Crop Profile for Peppers (Bell) in Florida

General Production Information

- Florida is the leading U.S. producer of bell peppers.
- Florida produces 42 percent of the total U.S. crop, and 100 percent of the domestically produced winter crop.
- Approximately 23,734,000 bushels of fresh bell peppers, valued in excess of $219.8 million (1), were produced during the 1993-94 crop year on 21,300 acres (2).
- Production costs vary with region, cropping system, and other factors, and can be as much as $9,662 per acre in the southwest Florida production region (3).
- Almost 90 percent of the state's pepper acreage is located in Florida counties south of Orlando.

Production Practices

Nearly all peppers grown in Florida are produced using multiple row transplants placed in polyethylene plastic-mulch raised beds. Transplants are typically planted from August through March (although peppers are present in the field in some area of Florida every month of the year). Fruit are harvested by hand two, three, or several more times per planting, depending on the production region. The plants are in the field from 2.5-5 months (10), depending on the season of the year. The average harvested yield is

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approximately 1,000 bushels per acre. Most varieties in use are tolerant to some strains of tobacco mosaic virus. Disease tolerant pepper varieties used in commercial production include Boynton Bell, X3R Camelot, Capistrano, Enterprise, Jupiter, King Aurthor, S3R Lancelot, Summer Sweet 860, and Valiant (4).

Peppers are subject to damage from many insect, nematode, fungal, viral, bacterial, and weed pests. Broadspectrum fumigants, such as methyl bromide, have shown to be effective in reducing soilborne pest populations resulting in an increase in pepper crop yields. Methyl bromide is applied approximately two weeks prior to planting transplants, and manages pests such as *Fusarium, Phytophthora, Pythium, Rhizoctonia*, wireworms, cutworms, rootworms, grubs, nematodes such as stubby-root, dagger, sting, ring, awl, cyst, spiral, lance, root-lesion, reniform, root-knot and stunt, broadleaf weeds, grassy weeds, and sedge weeds. Methyl bromide is applied to approximately 91 percent of Florida's pepper acreage (2). It is injected into the soil during construction of the raised-beds. Each bed is then immediately covered with plastic mulch. A single application of methyl bromide/chloropicrin is administered, at an average rate of approximately 175 pounds of product per acre. Total methyl bromide usage on Florida peppers is estimated to be 3,395,500 pounds of active ingredient annually (2).

**Chemical and Non-chemical Control Alternatives to Methyl Bromide**

Experts assert that no management strategy, described to date, can be relied upon exclusively for soilborne pest control to the level that methyl bromide has provided (4).

Also, where double cropping is practiced, data shows 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 recently in Florida show that no single, equivalent replacement (chemical or nonchemical) currently exists that exactly matches the broad spectrum efficacy of methyl bromide. In demonstration trials, soil solarization proved to be inadequate for nematode, weed, or disease management. Use of composted municipal solid wastes were shown to be non nematicidal, and did not enhance the ability of plants to tolerate root infection by root-knot nematodes. A summary of chemical alternatives research suggests that a chemical cocktail of different fumigants (i.e., 1,3-dichloropene with chloropicrin) and a separate, but complementary herbicide treatment (ex. pebulate) will be required to achieve what appears to be a satisfactory bell pepper yield response. The future success for development of nonchemical alternatives for effective soilborne pest and disease management 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 management and crop yields. However, the lack of sufficient research funding and the proximity of the currently defined phaseout date of January 1, 2005 are major obstacles to evaluation, development, and implementation of many of the proposed nonchemical alternatives (11).

**Insect Pests**

Primary insect/mite pests on Florida peppers include pepper weevils, caterpillar-type pests (armyworms, beet armyworms, Southern armyworms, yellowstriped armyworms, cutworms, and loopers), melon thrips, Western flower thrips, aphids, broad mites, and vegetable leafminers (4,9).

**Pepper Weevils.** Pepper weevils are shiny, brownish-black 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. Damaged fruit become contaminated by insect parts, frass and rotted tissue, and eventually fall from the plant. Black nightshade management is important as this weed can serve as a secondary host to pepper weevil during fallow periods. Timing of management practices is critical in managing and/or preventing this pest (4).

**Caterpillar-type pests** (armyworms, beet armyworms, southern armyworms, yellowstriped armyworms, 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 larva 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 (4).

**Melon Thrips.** Melon thrips is a recently introduced pest, first detected in southern Dade county in December 1992. 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 silverying, 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 (4).

**Western Flower Thrips.** Western flower thrips cause flower abortion and poor fruit set because the adult female inserts an egg in flower parts and very small fruit. This pest is also a vector of tomato spotted wilt virus (4).

**Aphids.** Aphids are soft-bodied, sucking insects that can rapidly colonize plants due to short generation time and efficient dispersal ability. 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 and pepper mottle. 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, rejecting, flying to another plant and probing again, rather than by feeding by colonizing aphids.

**Broad mite.** Broad mite adults are tiny, white, eight-legged 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.

**Leafminers.** Adult leafminers are a small fly, approximately 3/32 inch long, with a black head, yellow between the eyes and black thorax. Females have a tube-like 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, sickle-shaped mouth hooks, feeds between the upper and lower leaf surface for approximately seven days, leaving a serpentine mine containing a black string of frass (fecal matter).
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 on in order to incorporate new technologies and to adapt to new pests introduced into Florida, such as whiteflies and thrips.

**Non-chemical:**

Beneficial insects. Parasitic wasps (Hymenoptera: Braconidae and Chalcidoidea) generally kill their host in order to complete development to the adult. Adults may act as predators, too, by feeding on hemolymph (blood) from wounds made with the ovipositor (egg laying "stinger") of unused hosts. Eggs are often laid through a needle-like ovipositor into or near the insect host. Larvae are tiny and maggot-like, developing inside or feeding on their insect hosts that may include any pest species. Lysiphlebus is a small wasp that attacks aphids, laying their eggs inside the host and converting it to a bloated brownish "mummy" from which the adult emerges through a round hole in the abdomen.

Predator insects consume numerous prey through their lifetime. Minute pirate bugs are small (5/64 inch) insects that feed on insect eggs, thrips and mites. Green lacewings larvae have long sickle-like mandibles and feed on aphids, insect eggs, and small caterpillars. Ladybird beetle adults and larvae feed on insect eggs, aphids, mites and small caterpillars. Spiders are noninsect arthropods that are predaceous on a wide variety of insects.

Other nonchemical practices producers traditionally practice include pest population monitoring, ditchbank weed management, immediate crop residue destruction, using resistant varieties (when the variety is marketable), planting certified pest-free plants, and sanitation.

**Chemical:**

Commonly used insecticides on Florida peppers include acephate, chlorpyrifos, methomyl, dicofol, permethrin, esfenvalerate, oxamyl, imidaclorpid, abamectin, endosulfan, and *Bacillus thuringiensis* (B. t.). Insecticides are applied by ground application equipment.

- ** METHOMYL - (Lannate)** (median $/lb. a.i., $23.33) (3 day PHI) Methomyl is the insecticide growers utilize and depend upon the most in their broad spectrum insect pest management programs. Methomyl is a carbamate-type insecticide used mainly to manage caterpillar-type pests and aphids. It is applied to approximately 73-92 percent of the pepper acreage an average of 5.7-7.9 times, at a rate of approximately 0.56 pounds of active ingredient per acre. Total methomyl usage on peppers is estimated to be 49,800-58,900 pounds of active ingredient annually (2).
- **OXAMYL - (Vydate)** (median $/lb. a.i., $25.00) (7 day PHI) Oxamyl is the insecticide that is the industry standard in managing pepper weevils. It is a carbamate insecticide, and is also used by pepper producers to manage thrips, aphids, leafminers, and nematodes. Oxamyl is applied to approximately 19-41 percent of the pepper acreage an average of 2.4-3.1 times, at a rate of approximately 0.64-0.71 pounds of active ingredient per acre. Total oxamyl usage on peppers is estimated to be 6,100-16,100 pounds of active ingredient annually (2). There are currently no alternative chemicals as efficacious as oxamyl in managing populations of pepper weevil (6).

- **DICOFOL - (Kelthane)** (median $/lb. a.i., $13.00) (2 day PHI) Dicofol is an organochlorine miticide applied to approximately 25-39 percent of the pepper acreage an average of 1.4-2.0 times, at a rate of approximately 0.29-0.43 pounds of active ingredient per acre. Total dicofol usage on peppers is estimated to be 3,600-4,400 pounds of active ingredient annually (2). Under the proposed Reregistration Eligibility Decision document issued by EPA in November of 1998, the following risk mitigation measures would have to be followed when using dicofol on bell peppers: a) dicofol applications would be limited to no more than 1 per year; b) the application must not exceed 0.75 pounds of active ingredient per acre; and, c) applicators must use enclosed tractor cabs to apply dicofol.

- **PERMETHRIN - (Ambush/Pounce)** (median $/lb. a.i., $54.76) (3 day PHI) Permethrin is a synthetic pyrethroid insecticide used primarily to manage leafminers. It is applied to approximately 22-65 percent of the pepper acreage an average of 5.5-7.0 times, at a rate of approximately 0.12-0.14 pounds of active ingredient per acre. Total permethrin usage on peppers is estimated to be 3,100-11,500 pounds of active ingredient annually (2). Synthetic pyrethroids are used only on an "as needed" basis because: 1) they have a history of pest resistance problems; 2) they upset the balance of natural/beneficial organisms in pepper fields; and, 3) they tend to stimulate population surges of thrips (6).

- **ACEPHATE - (Orthene)** (median $/lb. a.i., $14.00) (7 day PHI) The organophosphate insecticide most extensively used by pepper growers typically is acephate. Acephate is used to manage all caterpillar-type pests, and it is also the material of choice to manage periodic outbreaks of aphids (6). It is applied to approximately 15-24 percent of the pepper acreage an average of 3.4-4.5 times, at a rate of approximately 0.62-0.69 pounds of active ingredient per acre. Total acephate usage on peppers is estimated to be 7,500-14,600 pounds of active ingredient annually (2).

- **CHLORPYRIFOS - (Lorsban)** (median $/lb. a.i., $12.23) (7 day PHI) Chlorpyrifos [Special Local Need 24(c) labeling on pepper for Florida] is an organophosphate insecticide that is an important "clean-up" insecticide used in the overall management scheme for beet armyworms. Chlorpyrifos is applied to approximately 25-30 percent of the pepper acreage at a rate of approximately 1.0 pound of active ingredient per acre (6).

- **ENDOSULFAN - (Thiodan)** (median $/lb. a.i., $11.34) Endosulfan is a chlorinated cyclic diol insecticide that is used for management of caterpillar-type pests, aphids, and whiteflies. It is
applied to approximately 11-39 percent of the pepper acreage an average of 1.5-2.7 times, at a rate of approximately 0.69-0.72 pounds of active ingredient per acre. Dependent on rate used, endosulfan has a 1 to 4 day preharvest interval on pepper. Total endosulfan usage on peppers is estimated to be 2,500-16,500 pounds of active ingredient annually (2).

- **Bacillus thuringiensis** - (median $/lb. a.i., $138.20) (0 day PHI, but Restricted Entry Interval of 4 hours) B.t. is used in a prophylactic manner by Florida pepper growers; however, if worms are larger and more mature, or if worm populations exceed threshold levels, then acephate, chlorpyrifos, or methomyl are commonly used. B.t. is applied to approximately 97 percent of the pepper acreage an average of 9.6-12.1 times (2,6).

- **ESFENVALERATE** - (Asana) (median $/lb. a.i., $199.67) (7 day PHI) Esfenvalerate is a synthetic pyrethroid insecticide used in management of caterpillar-type pests. It also can aid in management of pepper weevils. Esfenvalerate is applied to approximately 19-30 percent of the pepper acreage an average 3.2-4.2 times, at a rate of approximately 0.04-0.05 pounds of active ingredient per acre. Total esfenvalerate usage on peppers is estimated to be 600-1,000 pounds of active ingredient annually (2). Like permethrin, esfenvalerate is used only on an "as needed" basis because: 1) it has a history of pest resistance problems; 2) it upsets the balance of natural/beneficial organisms in pepper fields; and, 3) it tends to stimulate population surges of thrips (6).

- **IMIDACLOPRID** - (Admire/Provado) (median $/lb. a.i., $277.50) Imidacloprid is a chloronicotinyl insecticide used primarily to manage thrips (Admire), but it is also used in management of whiteflies and aphids. Imidacloprid is applied to approximately 17 percent of the pepper acreage an average of 1.1 times, at a rate of approximately 0.44 pounds of active ingredient per acre. Total imidacloprid usage on peppers is estimated to be 1,800 pounds of active ingredient annually (2). Foliar applications of imidacloprid (Provado) 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 (Admire) have a preharvest interval of 21 days. Grower surveys conducted in Florida on the use of imidacloprid indicate that using this insecticide reduces the total number of necessary foliar insecticide applications. More than 90 percent of growers believed that imidacloprid use allows for more use of less toxic pesticides, and that it contributes to greater flexibility with farmworkers. Nearly 60 percent believe that imidacloprid use allows for greater utilization of beneficial insects. Growers also believe that using imidacloprid results in more than a 14 percent reduction in production costs, and an additional 13 percent increase in yield (12).

- **ABAMECTIN** - (Agri-Mek) (median $/lb. a.i., $6,156.00) (7 day PHI) Abamectin is a soil bacterium derivative used to manage leafminers, mites, and thrips. It is applied to approximately 11-13 percent of the pepper acreage an average of 1.5 times, at a rate of approximately 0.008-0.01 pounds of active ingredient per acre. Total abamectin usage on peppers is estimated to be less than 50 pounds of active ingredient annually (2).
Diseases

Peppers are subject to attack from many disease-causing organisms including fungi, bacteria, and viruses. In addition, many physiological disorders, such as blossom-end rot can cause serious losses in pepper crops. Primary disease problems on Florida peppers includes damping-off, frogeye leaf spot, Southern blight, Phytophthora blight, Erwinia soft rot, gray leafspot, Sclerotinia stem rot, wet rot, Anthracnose, and viruses (4,5).

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, water-soaked, 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 spreads the bacterium.

Damping-off. Certain fungi usually present in the soil, such as Rhizoctonia solani and Pythium species, rot seed or damage seedlings. Plants attacked shrivel at the ground line and usually die. The disease is worse during damp conditions and can be serious in transplant production houses.

Frogeye spot. Sometimes called Cercospora spot, this disease is distinguished by large, circular or oblong leaf lesions that have light gray centers and dark brown margins. Field infection can often be traced to infected seedlings grown from contaminated seed.

Southern blight. 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 salmon-colored bodies (sclerotia). The fungus persists in the soil as sclerotia for many years and is most active in poorly drained fields, during hot weather.

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

Erwinia soft rot. This bacterial disease is a mushy, wet fruit rot that occurs primarily after harvest and during shipment. In the field, the fruit soften and sag from the plant. The rot is accompanied by a foul odor.
**Gray leafspot.** This disease appears as circular spots on leaves. The spots are at first brown, later turning tan, and then white, with sunken centers and reddish margins. The symptoms can appear on stems and pedicels but have not been observed on fruit.

**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 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.

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

**Viruses.** Several viruses, including pepper mottle, potato Y, tobacco etch, and tobacco mosaic, 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 vectors. These viruses are known to survive in several weeds, including ground cherry, nightshades, common groundsel, wild tobacco, toadflax, sicklepod, and jimson weed.

**Blossom-end rot.** A common problem of peppers, this disorder is not caused by bacteria, fungi, or virus. Blossom-end rot is related to low-water stress and calcium deficiency, often in association.

### Control

**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 fungicide-treated seed. Clean seed is the first course of action in frogeye spot management. 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 disease-free transplants and rotation are important components of a Phytophthora management program, and planting in low, poorly drained fields must be avoided. Management of Erwinia soft rot in the field centers around reducing fruit damage from any source, especially insects. Also, avoid bruising the fruit during harvest, and in the
packinghouse, use chlorinated water for washing and pack only unblemished and sound fruits. To manage wet rot, maintain proper plant spacing 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. Oil sprays have been approved in Florida for certain viruses. The oil interferes with the feeding by the aphid, thus inhibiting its ability to spread the virus. To manage blossom-end rot, maintain adequate soil moisture and calcium levels, and avoid late season cultivation that damages root systems and reduces the ability to obtain calcium. Calcium moves in the water stream of the plant, so it does not move preferentially to fruits, but to leaves. Excessive nitrogen can lead to excessive vegetation and encourage low calcium transport to fruits (4).

Chemical:

Fungicides used to manage diseases on susceptible varieties of peppers (following field fumigation with methyl bromide), after plants are established in the field, are primarily limited to the coppers, maneb, chlorothalonil, and mefanoxam/metalaxyl (4). Fungicides are applied by ground application equipment.

- **MANEB** - *(Maneb/Manex)* (median $/lb. a.i., $6.00) (7 day PHI) Maneb is composed as manganese ethylenebisdithiocarbamate (EBDC). It is classified as a B2 carcinogen, and used to manage diseases such as frogeye leaf spot, Phytophthora, and Anthracnose (5,7). Maneb, when tank-mixed with a copper fungicide, is also used for bacterial spot management. Maneb is applied to approximately 73-94 percent of the pepper acreage an average of 10.5-12.1 times, at a rate of approximately 1.01-1.18 pounds of active ingredient per acre. Total maneb usage on peppers is estimated to be 196,700-247,300 pounds of active ingredient annually (2).

- **COPPER** - *(Kocide/Champ)* Copper fungicides are used to manage various pepper diseases including bacterial spot, Erwinia soft rot, and frogeye leaf spot (5,7). Copper hydroxide is applied to approximately 85-90 percent of the pepper acreage an average of 10.4 times, at a rate of approximately 0.84-0.9 pounds of active ingredient per acre. Copper hydroxide may be legally applied on peppers right up to the day of harvest (PHI = 0 days), but the restricted entry interval under the Worker Protection Standard for copper hydroxide is 48 hours. Total copper hydroxide usage on peppers is estimated to be 164,800-180,300 pounds of active ingredient annually (2).

- **METALAXYL** - *(Ridomil)* (median $/lb. a.i., $79.39) (7 day PHI) Metalaxyl is used to manage damping off and Phytophthora (5,7). Metalaxyl is applied to approximately 23 percent of the pepper acreage an average of 1.2 times, at a rate of approximately 0.8 pounds of active ingredient per acre. Total metalaxyl usage on peppers is estimated to be 4,700 pounds of active ingredient annually (2).

**Nematodes**
Plant parasitic nematodes, are small microscopic roundworms that live in the soil and attack the roots of plants. Pepper production problems induced by nematodes 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 pepper production in Florida. In many cases a mixed community of plant parasitic nematodes is present in a field, rather than having a single species occurring alone. In general, the most widespread and economically important nematode species include the root-knot and sting nematodes. The host range of these nematodes, as with others, includes most if not all of the commercially grown vegetables within the state. Yield reductions can be extensive but vary significantly between plant 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, which contributes to additional yield reductions.

Typical symptoms of nematode injury to pepper can involve both aboveground 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.

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.

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 stunted 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 root-knot 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, tumorous 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 root-knot nematode. Symptoms of any pepper root galling can, however, provide positive diagnostic confirmation of nematode presence, infection severity, and potential for crop damage.
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.

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.

### 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 so as to avoid potentially significant pepper yield losses. Currently, nematode management considerations include crop rotation of less susceptible crops or resistant varieties, cultural and tillage practices, and the use of transplants. Where practical, these practices are generally integrated into the summer or winter 'off-season' cropping sequence. It should be recognized that not all land management and cultural control practices are equally effective in controlling plant parasitic nematodes and varying degrees of nematode control should be expected. These methods, unlike other chemical methods, tend to reduce nematode populations gradually through time. Farm specific conditions, such as soil type, temperature, moisture, can be very important in determining whether different cultural practices can be effectively utilized for nematode management.

High yielding fresh market bell type pepper varieties with resistance to *M. incognita* are currently not commercially available as a tactic for nematode management. Two newly developed root-knot nematode resistant varieties (Carolina Belle and Carolina Wonder) were released from the USDA Vegetable Research Laboratory for commercial seed increase in April 1997. Both varieties are open pollinated, and homozygous for the northern root-knot nematode resistant gene. Plant size is small and pepper yield
relatively low compared current commercial standards. Preliminary research has demonstrated that these varieties confer a high degree of resistance to the root-knot nematode, however expression of resistance is heat sensitive. Further research is necessary to characterize the usefulness of these varieties under the high soil temperature conditions of Florida. Like tomato, use of these varieties may have to be restricted to spring plantings when cooler soil temperatures prevail. It is also apparent from some field trials, that even highly resistant pepper varieties can suffer appreciable yield losses if initial root-knot nematode population densities are too high.

Presently, pepper plant resistance to root-knot nematode is thought to be conferred by as many as five plant genes. In a number of previous studies, low level reproduction of the root-knot nematode has occurred on these supposedly highly resistant pepper varieties. Given the potential development of resistance-breaking races of the root-knot nematode after repeated planting of these resistant crop varieties, it may also be necessary to alternate the use of resistant and susceptible pepper varieties to avoid population shifts of nematodes towards resistance-breaking races.

Other cultural measures that reduce nematode problems include rapid destruction of the 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 pepper 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 should 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. In these cases some form of pesticide assistance will still usually be necessary to improve crop production (4).

**Chemical:**

In Florida, extensive use of broadspectrum fumigants like methyl bromide and chloropicrin have been shown to effectively reduce nematode populations and increased pepper crop yields, particularly when compared with nonfumigant nematicides. Since fumigant products must diffuse through soil as gases to be effective, the most efficient fumigations occur when the soil is well drained, in seedbed condition, and at temperatures above 60 degrees. All of the fumigants are phytotoxic to plants. All of the nonfumigant nematicides currently registered for use are soil applied. They must be incorporated with soil or carried by water into soil to be effective. These compounds must be uniformly applied to soil, targeting the application toward the future rooting zone of the plant, where they will contact nematodes or, in the case of systemics, in areas where they can be readily absorbed. Further chemical control information for nematodes is discussed above in the Production Practices, Chemical and Non-chemical Alternatives to Methyl Bromide, and Insect/Mite Chemical Control sections.
Weeds

All weeds in the production beds are initially controlled by methyl bromide (see Production Practices section for discussion of methyl bromide use). 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. The greatest row-middle weed management problems confronting the pepper industry today is control of nightshade and dodder. 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 with dodder, control of the dodder in the row middle will not control the infection, and 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 (2,4,8).

Controls

Non-chemical:

The most widely used non-chemical weed management measures include plastic mulches, crop rotation, and hand weeding. Plastic mulch by itself is not effective in suppressing perennial weeds because weed emergence occurs through plant holes cut into the plastic. Hand weeding the row middles between the production beds is a laborious, time-consuming, and expensive exercise. Mechanical cultivation to control weeds in mulched row middles is difficult due to the potential of tearing of the polyethylene mulch.

Chemical:

In the Florida pepper production system, herbicides are applied only to the row middles between the raised production beds to manage grass, broadleaf, and sedge weed pests. Care is always 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 pepper production season (8). Herbicides used include paraquat, diquat, enquik, metolachlor, napropamide, sethoxydim, and trifluralin (8,10).

- PARAQUAT - (Gramoxone) (median $/lb. a.i., $13.50) (21 day PHI) Paraquat is a non-selective, post-emergent herbicide applied to approximately 35-55 percent of the pepper acreage an average of 1.7 times, at a rate of approximately 0.68 pounds of active ingredient per acre. Total paraquat usage on peppers is estimated to be 8,500-9,200 pounds of active ingredient annually (2,10).

- MCDS - (Enquik) Enquik is a post-emergent herbicide applied to approximately 5 percent of the
pepper acreage an average of 1.5 times, at a rate of approximately 79.8 pounds of active ingredient per acre. Total enquik usage on peppers is estimated to be 131,700 pounds of active ingredient annually (2). According to the Enquik label (EPA Registration Number 68891-1 dated 20 February, 1996), this product's preharvest interval "is not restricted".

- **DIQUAT** - (30 day PHI) Diquat is a non-selective post-emergent herbicide. Use of diquat on pepper is allowed only by a Florida 24(c) Special Local Need registration. Diquat is used to manage weeds in row middles and to burndown the pepper plants after final harvest. Diquat is applied to approximately 30-65 percent of the pepper acreage an average of 1-2 times, at a rate of approximately 0.5 pounds of active ingredient per acre (8,10).

- **METOLACHLOR - (Dual)** (median $/lb. a.i., $8.23) (60 day PHI) Metolachlor is sprayed pre-transplant or post-transplant for preemergent management of weeds. Its use on pepper is allowed only by a Florida 24(c) Special Local Need registration. It is applied to approximately 30 percent of the pepper acreage one time, at a rate of approximately 1.5 pounds of active ingredient per acre (8,10).

- **NAPROPAMIDE - (Devrinol)** (median $/lb. a.i., $22.00) Napropamide is a preplant incorporated herbicide thoroughly worked into row middle soils for management of germinating annual weeds. It is applied to approximately 30 percent of the pepper acreage an average of one time at a rate of approximately 1-2 pounds of active ingredient per acre (8,10).

- **TRIFLURALIN - (Treflan)** (median $/lb. a.i., $7.22) Trifluralin is another preplant incorporated herbicide incorporated to row middles. It is applied to approximately 1-5 percent of the pepper acreage an average of 1.0 time at a rate of approximately 0.5-1.0 pounds of active ingredient per acre (10).

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