

canopy size, also permitted prolific growth of surviving weeds, which further reduced pepper plant growth and yield, and at the same time provided alternate hosts for further root-knot nematode population increase (16).

Controls

Non-chemical

Nematode management must be viewed as a preplant consideration because once root infestation occurs and plant damage becomes visible it is generally not possible to resolve the problem completely to avoid potentially significant pepper yield losses. Currently, nematode management considerations include crop rotation of less susceptible crops, resistant varieties, cultural and tillage practices, and use of transplants. These methods, unlike other chemical methods, tend to reduce nematode populations gradually through time (16).

Other cultural measures that reduce nematode problems include rapid destruction of the infested crop root system following harvest. Fields that are disced as soon as possible after the crop is harvested will not only prevent further nematode population growth, but subject existing populations to dissipation by sun and wind. Use of nematode free transplants is also recommended since direct seeded plants are particularly susceptible since they are vulnerable to injury for a longer duration, during an early, but critical period of crop development. Since nematodes can be carried in irrigation water that has drained from an infested field, growers avoid use of ditch or pond waters for irrigation or spray mixtures. In most cases, a combination of these management practices will substantially reduce nematode population levels, but will rarely bring them below economically damaging levels. This is especially true of lands that are continuously planted to susceptible crop varieties (16).

Chemical

As previously discussed, Florida pepper production is predicated on the assumption that soil will be disinfested of nematodes. Although fumigation with methyl bromide plus some amount of chloropicrin has been historically used on all commercial acreage, oxamyl, dichloropropene and metam sodium are now being used in approximately thirty percent of operations. Total fumigant use (methyl bromide plus chloropicrin) has ranged from approximately 133 pounds per acre to 206 pounds per acre, which equates to between two and four million pounds each year. Due to availability, costs for fumigating an acre with this combination have climbed to approximately \$1,200 per acre. Methyl iodide registration is nearly complete and should be available in 2007 for use in pepper production.

Diseases

In Florida, peppers are affected by nearly two dozen disease-causing fungi, bacteria, and viruses, as well as physiological disorders such as blossom end rot and stem scald (17,18,19). According to Extension and scout survey responses, bacterial spot is perceived as being the most serious disease problem influencing Florida pepper production, followed by *Pythium*, *Phytophthora* blight, anthracnose, *Sclerotinia* stem rot, southern blight, and wet rot. Pepper diseases can attack the leaves, the roots and stems, and the fruit.

Bacterial Spot. This bacterial disease is the most prevalent of any of the pepper diseases observed in the field. Small, yellow, slightly raised spots appear on young leaves. On older leaves, the spots are dark, watersoaked, and not noticeably raised. The spots can enlarge to 1/8 to 1/4 inch and become brown with a dark margin. Infected leaves with numerous spots become distorted, turn yellow, and fall. Seedlings lose lower leaves with only a few leaves at the top remaining. On the fruit, the small, blisterlike spots are nearly circular and may be one-fourth of an inch in diameter. During damp weather, secondary organisms may enter these wounds and cause fruit to rot. Bacteria can be seedborne and can survive between crops in plant refuse. Plants infected in the seedling house can carry the disease to the fields. Severe outbreaks can occur during warm, moist weather, especially when heavy rains damage the plants and spread the bacterium. Infection occurs through natural openings as well as wounds (18).

Physical control methods include prompt destruction of field residues after harvest, attention to field sanitation, control of volunteer peppers, and hand labor sanitation. Bacterial spot has been historically hard to control, but this disease and other bacterial diseases are increasingly being managed with phage.

Phytophthora blight. The infected plant is girdled at the soil line, causing sudden wilt and death. A diseased stem will be dark green, followed by brown/black and will shrivel. All parts of the plant can be attacked. The fruit show water soaked areas that can become covered with white growth during wet periods (18).

Damping off. Certain fungi usually present in the soil, such as *Rhizoctonia solani* and *Pythium* species, rot seed or damage seedlings. In south Florida, damping-off is caused almost exclusively by *Pythium*. Plants attacked shrivel at the ground line and usually die. The disease is worse during the fall and/or in damp conditions and can be serious in transplant production houses (18).

Anthracnose. Also called ripe rot, this disease is increasingly important in pepper production. Damage appears primarily on the fruit. Fruit may be infected by spores of the fungus at any time of development, but symptoms are usually expressed on mature fruit. Symptoms first appear as small water-soaked lesions that can rapidly develop into larger sunken areas. A dark growth of the fungus may be visible in the lesions, with tan to pink concentric circles of spores evident. Occasionally, leaf spots and stem dieback may occur (18).

Sclerotinia stem rot. The causal fungus attacks the plant near the soil, or individual leaf petioles, or occasionally, fruit near the ground. The disease is worse during moist, cool weather periods when white mycelium grows over stems several inches above ground. Fruit can rot into a watery mass. The fungus

survives as black bodies (sclerotia) that can be found in and around infected plant parts. These sclerotia can remain viable for many years (18).

Southern blight. Similar to *Sclerotinia*, this fungal disease attacks the stem, girdling it at the ground. The plant wilts and a white mat of mycelium is noticeable on the infected area, on which there may be embedded, small, brown or salmoncolored sclerotia. The fungus persists in the soil as sclerotia for many years and the fungus is most active in poorly drained fields during hot weather (18).

Wet rot. The causal organism of wet rot causes blossom blight in addition to fruit rot. The blossoms wilt and stiff, whiskerlike strands of the fungus with black heads (sporangia) cover the infected area. Young fruits also may be infected (18).

Viruses. Several viruses, including *Cucumber mosaic*, *Pepper mottle*, *Potato Y*, *Tobacco etch*, *Tobacco mosaic*, and *Tomato spotted wilt* can infect peppers. It is difficult to distinguish single or multiple infections in the field. Most viruses produce various degrees of leaf mosaics, mottling, plant stunting, and malformation of leaves and fruit. Accurate diagnosis must be done in a laboratory. Tobacco mosaic is commonly transmitted mechanically during transplanting and harvesting. The remaining viruses are transmitted by aphid or thrips vectors. These viruses are known to survive in several weeds, including ground cherry, nightshades, common groundsel, wild tobacco, toadflax, sicklepod, and jimson weed (17,18).

Controls

Non-chemical

Although no pepper variety is resistant to all fungal pests, disease resistant varieties are employed, when possible, depending on feasibility and marketability of the variety. Management of bacterial diseases such as bacterial spot starts with good sanitation practices in the plant house and field. Removal of volunteer pepper and tomato plants, and strict management of the disease in the plant house, are two of the most effective means of reducing problems in the field. The use of varieties with resistance to the predominant races of bacterial spot is an important approach to disease management. Plants must be handled only when they are dry to avoid spreading bacterial spot bacterium. Losses from damping-off can be reduced by using fungicidetreated seed. Nonchemical control measures for southern blight and *Sclerotinia* stem rot is crop rotation, since the resting bodies are difficult to manage by chemicals or fumigation. Also, seedbeds need to be located on new land or where southern blight has never occurred. The use of diseasefree transplants and rotation are important components of a *Phytophthora* management program, and planting in low, poorly drained fields must be avoided. Management of soft rot in the field involves reducing fruit damage from any source, especially insects. Also, growers avoid bruising the fruit during harvest and in the packinghouse, and use chlorinated water for washing and packing only unblemished and sound fruits. To manage wet rot, proper plant spacing must be selected for adequate air circulation. To manage the *Tobacco mosaic* virus, growers use resistant varieties where possible and have workers who handle plants wash with strong soap or 70 percent ethyl alcohol,

especially those who use tobacco products. To reduce insect transmission of the other viruses, weed hosts must be eradicated and infected crops must be destroyed. Certain spray oils interfere with the aphid feeding, thus inhibiting their ability to spread the virus (17,18).

Chemical

The most effective control measure for certain diseases is to follow a fungicide application schedule in the seedbed and field. Fungicides are applied to 96 percent of Florida's pepper acreage (4). Fungicides used to manage diseases (following field fumigation with methyl bromide) on Florida peppers are primarily limited to the coppers, chlorothalonil, maneb, and mefenoxam (5). There has also been adoption of materials such as the strobilurins (azoxystrobin, pyraclostrobin), and famoxadone + cymoxanil. Thiophanate is available under a Section 18 registration. Other materials registered in Florida as of 2006 include: boscalid, dimethomorph, hydrogen peroxide, PCNB, potassium bicarbonate, potassium phosphite, streptomycin, sulfur, and trifloxystrobin. Fludioxonil is available as a seed treatment.

AZOXYSTROBIN. Azoxystrobin is a strobilurin fungicide which serves as a broad spectrum fungicide, helping in the management of anthracnose. The price of azoxystrobin is \$119 per pound of active ingredient, and the approximate cost of a maximum labeled application (0.25 lb ai/A) is \$29.75 (9,20). The label states that no more than 1.0 lb ai/A can be applied to any one crop and not to make more than four applications in a crop year. The REI is 4 hours and there is no PHI.

COPPER. Copper fungicides, which include basic copper sulfate, copper hydroxide, copper resinate, basic copper chloride, copper oleate, copper oxychloride sulfate, metallic copper, and cuprous oxide, are used to manage various pepper diseases including bacterial spot, anthracnose, and leaf spot. However, for bacterial diseases, copper fungicides should be tank-mixed with an EBDC fungicide (often full rate of copper + one-half to full rate of EBDC fungicide) for best performance. The price of copper ranges from \$2 to 3 per pound of active ingredient, and the approximate cost of a maximum labeled application (1.2 lb ai/A) is \$3.60 (9,13). The REI is 24 hours and there is no PHI.

In 2004, Florida growers applied an average of 0.48 pound of copper hydroxide per acre at each application to 76 percent of their pepper acreage, an average of 9.4 times. Total usage was 63,000 pounds of active ingredient. During the years in which usage data have been collected, pepper growers in Florida have applied copper hydroxide at an average rate ranging from 0.47 to 0.90 pounds of active ingredient per acre at each application, to between 76 and 95 percent of their acreage. Growers have made an average number of applications ranging from 8 to 15 each year, totaling between 63,000 and 180,300 pounds of active ingredient annually (5).

CYMOXANIL + FAMOXADONE. This is an equal mixture of two fungicides that is used to manage anthracnose and suppress other diseases. The price of the mixture is \$47.47 per pound of active ingredient, and the approximate cost of a maximum labeled application (0.31 lb ai/A) is \$14.83 (9,13). The label states that no more than 2.25 lb ai/A can be applied over one year or one crop cycle. The REI

is 12 hours and the PHI is three days.

MANEB/MANCOZEB. Although mancozeb is not registered for use in pepper, many growers throughout the country report its use in pepper, and its reported use may be due to confusion. Only reported use for maneb is included for this discussion. Maneb is used primarily to manage bacterial leaf spot, as well as anthracnose and *Phytophthora* blight. The price of maneb is \$3.67 per pound of active ingredient, and the approximate cost of a maximum labeled application (2.4 lb ai/A) is \$8.81 (9,21). The label states that no more than 14.4 lb ai/A can be applied to any one crop. The REI is 24 hours and the PHI is seven days.

In 2004, Florida growers applied an average of 0.67 pound of maneb per acre at each application to 85 percent of their pepper acreage, an average of 9.7 times. Total usage was 102,400 pounds of active ingredient. During the years in which usage data have been collected, pepper growers in Florida have applied maneb at an average rate ranging from 0.67 to 1.23 pounds of active ingredient per acre at each application, to between 73 and 94 percent of their acreage. Growers have made an average number of applications ranging from 10 to 13 each year, totaling between 102,400 and 247,300 pounds of active ingredient annually (5).

MEFENOXAM. Mefenoxam (isomer-resolved metalaxyl) is most commonly used to manage *Pythium* diseases and *Phytophthora* blight. The price of mefenoxam is \$157.00 per pound of active ingredient, and the approximate cost of a maximum labeled application (0.5 lb ai/A) is \$78.50 (9,20). The label states that no more than 1.5 lb ai/A can be applied to any one crop. The REI is 48 hours and the PHI is seven days.

During the years in which usage data have been collected, pepper growers in Florida have applied mefenoxam at an average rate ranging from 0.22 to 0.80 pound of active ingredient per acre at each application, to between 17 and 61 percent of their acreage. Growers have made an average number of applications ranging from 1.0 to 3.2 each year, totaling between 1,600 and 6,700 pounds of active ingredient annually (5).

PYRACLOSTROBIN. This is another strobilurin fungicide that is used for anthracnose, as well as suppression of other diseases. The price of the material is \$110.00 per pound of active ingredient, and the approximate cost of a maximum labeled application (0.20 lb ai/A) is \$22.00 (9,22). The label states that no more than 1.2 lb ai/A can be applied over one year with no more than two sequential applications. The REI is 12 hours and there is no PHI.

THIOPHANATE. This is a benzimidazole fungicide that is used for management of *Sclerotinia* stem rot. The price of the material is \$22.14 per pound of active ingredient, and the approximate cost of a maximum labeled application (0.7 lb ai/A) is \$15.50 (9,21). The section 18 states that no more than 2.45 lb ai/A can be applied on one crop. The REI is 12 hours and the PHI is two days.

Biological

Fungi and bacteria that are pathogenic to pepper plants are constantly evolving resistance to pesticides used for their control. For bacteria, Florida growers have consistently been converting to a biological system of control, which utilizes viruses that kill them (phages). As of 2006, phage in the form of Agriphage® has been registered for use in pepper. If applied correctly, these organisms have been shown to greatly reduce the pathogenic bacteria that infest pepper plants. At a cost of \$12/pt, at a rate of two pints per acre, the cost for this treatment is approximately \$24/acre (23).

Another biological product that is garnering increasing use is the beneficial bacterium *Bacillus subtilis*. This bacteria sets up a protective barrier on the plant that discourages fungi from colonizing the tissue. It is used to manage bacterial spot. In 2004, Florida pepper growers reported treating with this organism at some point in production (4).

Weeds

Broadleaf, grass, and sedge weeds impact Florida pepper production, however the most troublesome weeds are nightshade and dodder. All weeds in the production beds are initially controlled by methyl bromide. Weeds are a season long problem in the row middles (the area between the raised production beds). Weeds are effective alternative hosts to numerous pepper pests including nematodes, whiteflies, bacterial spot, and viruses transmitted by insects. Nightshade is a broadleaf weed that functions as an alternative host for nematodes, diseases, and virus-vectoring insects. It has developed varying levels of resistance to some post-emergent herbicides (including paraquat and diquat). Dodder is a parasitic plant that infects crop or weed plants. If a pepper plant is infected, the dodder may bridge to other pepper plants within the row. Some pests, such as nematodes, cannot be effectively managed without the simultaneous consideration and management of weeds (24).

Controls

Non-chemical

Nonchemical options for weed control are used to some extent by almost all pepper producers. The most widely used measures include cultivation, plastic mulches, crop rotation, and hand weeding. Plastic mulch by itself is not effective in suppressing perennial weeds, such as nutsedge, because weed emergence occurs through plant holes cut into the plastic as well as through the plastic in some instances. Cultivating or hand weeding the row middles between the production beds is a laborious, time-consuming, and expensive (approximately \$800/acre) exercise.

Chemical

Herbicides are applied to 26 percent of Florida's pepper acreage (4). In the Florida pepper production

system, herbicides are applied to the row middles between the raised production beds and to peripheral areas of fields by ground application equipment to manage grass, broadleaf, and sedge weeds. Care is taken to prevent any herbicide drift from contacting any portion of the pepper plant or its fruit. A long production season, coupled with variations in climatic conditions during this period, influences the diversity of weed species present in pepper fields. No herbicide or fumigant can be expected to suppress weeds for the total production season. Herbicides are also used to “burn down” the above ground portion of the pepper plants immediately following harvest, as a sanitation pest management tactic. Commonly used nonselective herbicides in Florida pepper field row middles include paraquat, diquat, and glyphosate. Selective herbicides used on the rows of pepper directly include napropamide, sethoxydim, and trifluralin. Other herbicides registered for pepper in Florida in 2006 include bensulide, carfentrazone, clethodim, clomazone, DCPA, halosulfuron, s-metolachlor, MCDS, oxyfluorfen, and pelargonic acid (24).

DIQUAT. Diquat use in Florida is permitted under Special Local Needs Registration (SLN). The price of the material is \$30.87 per pound of active ingredient, and the approximate cost of a maximum labeled application (0.5 lb ai/A) is \$15.44 (9,20). The SLN label states that the material may not be used more than twice. The REI is 24 hours and the PHI is 30 days.

GLYPHOSATE. The price of glyphosate is \$10.95 per pound of active ingredient, and the approximate cost of a maximum labeled application (1.5 lb ai/A) is \$16.43 (9,25). The label states that three days should elapse before planting and that material that gets on the plastic mulch should not be irrigated into the planting holes.

PARAQUAT. The price of paraquat is \$12.07 per pound of active ingredient, and the approximate cost of a maximum labeled application (1.38 lb ai/A) is \$16.66 (9,20). The label states that no more than three applications can be made in a single season. The REI is 12 or 24 hours depending whether it is used as an herbicide or burn-down treatment, respectively.

In 2004, Florida growers applied an average of 0.38 pound of paraquat per acre at each application to 18 percent of their pepper acreage, an average of 1.0 time. Total usage was 1,200 pounds of active ingredient. During the years in which usage data have been collected, pepper growers in Florida have applied paraquat at an average rate ranging from 0.34 to 0.68 pound of active ingredient per acre at each application, to between 2 and 87 percent of their acreage. Growers have made an average number of applications ranging from 1.0 to 1.9 each year, totaling between 200 and 10,500 pounds of active ingredient annually (5).

SETHOXYDIM. Sethoxydim is a selective postemergence herbicide which kills grasses. The price of the material is \$47.45 per pound of active ingredient, and the approximate cost of a maximum labeled application (0.28 lb ai/A) is \$13.29 (9,26). The label states that no more than 0.84 lb ai/A can be applied on one crop. The REI is 12 hours and the PHI is 20 days.

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