CIR 1238

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Florida Crop/Pest Management Profiles: Tomatoes[1]

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Production Facts

- As of 2004, Florida ranks first nationally in the acreage, production, and value of fresh market tomato. These rankings have remain unchanged since the early 1980s (1).
- In 2004, Florida harvested 33 percent of the national fresh market tomato acreage, produced 42 percent of the tomatoes, and earned 37 percent of the cash receipts for this crop (1).
- In 2004, Florida produced approximately 1.5 billion pounds of fresh market tomatoes on over 42,000 acres, valued at over 500 million dollars, equating to an average price of $0.33 per pound (1).
- Fresh market tomatoes comprised approximately 40 percent of Florida fresh market vegetable cash receipts in 2004 (2).
- Florida tomatoes account for most of the U.S. grown tomatoes eaten by Americans from October through June (2).
- Pests account for nearly 25 percent loss in fresh market tomatoes (9,056 pounds/acre), equating to $3,382/acre in losses (3).
- Total production cost for an acre of fresh market tomato is approximately $6,000 to $7,000, with nearly 25 percent of costs related to pest management (4).

Production Regions

Principal tomato production regions in Florida are partitioned into four districts. In 2001, 8 percent of tomatoes were planted in District 1 (Dade County), 10 percent were planted in District 2 (east coast), 34 percent were planted in District 3 (southwest), and 29 percent were planted in District 4 (Tampa Bay area). The remaining 19 percent were planted mainly in the panhandle region of the state, northwest of Tallahassee (3).

Production Practices

Production practices vary considerably among the major production areas, although almost all of the state's tomato crop is grown on

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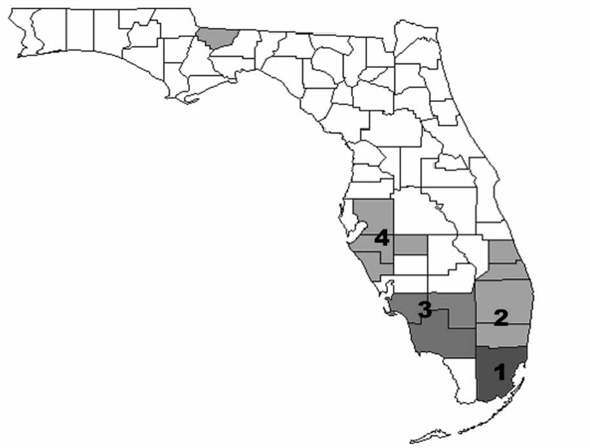

Figure 1. Major Tomato Production Regions of Florida.

polyethylene-mulched raised beds, using staked culture and drip or seep irrigation. Even with the advent of the methyl bromide phase out, methyl bromide in combination with chloropicrin is applied to more than 80 percent of Florida's tomato acreage (5). 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 tomato production. Historic methyl bromide usage on Florida tomatoes has ranged from 5,159,400 to 8,229,800 pounds of active ingredient annually (6). Nearly two-thirds of Florida's tomato producers surveyed believe they will NOT be able to produce tomatoes effectively without having an effective fumigant as a pest management tactic (7). It is estimated that the loss of methyl bromide would result in a 20-40 percent yield loss for Florida tomato growers (8). It is important to note that a tremendous amount of preventative pest management occurs before transplantation. Commercial tomato varieties must be resistant to *Fusarium*, *Verticillium* wilt, gray leaf spot, and early blight and some of these have moderate resistance to root-knot nematode (9).

Tomato transplants with the growing medium still attached to the roots are set in the mulched raised beds from July through March, depending on the specific production regions and whether the crop is destined for the fall or spring market. Standard spacings allow for approximately six feet between bed centers, with plants typically planted 18-30 inches apart. Maximum plant density per acre is approximately 4,840 plants per acre. To provide tomato fruits higher in quality, plants are kept upright using the stake tomato culture system. This system also makes for easier hand harvesting operations versus ground tomatoes. Wooden or metal stakes approximately four feet long are driven into the ground. Stakes are placed halfway between two plants 2-3 weeks after transplanting. Pruning and tying plants begins 3-4 weeks after transplanting. Tying provides vertical support for the plant, and is usually done 3-4 times during the season. For these and other reasons, repeated access and entry into fields is absolutely essential, and Worker Protection Standard pesticide restricted entry intervals must be managed to permit worker access in fields to perform these tasks. A total of 70-90 days elapses from transplanting to harvest. The most active harvest period extends from November through June. Tomatoes are usually hand harvested at least twice, with the first pick the most economically important. Following harvest, plants are desiccated using herbicides and ties are burned. Stakes are removed by hand or mechanical stake puller and then disinfested of disease organisms before re-use.

Chemical and Non-Chemical Control Alternatives to Methyl Bromide

Administering 1,3-dichloropropene and chloropicrin as a combination soil fumigant was listed by more than 70 percent of surveyed growers as an alternative practice/pesticide they would utilize in an attempt to manage pests if methyl bromide use was not allowed. Nearly 60 percent of growers indicated they would try metam as an alternative, while 55 percent would try and rotate crops, 30 percent would apply only chloropicrin, and 18 percent would try soil solarization as a means to manage the pests that methyl bromide now controls (7). Also, where double cropping is practiced, data show that pest densities are higher when using alternatives than using methyl bromide. This suggests that it will be more difficult to economically produce second crops if methyl bromide is not used (8).

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 tomato 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

Tomato production in Florida is labor intensive. A full appreciation for the activities that occur during a production season can be found in the Tomato Timeline located at the SRIPMC's Website (3). Briefly, 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, usually using a setting aid. These workers can cover about 10 to 15 acres a day. Several weeks after transplanting, stakes are set in the field, plants are pruned of one or two bottom stems, and a single row of twine is placed around the plants. New twine is set every two weeks up to eight tiers. Certain varieties may also be topped after this time. 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 or three times at 10 to 14 day intervals. Workers then pull the stakes and string prior to crop destruction (3).

Insect/Mite Management

Insect/Mite Pests

At least 27 arthropod pests have the potential of seriously reducing both yields and the market value of tomato fruit (9). Florida's fresh market tomatoes 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 organisms such as viruses, especially the recently discovered *Tomato yellow leaf curl* virus. Insect pests are presented in order of importance according to producers.

Whitefly. Survey results have consistently ranked whiteflies as the most serious insect pest influencing tomato production, affecting 90 percent of the acreage and reducing yield by over two percent (3,7). Whiteflies feed while in both the immature and the adult stages by sucking plant juices, generally on the underside of leaves. Heavy feeding gives the infested leaves a mottled appearance or causes them to turn yellow and die. The sticky honeydew excreted by whitefly feeding activity often glazes the plant's surface and permits the development of black sooty mold on the surface. This honeydew-induced fungus often covers both foliage and fruits, retarding growth and reducing the market value of the fruit. Probably more important, whiteflies vector destructive gemini viruses such as *Tomato mottle* and *Tomato yellow leaf curl* virus, which can and have resulted in total crop failure.

With the advent of insect growth regulator insecticides available for tomato production, the product selection has changed over the past decade so that "softer" materials (buprofezin, pymetrozine, pyriproxyfen) are used in the beginning of the season, with an effort to restrain non-selective material use until absolutely necessary based on scouting counts. The season-long action threshold for silverleaf whitefly is 5 pupae and/or nymphs on 10 leaflets from the middle of the plant, but may be lower if whiteflies are known to have emigrated from other tomato fields. For the first three true-leaf stage, the threshold is 10 adults/plant, and for 3-7 true leaves, it is 1 adult/plant (10). If the pest pressures become too intense or near season end, materials such as endosulfan, methamidophos, and pyrethroids may be used in an effort to "clean up" whiteflies so they will be less problematic in future plantings.

Another strategy employed by growers is the use of a crop-free period in the summer. This forces whiteflies into refugia where parasitism may range as high as 80 percent. This strategy is also being counted on to mitigate the arrival of the Q biotype of whitefly, which is resistant to many insecticides. The Q biotype is outcompeted by the resident biotype under lack of pesticide selection pressure. It is therefore hoped that the crop-free period will serve to dampen the pressure of this new pest.

Leafminer. Florida growers report that leafminers are the second most prevalent tomato insect pest, affecting 90 percent of the acreage and causing losses of over one percent (3,7). Leafminer damage is foliar, appearing as serpentine mines carved in leaves by feeding leafminer larvae. Heavy leafmining damage can reduce photosynthesis and cause leaf desiccation and abscission, as well as create infection ports for diseases.

The use of softer materials has resulted in higher parasitic wasp infection rates, reducing the number of treatments (rotation of cyromazine, abamectin, and spinosad) required (3). The threshold is less than one larva/plant during the second true leaf stage, and is 0.7 larvae/3 terminal leaflets thereafter (10).

Pinworm. Pinworms can be a significant pest causing direct damage to tomato fruit. Mature larvae of pinworms mine through and roll the foliage. Larvae also bore small holes (pin-sized) into the fruit under the calyx, the preferred point of entry. Through improved management methods, this pest has become less problematic. Specifically, a pinworm pheromone is employed in trapping and for mating disruption.

At planting, a minimum of one trap is placed per ten acres, at least 25 paces into the field. When three to five adults are found in a trap during the night, the pheromone is released in larger amounts for mating disruption (3,10).

Caterpillar-type pests (beet armyworm, southern armyworm, yellowstriped armyworm, loopers, hornworms, and tomato fruitworms). These pests are responsible for approximately one percent damage on over three-quarters of the acreage. Caterpillar-type pests cause damage by their feeding. Young larvae feed on under-surfaces of leaflets, which leaves the upper epidermis intact ("windowpaned"). Older larvae consume foliage and eat large holes anywhere on the fruit's surface, which can also lead to secondary rots becoming established (3).

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 (now unavailable on tomato), are now more often treated with spinosad, tebufenozide, or indoxacarb (3). The pre-bloom threshold is 1 larva/6 plants while the post-bloom threshold is 1 egg or larva per field (10).

Thrips. Thrips injury to tomato plants is caused by both nymphs and adults that rasp the bud, flower, and/or leaf tissues, and then suck the exuding sap.

Thrips feeding damage on tomato fruit causes the formation of dimples that may be surrounded by whitish halos. Damage on immature fruit appears as dimples on the blossom end.

Thrips infest tomatoes primarily during the spring months when they invade fields in massive numbers. Population peaks are often correlated with flowering in alternate hosts, particularly citrus. In the peninsular portion of Florida, thrips damage is due largely to egg-laying on the fruit. However, in the panhandle of Florida, western flower thrips effectively vectors the *Tomato spotted wilt* virus. Although spinosad is effective in conjunction with reflective mulch or partially effective alone against western flower thrips, a combination of methamidophos and fenpropathrin are needed to manage this pest if the former treatment fails (3). The post-bloom threshold for thrips is greater than five per flower (10).

Aphids. Aphids feed on plant juices and cause plant debilitation, sooty mold buildup, and leaf distortion. They can transmit a range of viruses that includes *Tobacco etch*, *Potato Y*, and *Tomato yellows* viruses (9). The season-long threshold for aphids is greater than three aphids per plant (10). These pests in addition to whiteflies have been managed by the neonicotinoids. Pymetrozine and pyriproxyfen use has also been reported (5).

Plantbugs/stinkbugs. Nymph and adult plantbugs suck juices from green fruit causing a lightened, sometimes depressed blotch beneath fruit surface, rendering it unmarketable. These bugs are often incidentally managed with schemes used for more primary pests, but may need occasional treatment for their presence alone. The post-bloom threshold for stinkbugs is one or more on six plants (10).

Mole crickets. Mole cricket nymphs and adults damage tomato plants by chewing on roots and underground portions of stems, and on fruit that touch the ground. If planting areas show evidence of high mole cricket activity, growers may treat with diazinon (7).

Insect/Mite Pest Controls

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

Non-Chemical

Florida tomato producers traditionally practice a variety of nonchemical pest management practices to control insect pests. These practices include pest population monitoring, ditchbank weed control, immediate crop residue destruction (60 percent of producers indicate they destroy crop residues within one week of harvest), and the use of pheromone traps as a means to monitor tomato pinworm populations (7). Other nonchemical measures include using certified pest-free plants and sanitation.

All Florida tomato producers do some type of scouting for pests in their fields, and they typically do it more than once a week. A total of 93 percent of Florida tomato producers indicate that they scout using general observations while performing routine tasks in the field, while 81 percent indicate that they perform deliberate scouting activities on a scheduled basis, and 56 percent perform systematic sampling or counting (7).

Chemical

Insecticides are applied to 100 percent of Florida's tomato acreage (5). Chemical insecticide/miticide products commonly used on Florida tomatoes include abamectin, cyfluthrin, endosulfan, esfenvalerate, imidacloprid, indoxacarb, cyhalothrin, methamidophos, methomyl, oxamyl, permethrin, pymetrozine, pyriproxyfen, and spinosad (5). A full listing of insecticides/miticides and their affect on beneficial insects can be found in Table 1. Nearly 89 percent of producers have indicated that participating in an Integrated Pest Management program has resulted in an increase of using “reduced risk” pesticides (7). It is estimated that the loss of all insecticides used on tomatoes would result in more than a 64 percent yield loss for producers (8).

ABAMECTIN. This microbial fermentation product is a chloride-channel activating glycoside. It is used in the management of leafminers and pinworm, as well as whiteflies and aphids. The price of abamectin is $4,570 per pound of active ingredient, and the approximate cost of a maximum labeled application (0.019 lb ai/A) is $85.69 (11,12). The label states that no more 0.056 lb ai/A can be applied to any one crop and not to make more than two sequential applications. The restricted entry interval (REI) is 12 hours and the pre-harvest interval (PHI) is seven days.

In 2004, Florida growers applied an average of 0.009 pound of abamectin per acre at each application to 34 percent of their tomato acreage, an average of 3.2 times. Total usage was 400 pounds of active ingredient. During the years in which usage data have been collected, tomato growers in Florida have applied abamectin at an average rate ranging from 0.008 to 0.01 pound of active ingredient per acre at each application, to between 31 and 74 percent of their acreage. Growers have made an average number of applications ranging from 1.1 to 3.2 each year, totaling between 100 and 600 pounds of active ingredient annually (6).

CYFLUTHRIN. Cyfluthrin is a synthetic pyrethroid insecticide used to manage whiteflies, leafminers, pinworms, armyworms and other caterpillar-type pests, and thrips. The price of cyfluthrin is $234 per pound of active ingredient, and the approximate cost of a maximum labeled application (0.044 lb ai/A) is $10.30 (11,13). The label states that no more 0.263 lb ai/A (six applications) can be applied to any one crop and not to make more than two applications in one week. The REI is 12 hours and there is no PHI.

In 2004, Florida growers applied an average of 0.03 pound of cyfluthrin per acre at each application to 44 percent of their tomato acreage, an average of 5.3 times. Total usage was 2,700 pounds of active ingredient. During the years in which usage data have been collected, tomato growers in Florida have applied cyfluthrin at an average rate ranging from 0.03 to 0.04 pound of active ingredient per acre at each application, to between 13 and 44 percent of their acreage. Growers have made an average number of applications ranging from 3.5 to 5.3 each year, totaling between 500 and 2,700 pounds of active ingredient annually (6).

ENDOSULFAN. Endosulfan is a cyclodiene organochlorine insecticide used by tomato producers to manage 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 REI is 48 hours and the PHI is one day (11,14).

In 2004, Florida growers applied an average of 0.71 pound of endosulfan per acre at each application to 44 percent of their tomato acreage, an average of 3.8 times. Total usage was 50,600 pounds of active ingredient. During the years in which usage data have been collected, tomato growers in Florida have applied endosulfan at an average rate ranging from 0.43 to 0.76 pound of active ingredient per acre at each application, to between 23 and 77 percent of their acreage. Growers have made an average number of applications ranging from 2.8 to 5.9 each year, totaling between 15,500 and 149,700 pounds of active ingredient annually (6). Total endosulfan usage on tomatoes has dropped by approximately two-thirds when values from 2004 are compared to the year of peak use (1994).

ESFENVALERATE. Esfenvalerate is a synthetic pyrethroid insecticide commonly used to manage whiteflies, armyworms and other caterpillar-type pests, thrips, aphids, and pinworms. 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 (11,15). The label states that no more 0.5 lb ai/A can be applied in any one season. The REI is 12 hours and the PHI is one day.

In 2004, Florida growers applied an average of 0.04 pound of esfenvalerate per acre at each application to 47 percent of their tomato acreage, an average of 5.9 times. Total usage was 4,800 pounds of active ingredient. During the years in which usage data have been collected, tomato growers in Florida have applied esfenvalerate at an average rate ranging from 0.03 to 0.04 pound of active ingredient per acre at each application, to between 22 and 82 percent of their acreage. Growers have made an average number of applications ranging from 3.3 to 8.4 each year, totaling between 1,200 and 10,700 pounds of active ingredient annually (6).

IMIDACLOPRID. Imidacloprid is a chloronicotinyl compound used for whitefly management on Florida tomatoes. It also aids in management of aphids, thrips, armyworms and other caterpillar-type pests, and leafminers. The price of imidacloprid is $281 per pound of active ingredient, and the approximate cost of a maximum labeled application (0.38 lb ai/A) is $106 (11,12). Foliar applications of imidacloprid may be applied up to and including the day of harvest (PHI = 0), 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 2004, Florida growers applied an average of 0.20 pound of imidacloprid per acre at each application to 74 percent of their tomato acreage, an average of 1.8 times. Total usage was 11,000 pounds of active ingredient. During the years in which usage data have been collected, tomato growers in Florida have applied imidacloprid at an average rate ranging from 0.17 to 0.27 pound of active ingredient per acre at each application, to between 35 and 74 percent of their acreage. Growers have made an average number of applications ranging from 1.1 to 1.8 each year, totaling between 4,500 and 11,100 pounds of active ingredient annually (6).

INDOXACARB. Indoxacarb is an insecticide with a unique mode of action-inhibiting sodium entry into cells. It is used to manage caterpillar type pests, as well as pinworm and leafminer. The price of indoxacarb is $262 per pound of active ingredient, and the approximate cost of a maximum labeled application (0.065 lb ai/A) is $17.03 (11,15). The label states that no more than 0.26 lb ai/A can be applied to any one crop and the minimum treatment interval is five days. The REI is 12 hours and the PHI is three days. In 2004, Florida growers applied an average of 0.06 pound of indoxacarb per acre at each application to 11 percent of their tomato acreage, an average of 1.9 times. Total usage was 600 pounds of active ingredient (5).

LAMBDA-CYHALOTHRIN. Lambda-cyhalothrin is used to manage armyworms and other caterpillar-type pests, and to suppress populations of whiteflies, pinworms, thrips and aphids. The price of lambda-cyhalothrin is $331 per pound of active ingredient, and the approximate cost of a maximum labeled application (0.03 lb ai/A) is $9.93 (11,12). The label states that no more 0.36 lb ai/A can be applied to any one crop and the minimum spray interval is five days. The REI is 24 hours and the PHI is five days.

In 2004, Florida growers applied an average of 0.02 pound of lambda-cyhalothrin per acre at each application to 35 percent of their tomato acreage, an average of 7.3 times. Total usage was 2,400 pounds of active ingredient. During the years in which usage data have been collected, tomato growers in Florida have applied lambda-cyhalothrin at an average rate ranging from 0.02 to 0.03 pound of active ingredient per acre at each application, to between 16 and 46 percent of their acreage. Growers have made an average number of applications ranging from 3.7 to 7.3 each year, totaling between 600 and 2,800 pounds of active ingredient annually (6).

METHAMIDOPHOS. Methamidophos is an organophosphate insecticide primarily used to manage thrips in northern Florida production. Methamidophos has several 24(c) Special Local Need registrations for use on tomatoes in Florida. The price of methamidophos is approximately $27 per pound of active ingredient, which is also the maximum labeled application rate (i.e., $27/acre). The label states that no more than 5 lb ai/A can be applied to any one crop or 9 lb ai/A in certain north Florida counties. The REI is 48 hours and the PHI is seven days (11,13).

In 2004, Florida growers applied an average of 0.84 pound of methamidophos per acre at each application to 21 percent of their tomato acreage, an average of 3.4 times. Total usage was 25,300 pounds of active ingredient. During the years in which usage data have been collected, tomato growers in Florida have applied methamidophos at an average rate ranging from 0.47 to 0.84 pound of active ingredient per acre at each application, to between 11 and 84 percent of their acreage. Growers have made an average number of applications ranging from 2.5 to

7.1 each year. Use has dropped greatly from a peak of 152,600 pounds of annual use in the early 90's to amounts as low as 9,100 pounds per year (6).

METHOMYL. Methomyl is a carbamate insecticide that tomato growers utilize in their broad spectrum insect pest management programs which are more typical toward the season's end. It is used to manage armyworms and other caterpillar-type pests, pinworms, aphids, thrips, and whiteflies. 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 (11,15). The label states that no more than 6.3 lb ai/A can be applied to any one crop and not to make more than 16 applications. The REI is 48 hours and the PHI is one day.

In 2004, Florida growers applied an average of 0.46 pound of methomyl per acre at each application to 4 percent of their tomato acreage, an average of 2.9 times. Total usage was 2,000 pounds of active ingredient. During the years in which usage data have been collected, tomato growers in Florida have applied methomyl at an average rate ranging from 0.41 to 0.65 pound of active ingredient per acre at each application, to between 4 and 65 percent of their acreage. Growers have made an average number of applications ranging from 1.3 to 5.7 each year. Use has dropped greatly from a peak of 47,100 pounds of annual use in the early 90's to amounts as low as 2,000 pounds per year (6).

OIL. Refined petroleum oils are applied by approximately 15 percent of producers to suppress whiteflies, pinworms, thrips, and aphids. It is applied to 26 percent of the state's total tomato acreage an average of 3.0 times (7). The use of oil can cause phytotoxic burns if used during periods of prolonged high temperature and high relative humidity, a climatologically common occurrence in Florida. Likewise, oil also cannot be used immediately before or after spraying with many fungicides registered for use on tomatoes. Some oils (stylet oils) interfere with the successful acquisition or deposition of plant viruses by vector insects.

OXAMYL. Oxamyl is a carbamate insecticide that is occasionally used by tomato producers to manage nematodes, but it also aids in suppression of leafminers, whiteflies, 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, but the rate (and price) is double for nematode control by drip irrigation (11,15). The label states that no more than 8 lb ai/A can be applied to any one crop. The REI is 48 hours and the PHI is three days. In 2004, Florida growers applied an average of 0.50 pound of oxamyl per acre at each application to 8 percent of their tomato acreage, an average of 4.4 times. Total usage was 7,700 pounds of active ingredient (5).

PERMETHRIN. Permethrin is a synthetic pyrethroid insecticide that is commonly used to manage armyworms and other caterpillar-type pests, whiteflies, pinworms, aphids, and thrips. 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 (11,12). The label states that no more than 1.2 lb ai/A can be applied to any one crop and not to apply it to any variety that is less than one inch in diameter when mature (grape or cherry tomatoes). The REI is 12 hours and there is no PHI.

In 2004, Florida growers applied an average of 0.11 pound of permethrin per acre at each application to 9 percent of their tomato acreage, an average of 4.3 times. Total usage was 1,700 pounds of active ingredient. During the years in which usage data have been collected, tomato growers in Florida have applied permethrin at an average rate ranging from 0.07 to 0.17 pound of active ingredient per acre at each application, to between 9 and 75 percent of their acreage. Growers have made an average number of applications ranging from 3.5 to 7.5 each year. Use has dropped greatly from a peak of 32,900 pounds of annual use in the early 90's to amounts as low as 1,700 pounds per year (6).

PYMETROZINE. Pymetrozine is a pyridine azomethine that acts as an anti-feeding compound in aphids and whiteflies. The price of pymetrozine is $174 per pound of active ingredient, and the approximate cost of a maximum labeled foliar application (0.086 lb ai/A) is $15.00 (11,12). The national label states that no more than two applications can be made. However, 24(c) Special

Local Need registrations allow up to four applications (two in transplants and two in the field, or all in the field, or any combination of four). The REI is 12 hours and there is no PHI if the material is used twice or less. If the material is used three or four times, the PHI is 14 days. In 2004, Florida growers applied an average of 0.06 pound of pymetrozine per acre at each application to 13 percent of their tomato acreage, an average of 2.6 times. Total usage was 800 pounds of active ingredient (5).

PYRIPROXYFEN. Pyriproxyfen is a pyridine that acts as an insect growth regulator on aphids and whiteflies. The price of pyriproxyfen is $363 per pound of active ingredient, and the approximate cost of a maximum labeled foliar application (0.067 lb ai/A) is $24.39 (11,16). The REI is 12 hours and the PHI is 14 days. In 2004, Florida growers applied an average of 0.05 pound of pyriproxyfen per acre at each application to 23 percent of their tomato acreage, an average of 1 time. Total usage was 400 pounds of active ingredient (5).

SOAP. Insecticidal soaps are applied by approximately 7 percent of tomato producers to aid in management of whiteflies and aphids. It is applied to 17 percent of the state's total tomato acreage an average of 2.5 times (7).

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 (11,17). 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 0.06 pound of spinosad per acre at each application to 37 percent of their tomato acreage, an average of 5.2 times. Total usage was 5,200 pounds of active ingredient. During the years in which usage data have been collected, tomato growers in Florida have applied spinosad at an average rate ranging from 0.06 to 0.08 pound of active ingredient per acre at each application, to between 37 and 61 percent of their acreage. Growers have made an average number of applications ranging from 4.1 to 6.1 each year, totaling between 5,200 and 9,900 pounds of active ingredient annually (6).

Biological

The preponderant use of biological arthropod control in Florida fresh market tomato 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 10.2 times to 62 percent of their tomato acreage. During the years in which usage data have been collected, tomato growers in Florida have applied B.t. to between 41 and 88 percent of their acreage and made an average number of applications ranging from 2.6 to 10.2 (6). Adoption of B.t. is currently very high among Florida growers.

Nematode Management

Nematode Pests

Plant parasitic nematodes are small microscopic roundworms that live in the soil and attack the roots of plants. Tomato crop production problems induced by nematodes therefore generally occur as a result of root dysfunction, reducing rooting volume and foraging and utilization efficiency of water and nutrients. Many different genera and species of nematodes can be important to tomato crop production in Florida. 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.*, and sting nematode, *Belonolaimus longicaudatus*. The host range of these nematodes, as with others, include most if not all of the commercially grown vegetables within the state. Yield reductions can be extensive but vary significantly between tomato cultivar (i.e., root-knot resistant varieties) and nematode species. 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, and example of which is the weakening of *Fusarium* resistance in infested plants (9).

Typical symptoms of nematode injury can involve both above-ground and below-ground plant parts. Foliar symptoms of nematode infestation of roots includes stunting, premature wilting and slow recovery to improved soil moisture conditions, leaf chlorosis (yellowing) and other symptoms characteristic of nutrient deficiency. Root tissue is galled in the case of root-knot nematode and stunted in the case of sting nematode. Plants exhibiting stunted or decline symptoms usually occur in patches of nonuniform growth rather than as a overall decline of plants within an entire field.

For most crop and nematode combinations the damage caused by nematodes has not been accurately determined, although reductions as high as 27 percent have been observed in tropic tomato plantings (9). Plant symptoms and yield reductions are often 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. 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 doubling cropping, plants may be killed.

Nematode 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 tomato 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.

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 tomato transplants is also recommended since direct seeded plants are particularly susceptible as 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.

Chemical

As previously discussed, Florida tomato 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, dichloropropene is now being used in approximately ten percent of operations. When applied via drip irrigation, this material can also be used to kill nematodes at season's end to reduce subsequent populations. Total fumigant use (methyl bromide plus chloropicrin) has ranged from approximately 160 pounds per acre to 220 pounds per acre, which equates to between seven and ten 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 2006 for use in tomato production.

Disease Management

In Florida, tomatoes are affected by nearly 30 disease causing fungi, bacteria, and viruses (9). According to survey responses from growers, bacterial spot is perceived as being the most serious disease problem influencing Florida tomato production, followed by target spot, early blight, late blight, viruses, *Fusarium* wilt, *Fusarium* crown rot, *Verticillium* wilt, southern blight, bacterial wilt, and white mold, respectively (3,7). Tomato diseases can attack the leaves, the roots and stems, and the fruit.

Diseases

Bacterial spot. Bacterial spot is a serious disease because it has a high rate of spread, especially during warm periods with wind-driven rains. Bacterial spot symptoms on fruit reduce marketability and it is estimated that over ninety percent of acreage is affected. Nearly ten percent yield losses were attributed to bacterial spot. This disease causes brown, irregularly shaped, greasy lesions on leaves. Leaf infection occurs through natural openings, while unprotected wounds are common entries for fruit infection.

Physical control methods include prompt destruction of field residues after harvest, attention to field sanitation, control of volunteer tomatoes, 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 (3,18).

Target Spot. Target spot has a wide host range, attacking over 60 species of plants. On tomato leaves, the fungal disease first appears as small necrotic lesions with light brown centers and dark margins. Some varieties show a pronounced yellow halo around these leaf spots. Later, somewhat circular lesions develop with sunken tan to light-brown centers. Individual lesions often coalesce and cause a general blighting of leaves. Symptoms also occur on flower and fruit stalks and stems. On fruit, a succession of symptoms is observed. Small, brown, slightly sunken flecks are observed first. As fruits mature and the disease progresses, lesions become larger and darker. Coalescence of lesions result in large pitted areas. Advanced disease on fruit appears as large and deeply sunken lesions, often with visible dark gray to black growth of the fungus in the center (18).

Early Blight. Early blight produces a wide range of symptoms at all stages of plant growth. It can cause dampingcollar rot, stem cankers, leaf blight, and fruit rot. The classic symptoms of this fungal disease occur on the leaves, where circular lesions up to one-half inch in diameter are produced. Within these lesions dark, concentric circles can be seen. The leaf blight phase usually begins on the lower, older leaves and progresses up the plant. Infected leaves eventually wither, die, and fall from the plant. On the fruit the black spots are ridged, sunken, starting around the calyx scar (18).

Late Blight. The development of late blight rots or lesions varies with environmental conditions. The relative humidity, temperature, light intensity, and tomato cultivar all affect symptom expression. Leaf lesions begin as small, irregularly shaped, light green to gray spots. In cool, moist environments, lesions expand rapidly to form large black rots (blights) that spread throughout the leaf and into petioles (leaf stem) and into the stem of the plant that girdle the plant, causing death. Apical tips, flowers, and young stems are very susceptible. Large sections of the plant are rotted and plants are eventually killed. Nearly ten percent of acreage is historically affected by this disease and it is estimated to reduce yields by one percent (3,18).

Fusarium Wilt. Most tomato cultivars currently planted in Florida are resistant to races 1 and 2. When this disease infects a tomato plant, eventually the whole plant wilts and dies. The fungus enters roots through wounds in the taproot and continues into the xylem, the water-conducting tissue. Shoots and leaves may wilt during the day but regain turgidity at night. As the infection progresses, stems become bleached. Toxins produced by the fungus discolor host tissue; a red discoloration appears on leaves. The xylem eventually becomes plugged, causing death. Fusarium spores may persist in soil for several years. Fusarium wilt is more severe when plants are infested with root-knot nematodes (9,18).

***Verticillium* Wilt.** *Verticillium* wilt is a soil-borne organism that can survive in the soil for many years. Lower or upper leaves may yellow and wither, eventually the whole plant may wilt and die. The disease does not rapidly kill the plant but results in severely reduced yields (18).

***Fusarium* Crown Rot.** Disease incidence correlates more with the cool spring periods at fruit sizing stages of production and can infect up to 40 percent of the production acreage, causing yield losses of over two percent. Lower leaf yellowing, a slow-to-rapid plant decline to death, and internal vascular and pith discoloration at and above the soil line characterize this disease (9,18).

Bacterial Wilt. Affected plants demonstrate a progressive wilt period across days to weeks prior to plant death. Leaf yellowing is not consistently associated with this disease. Diseased plants are stunted with dark, discolored pith at the soil line. Lower stems may hollow in advanced stages of decline (18).

White Mold. This disease can attack young transplants causing damping off. Infected plant tissue wilts, withers and becomes covered with a grayish-white mycelium. Infected stem, petioles, or fruit hollow and become filled with hard black fungal survival structures (sclerotia) (18).

Southern Blight. This disease is more damaging during moist, high temperature seasons. The fungus attacks the lower stem below the soil line, and often the first fruit cluster (if in contact with the soil). The fungus forms a white mat of hyphae with tan, mustard seed-sized structures (sclerotia) on stem, fruit, and the soil surface. Affected plants wilt and brown rapidly (18).

Viruses. A range of viruses can impact Florida's tomato crops that includes the mechanically transmitted *Tomato mosaic* virus, the thrips-vectored *Tomato spotted wilt* virus, the aphid-vectored *Cucumber mosaic, Tobacco etch, Pepper mottle* and *Potato Y* viruses, and the whitefly-vectored *Tomato mottle* and *Tomato yellow leaf curl* virus. Affected plants may exhibit a range of symptoms that include stunting, leaf deformation, mosaic/mottled leaves, fruit deformation, or flower abscission depending on the virus involved (18).

Disease Controls

Non-chemical

Non-chemical disease control practices are a significant part of overall disease management strategies. Commercially marketable tomato varieties resistant to one or more diseases are planted on all of Florida's tomato acreage. Resistance to *Fusarium* wilt (two races), *Verticillium* wilt, and some strains of *Tobacco mosaic* virus are common in commercial varieties. Nonchemical tactics used on a significant portion of tomato acreage for disease management include crop debris destruction, crop rotation and fallowing, and proper irrigation and fertilization management (8). Other cultural practices, such as planting stock certified to be free of bacterial, fungal or viral disease, are tactics implemented whenever possible. All Florida tomato producers do some type of scouting for pests in their fields (see narrative under Insect, Non-chemical Control for a breakdown of scouting types).

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 100 percent of Florida's tomato acreage (5). Fungicides used to manage diseases (following field fumigation with methyl bromide) on Florida tomatoes are primarily limited to the coppers, chlorothalonil, the ethylenebisdithiocarbamates (mancozeb, maneb, etc.), and mefenoxam (5). There has also been adoption of materials such as the strobilurins (azoxystrobin, pyraclostrobin, trifloxystrobin), propamocarb, and famoxadone + cymoxanil. Thiophanate is available under a Section 18 registration. Other materials registered in Florida as of 2006 include: acibenzolar, boscalid, cyazofamid, dicloran, dimethomorph, fosetyl-Al, hydrogen peroxide, myclobutanil, PCNB, potassium bicarbonate, potassium phosphite, pyrimethanil, streptomycin, sulfur, ziram, and zoxamide. Fludioxonil is available as a seed treatment. It is estimated that the loss of all fungicides would result in more than a 60 percent yield loss for tomato growers (8).

AZOXYSTROBIN. Azoxystrobin is a strobilurin fungicide that serves as a broad spectrum fungicide, helping in the management of early and late blight, as well as suppression of target spot. The price of azoxystrobin is $119 per pound of active ingredient, and the approximate cost of a maximum labeled application (0.1 lb ai/A) is $11.90 (11,12). The label states that no more than 0.6 lb ai/A can be applied to any one crop and not to make more than five applications in a year. The REI is 4 hours and there is no PHI.

In 2004, Florida growers applied an average of 0.1 pound of azoxystrobin per acre at each application to 23 percent of their tomato acreage, an average of 3.0 times. Total usage was 3,000 pounds of active ingredient. During the years in which usage data have been collected, tomato growers in Florida have applied azoxystrobin at an average rate ranging from 0.08 to 0.1 pound of active ingredient per acre at each application, to between 23 and 39 percent of their acreage. Growers have made an average number of applications ranging from 1.6 to 5.3 each year, totaling between 2,400 and 4,900 pounds of active ingredient annually (6).

CHLOROTHALONIL. Chlorothalonil is a chloronitrile fungicide that serves as a broad spectrum tomato disease management agent. It is recommended in Florida for management of target spot, and it also manages early blight and late blight. The price of chlorothalonil is $10.32 per pound of active ingredient, and the approximate cost of a maximum labeled application (2.1 lb ai/A) is $21.67 (11,12). The label states that no more than 15 lb ai/A can be applied to any one crop and not to make more than one application in one week. The REI is 12 hours and there is no PHI.

In 2004, Florida growers applied an average of 1.3 pounds of chlorothalonil per acre at each application to 88 percent of their tomato acreage, an average of 6.7 times. Total usage was 325,300 pounds of active ingredient. During the years in which usage data have been collected, tomato growers in Florida have applied chlorothalonil at an average rate ranging from 0.89 to 1.4 pounds of active ingredient per acre at each application, to between 59 and 95 percent of their acreage. Growers have made an average number of applications ranging from 5.4 to 8.5 each year, totaling between 116,300 and 446,600 pounds of active ingredient annually (6).

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 tomato diseases including bacterial spot, early blight, and late blight. 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 (1.6 lb ai/A) is $4.80 (11,15). The REI is 24 hours and there is no PHI.

In 2004, Florida growers applied an average of 0.68 pound of copper hydroxide per acre at each application to 92 percent of their tomato acreage, an average of 23 times. Total usage was 610,200 pounds of active ingredient. During the years in which usage data have been collected, tomato growers in Florida have applied copper hydroxide at an average rate ranging from 0.67 to 1.01 pounds of active ingredient per acre at each application, to between 67 and 98 percent of their acreage. Growers have made an average number of applications ranging from 9 to 23 each year, totaling between 285,100 and 706,800 pounds of active ingredient annually (6).

CYMOXANIL + FAMOXADONE. This is an equal mixture of two fungicides that is used to manage early and late blight, target spot and suppress bacterial spot. The price of the mixture is $47.47 per pound of active ingredient, and the approximate cost of a maximum labeled application (0.25 lb ai/A) is $11.87 (11,15). The label states that no more than 2.25 lb ai/A can be applied over one year. The REI is

12 hours and the PHI is three days. In 2004, Florida growers applied an average of 0.22 pound of cymoxanil + famoxadone per acre at each application to 43 percent of their tomato acreage, an average of 2.1 times. Total usage was 8,000 pounds of active ingredient (5).

MANCOZEB. Mancozeb is the most commonly used ethylenebisdithiocarbamate (EBDC) fungicide on tomatoes. The EBDCs are used to aid in management of early and late blights. The price of mancozeb is $4.80 per pound of active ingredient, and the approximate cost of a maximum labeled application (2.25 lb ai/A) is $10.80 (11,15). The label states that no more than 16.8 lb ai/A can be applied to any one crop. The REI is 24 hours and the PHI is five days.

In 2004, Florida growers applied an average of 0.75 pound of mancozeb per acre at each application to 92 percent of their tomato acreage, an average of 19 times. Total usage was 546,000 pounds of active ingredient. During the years in which usage data have been collected, tomato growers in Florida have applied mancozeb at an average rate ranging from 0.75 to 1.5 pounds of active ingredient per acre at each application, to between 60 and 96 percent of their acreage. Growers have made an average number of applications ranging from 10 to 19 each year, totaling between 362,900 and 784,400 pounds of active ingredient annually (6).

MANEB. Maneb is the other commonly used EBDC on tomatoes. It, too, is used to aid in management of early and late blights. 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 (11,15). The label states that no more than 16.8 lb ai/A can be applied to any one crop. The REI is 24 hours and the PHI is five days.

In 2004, Florida growers applied an average of 1.0 pound of maneb per acre at each application to 7 percent of their tomato acreage, an average of 5.7 times. Total usage was 18,100 pounds of active ingredient. During the years in which usage data have been collected, tomato growers in Florida have applied maneb at an average rate ranging from 1.0 to 1.7 pounds of active ingredient per acre at each application, to between 3 and 32 percent of their acreage. Growers have made an average number of applications ranging from 4.0 to 7.9 each year, totaling between 17,600 and 78,600 pounds of active ingredient annually (6).

MEFENOXAM. Mefenoxam (isomer-resolved metalaxyl) is most commonly used to manage *Pythium* diseases. The price of mefenoxam is $157.00 per pound of active ingredient, and the approximate cost of a maximum labeled application (1.0 lb ai/A) is $15.70 (11,12). 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 there is no PHI.

In 2004, Florida growers applied an average of 0.58 pound of mefenoxam per acre at each application to 43 percent of their tomato acreage, an average of 1.5 times. Total usage was 15,900 pounds of active ingredient. During the years in which usage data have been collected, tomato growers in Florida have applied mefenoxam at an average rate ranging from 0.10 to 0.58 pound of active ingredient per acre at each application, to between 10 and 47 percent of their acreage. Growers have made an average number of applications ranging from 1.2 to 3.8 each year, totaling between 2,100 and 15,900 pounds of active ingredient annually (6).

PYRACLOSTROBIN. This is another strobilurin fungicide that is used for early and late blight, as well as suppression of target spot. 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 (11,19). 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. In 2004, Florida growers applied an average of 0.11 pound of pyraclostrobin per acre at each application to 23 percent of their tomato acreage, an average of 2.0 times. Total usage was 2,100 pounds of active ingredient (5).

THIOPHANATE. This is a benzimidazole fungicide that is used for management of white mold. 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 (11,20). 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. In 2004, Florida growers applied an average of 0.37 pound of thiophanate per acre at each application to 29 percent of their tomato acreage, an average of 2.6 times. Total usage was 11,900 pounds of active ingredient (5).

Biological

Fungi and bacteria that are pathogenic to tomato 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 tomato. If applied correctly, these organisms have been shown to greatly reduce the pathogenic bacteria that infest tomato plants. At a cost of $12/pt, at a rate of two pints per acre, the cost for this treatment is approximately $24/acre (21).

Another biological product that is garnering increasing use is the beneficial bacterium *Bacillus subtilus*. This bacteria sets up a protective barrier on the plant that discourages fungi from colonizing the tissue. It is used to manage late and early blight as well as bacterial spot. In 2004, 26 percent of tomato acreage was treated with this organism an average of 9 times through the season (5).

Weed Management

Weeds

Broadleaf, grass, and sedge weeds impact Florida tomato production; however ,the most troublesome weeds are nightshade, nutsedge, and eclipta (9,22). 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). Weed management in tomato fields has increased in importance because they are effective alternative hosts to numerous tomato pests including nematodes, whiteflies, bacterial spot, and viruses transmitted by whiteflies and aphids. Nightshade is a broadleaf weed in the same botanical family as tomatoes and 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). Some pests, such as nematodes, cannot be effectively managed without the simultaneous consideration and management of weeds.

Weed Controls

Non-Chemical

Nonchemical options for weed control are used to some extent by almost all tomato producers (8). 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 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 86 percent of Florida's tomato acreage (5). In the Florida tomato 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 tomato plant or its fruit. A long production season(s), coupled with variations in climatic conditions during this period, influences the diversity of weed species present in tomato fields. No herbicide or fumigant can be expected to suppress weeds for the total tomato production season. Herbicides are also used to “burn down” the above ground portion of the tomato plants immediately following harvest, as a sanitation pest management tactic. According to survey data, nearly 60 percent of producers apply herbicides to burn down their tomato plants within one week after harvest (7). Commonly used nonselective herbicides in Florida tomato field row middles include paraquat, glyphosate, diquat, and MCDS. Selective herbicides used on the rows of tomato directly include clethodim, DCPA, halosulfuron, S-metolachlor, metribuzin, napropamide, oxyfluorfen, rimsulfuron, sethoxydim, trifloxysulfuron, and trifluralin. Other herbicides registered for fresh market tomato in Florida in 2006 include carfentrazone and pelargonic acid, which are both contact (nonselective) materials. If all herbicides were no longer registered for fresh market tomatoes, yields are estimated to decline by more than 36 percent (8).

PARAQUAT. Paraquat is a non-selective post-emergent herbicide used in row middles for total vegetation control. 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 (11,12). 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 0.54 pound of paraquat per acre at each application to 53 percent of their tomato acreage, an average of 1.6 times. Total usage was 19,400 pounds of active ingredient. During the years in which usage data have been collected, tomato growers in Florida have applied paraquat at an average rate ranging from 0.36 to 0.69 pound of active ingredient per acre at each application, to between 22 and 95 percent of their acreage. Growers have made an average number of applications ranging from 1.1 to 1.9 each year, totaling between 4,200 and 33,000 pounds of active ingredient annually (6).

METRIBUZIN. Metribuzin is a broadleaf and grass herbicide that can be used pre-plant incorporated or post-emergence. The price of metribuzin is $23.04 per pound of active ingredient, and the approximate cost of a maximum labeled application (1.0 lb ai/A) is $23.04 (11,13). The label states that no more than1.0 lb ai/A can be applied within a crop season. The REI is 12 hours and the PHI is seven days.

In 2004, Florida growers applied an average of 0.37 pound of metribuzin per acre at each application to 73 percent of their tomato acreage, an average of 1.2 times. Total usage was 13,400 pounds of active ingredient. During the years in which usage data have been collected, tomato growers in Florida have applied metribuzin at an average rate ranging from 0.25 to 0.56 pound of active ingredient per acre at each application, to between 29 and 73 percent of their acreage. Growers have made an average number of applications ranging from 1.0 to 1.3 each year, totaling between 4,700 and 14,100 pounds of active ingredient annually (6).

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 (11,19). 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. In 2004, Florida growers applied an average of 0.35 pound of sethoxydim per acre at each application to 20 percent of their tomato acreage, an average of 1.0 time. Total usage was 3,100 pounds of active ingredient (5).

DIQUAT. Diquat use in Florida, either as an herbicide or as a desiccant, is permitted under Special Local Needs Registrations (SLNs). The importance of rapid and complete vine destruction to aid in insect, nematode and disease pest management for the following season cannot be over-stressed. The price of the material is $30.87 per pound of active ingredient, and the approximate cost of a maximum labeled application (0.93 lb ai/A) is $28.71 (11,12). The SLN label states that the material may not be used more than twice as an herbicide. The REI is 24 hours and the PHI is 30 days. In 2000, Florida growers applied an average of 0.84 pound of diquat per acre at each application to 27 percent of their tomato acreage, an average of 1.0 time. Total usage was 9,700 pounds of active ingredient (6).

Key Contacts

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References

1. United States Department of Agriculture, National Agricultural Statistics Service. 2005. Vegetables: 2004 Summary.

2. Florida Agricultural Facts - Vegetables, Field Crops, and Livestock - 2005.

3. Florida Tomato Timeline: http://pestdata.ncsu.edu/croptimelines/

4. Olson, S.M., D.N. Maynard, G.J. Hochmuth, C.S. Varina, W.M. Stall, M.T. Momol, S.E. Webb, T.G. Taylor, S.A. Smith, and E.H. Simmone. 2005. Tomato Production in Florida. Horticultural Department Document HS-739, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL 32611.

5. United States Department of Agriculture, National Agricultural Statistics Service. 2005. Agricultural Chemical Usage - 2004 Vegetables Summary.

6. United States Department of Agriculture, National Agricultural Statistics Service. Agricultural Chemical Usage: 1992 - 2004 Vegetable Summaries.

7. Tomato Integrated Pest Management and Pesticide Use Survey. UF/IFAS Pesticide Information Office.

8. The Importance of Pesticides and Other Pest Management Practices in U.S. Tomato Production, 1998. USDA-NAPIAP. Document Number 1-CA-98.

9. Bloem, S. and R. F. Mizell. 2004. Tomato IPM in Florida. Department of Entomology and Nematology Document ENY-706, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL 32611.

10. Florida Tomato Scouting Guide. 1996. Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL 32611.

11. Pesticide pricing obtained from multiple unnamed sources (2001-2006).

12. Syngenta labels, Greensboro, NC.

13. Bayer CropScience labels, Research Triangle Park, NC.

14. Universal labels, Egan, MN.

15. Dupont labels, Wilmington, DE.

16. Valent U.S.A. Corporation labels, Walnut Creek, CA.

17. Dow AgroSciences labels, Indianapolis, IN.

18. Momol, T. and K. Pernezny. 2005. 2006 Florida Plant Disease Management Guide: Tomato. Department of Plant Pathology Document PDMG-V3-53, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL 32611.

19. BASF labels, Research Triangle Park, NC.

20. Cerexagri labels, King of Prussia, PA.

21. Omnilytics, Logan, UT.

22. Stall, W.M. and J.P. Gilreath. 2005. Weed Control in Tomato. Horticultural Sciences Department Document HS-200, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL 32611.

Table 1. Toxicity of chemical pest management tools to beneficial invertebrates in Florida tomato.

Beneficial Insects/ Mites **Pest Management Tools (IRAC MoA Class)**	Beneficial mites	Big-eyed bugs	Damsel bugs	Ground beetles	Honey bees	Lace-wings	Ladybird beetles	Minute pirate bugs	Parasitic wasps	Preda-tory midges	Preda-tory thrips	Spiders	Syrphid fly larvae
Registered materials													
Abamectin (6)	H	O	H	O	H	H	S	O	H	H	H	O	S
Acetamiprid (4)	S	O	O	O	M	M	M	O	M	H	H	O	O
Azadirachtin (18)	S	O	O	O	S	S	S	O	M	O	O	O	O
Azinphos-methyl (1)	M	H	H	H	H	H	H	H	H	H	H	H	H
Bifenazate (25)	S	O	O	O	M	S	S	O	S	O	O	O	O
Bifenthrin (3)	H	H	H	H	H	H	H	H	H	H	H	H	H
Boric acid (no class)	M	O	O	O	S	S	S	S	O	M	M	O	M
Buprofezin (16)	O	O	O	O	O	S	O	O	S	M	O	O	O
Carbaryl (1)	S	H	H	H	H	H	H	H	H	H	H	H	H
Cryolite (9)	O	O	O	O	O	O	O	O	O	O	O	O	O
Cyfluthrin (3)	H	H	H	H	H	H	H	H	H	H	H	H	H
Cyhalothrin (gamma/lambda) (3)	H	H	H	H	H	H	H	H	H	H	H	H	H
Cyromazine (17)	O	M	M	O	O	O	O	M	O	O	O	O	O
Diazinon (1)	H	H	H	H	H	H	H	H	H	H	H	H	H
Dicofol (20)	H	S	S	S	S	S	S	S	M	H	S	S	H
Dimethoate (1)	H	H	H	H	H	H	H	H	H	M	H	H	H
Dinotefuran (4)	M	M	M	M	H	M	H	H	H	H	H	M	H
Emamectin (6)	H	O	H	O	H	H	S	O	H	H	H	O	S
Endosulfan (2)	H	H	H	H	H	H	H	H	M	H	H	H	H
Esfenvalerate (3)	H	H	H	H	H	H	H	H	H	H	H	H	H
Fenpropathrin (3)	H	H	H	H	H	H	H	H	H	H	H	H	H
Imidacloprid (4)	M	M	M	M	H	M	H	H	H	H	H	M	H
Indoxacarb (22)	S	S	S	S	H	S	S	S	H	S	S	O	H
Malathion (1)	M	H	H	H	H	H	H	H	H	H	H	H	H
Methamidophos (1)	H	H	H	H	H	H	H	H	H	H	H	H	H

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Beneficial Insects/ Mites **Pest Management Tools (IRAC MoA Class)**	Beneficial mites	Big-eyed bugs	Damsel bugs	Ground beetles	Honey bees	Lace-wings	Ladybird beetles	Minute pirate bugs	Parasitic wasps	Preda-tory midges	Preda-tory thrips	Spiders	Syrphid fly larvae
Registered materials													
Methomyl (1)	H	H	H	H	H	H	H	H	H	H	H	H	H
Methoxyfenozide (18)	O	O	S	O	O	O	O	S	O	O	O	O	O
Oils (no class)	M	O	O	O	O	S	S	O	S	S	S	O	S
Oxamyl (1)*	H	H	H	H	H	H	H	H	H	H	H	H	H
Permethrin (3)	H	H	H	H	H	H	H	H	H	H	H	H	H
Pymetrozine (9)	O	O	O	O	O	O	O	O	O	O	O	O	O
Pyrethrins + Rotenone (3)	M	M	M	M	H	M	M	M	M	M	M	M	M
Pyrethrins + PBO (3)	M	M	M	M	H	M	M	M	M	M	M	M	M
Pyriproxyfen (7)	S	S	S	S	O	S	H	S	S	S	S	S	M
Soaps (no class)	H	M	M	S	O	H	M	S	M	M	M	O	M
Spinosad (5)	M	S	S	S	H	M	M	S	M	S	S	O	S
Spiromesifen (23)	M	O	O	O	O	S	S	S	S	S	S	O	S
Sulfur (8)	M	S	S	S	S	S	S	S	S	S	S	O	S
Tebufenozide (18)	O	O	S	O	O	O	O	S	O	O	O	O	O
Thiamethoxam (4)	S	M	H	M	H	S	H	H	H	H	H	M	H
zeta-Cypermethrin (3)	H	H	H	H	H	H	H	H	H	H	H	H	H

Toxicity scale: O=nontoxic; S=slightly toxic; M=moderately toxic; H=highly toxic.
*When applied on foliage.