Crop Profile for Tomatoes in Tennessee

Prepared: December, 2001
Revised: July 10, 2002

General Production Information

(Lycopersicon esculentum) During 2000, Tennessee was ranked 7th in the nation for production of fresh-market tomatoes, and tied with production in Georgia and Virginia. Tennessee produces approximately 3 percent of U.S. fresh-market tomatoes. During 2001, reports by the Tennessee Department of Agriculture, Agricultural Statistics Service estimated 3,600 acres were planted and 3,000 were harvested. This is a fairly conservative estimate and state Extension specialists believe that an additional 1,200 acres were planted during 2001, however only an additional 500 acres were harvested. State Extension specialists indicated that the total harvested acreage was less than planted acreage due to losses during spring floods which occurred in Eastern Tennessee.

Tennessee also has approximately 500 tomato greenhouses, which average between 2,500 and 2,800 square feet each. Greenhouses of this size would contain approximately 750 to 800 plants. The average yield would be between 10 lbs per plant. An estimate of total greenhouse tomato production is approximately 3,750,000 lbs which is estimated at a value of $1.35 million for the 2001 wholesale market.

Official 2001 figures from Tennessee Agricultural Statistics Service indicate that average yields were 8.25 tons per acre, resulting in total state production of 24,750 tons of fresh-market tomatoes and were valued at $9.90 million. University specialists dispute this estimate and believe that 58,125 tons of fresh-market tomatoes were harvested during 2001 and would have been valued at $41.85 million in the wholesale market.

State researchers and crop specialists work closely with growers and the industry. State crop specialists estimate that the statewide per-acre yields were 30,000 lbs per acre for tomatoes in plastic culture production and 15,000 lbs per acre in non-plastic production during 2001. Approximately 1,875 tons were greenhouse produced tomatoes. Average market price of fresh market tomatoes was $9.00 per 25-pound box, this would result in a total value of $1.35 million dollars for 2001. Average retail pricing was approximately between $0.50 to $1.00 per lb. during peak production in Tennessee. Production costs for fresh-market tomatoes is generally $7,500 to $9,500 per acre. All Tennessee tomato production was destined for fresh market.

Three major varieties are 'Mountain Spring', Mountain Fresh' and 'Florida 47'. These three varieties account for more than 50% of all acreage of commercially planted tomatoes. Other varieties that are
produced commercially include 'BHN 444', 'BHN 543' and 'Floralina'.

Production Regions

There are three major production areas for fresh-market tomatoes in the state—western Tennessee (Lauderdale county), eastern Tennessee (Cocke, Grainger, Washington, Unicoi, Greene and Hamblen counties) and east-central Tennessee (an area known as Walden's Ridge which includes Bledsoe and Rhea counties). Other production is scattered across the state.

Cultural Practices

Tomatoes are grown on a wide range of soil types in Tennessee, from rich, silty loams in the western part of the state to silty river bottoms of the eastern region. Standard production practices include use of methyl bromide fumigation, raised beds, black polyethylene plastic-culture mulch, and drip-irrigation. Rows are usually spaced 4 to 6 feet apart, and plants are spaced at 18 inches within the row. Most growers produce their own transplants in greenhouses. Some transplants are purchased from Florida. Tomatoes are staked, pruned, and tied using the Florida string-weave system. All varieties are determinate, slicing-type tomatoes, and with the exception of a few cherry types.

Full-season production takes place in western Tennessee, with planting beginning in mid-April. The production season is later in eastern and central counties, with mid-May to mid-June plantings. Late season production is practiced in eastern and western Tennessee, with late-June plantings. Much of the production is for mature green tomatoes, although there is some vine-ripe production in all areas. It is difficult to plant early season in eastern Tennessee due to frost risks and all regions produce till fall frosts occur.

The majority (75-80%) of tomato transplants are set using a water wheel transplanter, with the remainder be planted using a mechanical transplanter (5-15%) and/or hand set (10-20%). All tomato transplants will have some type of physical contact by individuals who ride planters or if transplants are hand set. Tomatoes are hand-harvested. Approximately 65% of the tomato acreage harvested is harvested using migrant workers. Due to the implementation of the Worker Protection Standards, state producers are required to provide personal protective equipment to migrant workers. Many migrant workers have requested for producers to provide rubber dishwashing type gloves for use during planting, pruning and/or harvesting. Since the inception of the Worker Protection Standard (WPS) and the increase of migrant workers into the state, the use of chemical resistant gloves has been on the rise. The majority (75%) of transplants have insecticide(s) applied to them as a preventative, when plants are grown in the
greenhouse. Primary targeted pests during this time include, aphids and thrips.

The majority of commercially produced tomatoes are hand pruned/suckered approximately 3 weeks after transplanting and in large scale plantings this the only time that suckering occurs in tomato production. On smaller scale truck crop plantings, producers sucker continually throughout the season. This would occur only 5-10% of the crop acreage.

Many commercial fields are stripped 2 to 4 times for mature green fruit, which is then exposed to ethylene to begin the ripening process. However, until enough mature green fruit is present, vines are roughed for fruit that is beginning to turn red. Some producers (25%) field pack tomatoes (box them in the field as they are harvested). This method of harvest may occur over an 8 week period and may be harvest 10-16 times per season.

Most irrigation in tomato production is trickle irrigation. Installation normally occurs prior to planting and little, if any manipulation of lines occurs after initial installation.

The majority of weeds in commercial tomato production are controlled by use of chemicals and not by physical removal.

Most large scale tomato producers hire migrant workers or individuals located near their community. Tennessee producers are required by federal and state laws to follow safety standards known as the Worker Protection Standards (WPS). The Worker Protection Standards are regulations which cover pesticide usage in agricultural, forest, nursery and greenhouse production. Any Tennessee producer employing individuals to work in agricultural production must inform and/or train workers concerning the Worker Protection Standards. Worker Protection Standards are standards which are to be followed by employers to help eliminate possible pesticide contamination of pesticide applicators, handlers or workers. Information pertaining to pesticide application must be posted in a central location. Information concerning products used, location of application and re-entry interval is posted at the central location. Also, other items pertaining to safety are provided to workers, applicators and/or handlers. Commercially product tomatoes are normally sprayed on a schedule basis, so it is a constant balancing act to maintain REI’s and PHI’s. Table 1, includes re-entry intervals of products commonly used in Tennessee tomato production. If workers, handlers and/or applicators must enter the field earlier than indicated by the pesticide label, individuals maybe required to wear certain personal protective equipment. In most cases this includes boots, gloves, hat, long sleeve shirts, and long legged trousers. The Signal Word indicated by Caution, Warning or Danger are indicators of the level of human hazard which may vary between formulations containing the same active ingredient. The Signal Word lets the applicator, handler or worker know the relative toxicity of a product. Early re-entry is generally not necessary in Tennessee tomato production. Treated areas are also posted to inform workers that treatments have been made and re-entry is restricted. If employers and employees follow WPS regulations, harvest interval and re-entry intervals, agricultural workers are less likely to be at risk to pesticide exposure in Tennessee agricultural production.
<table>
<thead>
<tr>
<th>Pesticide Type</th>
<th>Active Ingredient</th>
<th>Re-entry Interval</th>
<th>Signal Word</th>
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<tr>
<td><strong>Fungicides</strong></td>
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<tr>
<td></td>
<td>Chlorothalonil</td>
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<td>Mancozeb</td>
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<tr>
<td></td>
<td>Maneb</td>
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</tr>
<tr>
<td></td>
<td>Mefenoxam</td>
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</tr>
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<td>Benlate</td>
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<td></td>
<td>Terraclor</td>
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</tr>
<tr>
<td></td>
<td>Copper</td>
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<td><strong>Herbicides</strong></td>
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<td>Metribuzin</td>
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<tr>
<td></td>
<td>Trifluralin</td>
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<tr>
<td></td>
<td>Paraquat</td>
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</tr>
<tr>
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<td>Clethodim</td>
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</tr>
<tr>
<td></td>
<td>Sethoxydim</td>
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<tr>
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</tr>
<tr>
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<tr>
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</tr>
<tr>
<td>Cyromazine</td>
<td>12 hrs</td>
<td>Caution</td>
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</table>

* Signal word may vary depending on formulation of product used.
Insect Pests

Staked tomatoes are a high-value crop, and the tolerance level for damage is extremely low. Consequently, management programs for direct pests are designed to control insects before they damage fruit. In contrast, population densities of indirect pests (i.e., insects feeding on the leaves) can be allowed to become established before control measures are used. Most tomato producers are practicing a spray on schedule method of control. At least 14 species of insects and mites can infest tomatoes in Tennessee. However, only six of these insects (tomato fruitworm, stink bugs, thrips, aphids, Colorado potato beetle and flea beetles) are common in the majority of fields throughout the state, while the remaining eight insects occur more sporadically from field to field and from year to year.

Insecticides used during 2001 tomato production

<table>
<thead>
<tr>
<th>Product</th>
<th>Ave. number of apps.*</th>
<th>% acreage treated</th>
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<tr>
<td>Sulfur</td>
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</tr>
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<tr>
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<tr>
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<td>40</td>
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<tr>
<td>Spinosad</td>
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<tr>
<td>Azinophos-methyl</td>
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<td>40</td>
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<tr>
<td>Lambda-cyhalothrin</td>
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<tr>
<td>Cyfluthrin</td>
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<td>25</td>
</tr>
<tr>
<td>Carbaryl</td>
<td>4</td>
<td>35</td>
</tr>
<tr>
<td>others</td>
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<td>25</td>
</tr>
<tr>
<td>Endosulfan</td>
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<td>35</td>
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</table>
Tomato fruitworm, *Helicoverpa zea*

The tomato fruitworm, also called the corn earworm and cotton bollworm, is the most common direct pest of field-grown tomatoes in Tennessee. The state is on the northern-most fringe of the overwintering range of this insect, and the occurrence and/or abundance of overwintering pupae varies among different areas; fruitworm overwinters poorly in the eastern regions. However, immigrating populations from nearby areas ensure annual infestations in all production regions. Although the time of infestations varies among years, populations on tomatoes are generally highest in July and August and are generated from earlier infestations in nearby corn. Moths deposit eggs on tomato foliage, and control tactics aim to stop larvae as they hatch from eggs and before they bore into fruit. The closely related tobacco budworm, *Heliothis virescens*, sometimes infests tomatoes, and control strategies for this insect are the same as those for fruitworms.

**Biological control:**
A diversity of natural enemies can impact fruitworm populations on tomatoes, including egg parasites (*Trichogramma* spp. and *Telenomus helithidis*), larval parasites (*Camptotis sonorensis* and *Cotesia marginiventris*), and predators (*Orius insidiosus* and *O. Tristicolor*). However, because of the low tolerance for damage to tomatoes, the combined action of these natural enemies does not provide economic levels of control. Most Tennessee growers do not practice augmentative release of *Trichogramma* and poor quality of commercially available *Trichogramma* makes this approach questionable. Applications of *Bacillus thuringiensis* (*Bt*) products (Dipel, Xentari, Javelin, or Biobit HP @ 1 lb/acre) provide good control of fruitworms, but *Bts* are less effective than many synthetic insecticides against high-density populations. *Bts* also have no effect on other secondary pests which often occur in conjunction with fruitworm infestations.

**Cultural control:**
Early plantings of tomatoes have considerably less fruitworm, and whitefly pressure than later plantings.
However, simply planting earlier does not eliminate the need for control, and late frosts or cool conditions sometimes limit the overall utility of this management approach.

**Chemical control:**

*Esfenvalerate (Asana XL 0.66EC)* 1-day PHI with a rate range of 0.03 - 0.05 lbs active ingredient/acre. No more than 0.5 lbs ai per acre per season. Costs vary depending on rate or product used from $4.32 – 7.16 per acre for a one time application.

*Fenpropathrin (Danitol 2.4EC)* is a restricted use pesticide with a 3-day PHI. 0.2 lbs active ingredient/acre and not to exceed 0.8 lbs. ai per acre per season. Cost per acre is $11.43 per application.

*Methomyl (Lannate 2.4LV or 90SP)* is a restricted use pesticide and has a 1-day PHI. Rate range of 0.45- 0.90 lbs active ingredient per acre. No more than 7.2 lbs ai per acre per crop may be applied. Usage of this product may induce the outbreaks of leafminers. At a cost of $10.30 – 22.35 / acre depending on use rate and formulation used. Cost of LV formulation is slightly less than the price of SP formulation. No more than 16 applications per crop may be applied.

*Methamidophos (Monitor 4EC)* has a 7-day PHI with a rate range of 0.75 - 1 lb active ingredient/acre. State Label 24(c) registration for fresh fruit only. Cost of $15.54 – 20.72 per application depending on rate used.

*Spinosad (SpinTor 2SC)* 1-day PHI, rate range of 0.047 - 0.094 lbs active ingredient/acre. Spinosad is used for insecticide resistance management program. No more than 0.45 lbs ai per acre per crop. Do not apply more than 3 times during a 21 day period. Cost of this product was not available.

*Azinophos-methyl (Guthion 50WP, 2L)* is a restricted use pesticide with a 14-day PHI. Rates range from 0.75 - 1.5 lbs active ingredient/acre, possible development of resistance in aphids and Colorado potato beetle. No more the than 4 applications per season per acre. At a cost ranging from $4.70-9.40 per acre for the 2L formulation and a cost ranging from $8.10 – 10.80 / acre for the WP formulation depending on rates used.

*Lambda-cyhalothrin (Warrior T 1CS)* 5-day PHI. Rate range of 0.02 - 0.03 lbs active ingredient/acre. No more than 0.36 lbs ai per acre per season. Not to be used on cherry type tomatoes. Cost varies from $5.37 – 8.05 depending on rate used.

*Cyfluthrin (Baythroid 2)* is a restricted use pesticide and has a 0-day PHI with a rate range of 0.025 - 0.044 lbs active ingredient/acre. No more than 0.2625 lbs active ingredient per acre per season may be applied. Cost of $4.35 – 7.16 per application depending on rate used.

**Alternative chemical controls:**
Endosulfan (Thiodan/Phaser 3EC and 50WP @ 1 lb active ingredient/acre) has a 2-day PHI and is applied to approximately 35 percent of the acreage with an average of four times per season. Endosulfan is often rotated with a pyrethroid insecticide to improve stink bug control. The cost of an endosulfan application varies depending on formulation from $13.50 cost of WP and $9.87 for the EC formulation.

Carbaryl (Sevin XLR, 80S) has a 3-day PHI. It has a rate range of 1 – 2 lbs ai per acre per application. Up to 7 applications may be made with no more than 8 lbs active ingredient per acre per crop may be applied. Cost per acre per application varies with rate which is $7.83 – 15.75.

*Bacillus thuringiensis* subspecies *aizawai* and *kustaki* products (Dipel, Javelin, Biobit subspecies *kurstaki*, Xentari, Agree, Ketch, *aizawai* subspecies) are applied to approximately 50 percent of the acreage. These products have a 0-day PHI. Approximately 0.5 – 2 lbs formulation are applied per acre per application. Cost ranges from $4.05 – 18.20 per application.

**Stink bugs, *Euschistus servus, Acrosternum hilare***

The brown (*E. servus*) and green (*A. hilare*) stink bugs are common pests of tomatoes, although the severity of damage varies considerably among fields. Adults and immatures feed on developing fruit with their piercing mouth parts, causing discolored blemishes that render fruit unmarketable. Both species overwinter as adults in weeds and debris surrounding fields and migrate into tomato fields throughout the season. Stink bugs are very difficult to detect in tomatoes because they are easily startled and seek shelter when disturbed.

**Cultural control:** Cut grass or weeds in areas surrounding the field in late fall helps reduce overwintering populations.

**Chemical control:**

Insecticides are the only method of effectively controlling stink bugs and these are usually applied 4 times per season.

Endosulfan (Phaser/ Thiodan 3EC or 50WP) has a 2-day PHI at a rate of 1 lb active ingredient per acre. The cost of an endosulfan application varies depending on formulation used from $13.50 cost of WP and $9.87 for the EC formulation.

Methamidophos (Monitor 4EC) has a 7-day PHI with a rate range of 0.75 - 1 lb active ingredient per acre. Monitor has a State Label 24(c) registration for fresh fruit only. Cost of $15.54 – 20.72 per application depending on rate used.

**Alternative chemical controls:**
Other less effective products include diazinon (Diazinon 50WP and 4EC @ 0.5 lb active ingredient/acre is a restricted use pesticide has a 1-day PHI at a cost of $4.06 per application) and dimethoate (Dimethoate 4EC at 0.5 lb active ingredient/acre has a 7-day PHI at a cost of $4.54 per application) also control stink bugs, but they are used on less than 5 percent of the acreage. Pyrethroid insecticides generally provide poor control, although lambda-cyhalothrin (Warrior 1EC @ 0.025 lb active ingredient/acre has a 5-day PHI) is more effective than others with a cost of $6.60 per acre. Carbaryl (Sevin) at 1-2 lbs ai per acre has suppression activity against stink bugs at a cost of $7.83 – 15.75 per application.

**Thrips, Franklinellia fusca, F. occidentalis**

Thrips cause damage directly by ovipositing in small, developing fruit before stamens have been shed and indirectly by transmitting tomato spotted wilt virus (TSWV). In addition to tobacco thrips (F. fusca) and western flower thrips (F. occidentalis), flower thrips (F. tritici) also infest flowers, but only F. occidentalis causes direct damage through oviposition scars. Both F. fusca and F. occidentalis are vectors of TSWV, but F. fusca is more important on tomato.

**Chemical control:**
For flower infestations of F. occidentalis, methomyl (Lannate 90SP or 2.4LV) rate range of 0.45 - 0.9 lbs active ingredient per acre with a 1-day PHI and cost range of $10.31 – 20.63 per application. Methamidophos (Monitor 4EC) rate range of 0.75 - 1 lb active ingredient per acre with a 7-day PHI. This product has a State Label 24(c) registration for fresh fruit only. Cost of methamidophos ranges from $15.54 – 20.73 per application, imidacloprid (Admire 2F) rate range of 0.25 - 0.375 lbs active ingredient/acre with a 21-day PHI at a cost of $14.50 – 21.75 per acre. Imidacloprid is applied at transplant to the soil. Spinosad (SpinTor 2SC at a rate range of 0.062 - 0.125 lbs active ingredient per acre with a 1-day PHI). These products are the most effective options. F. occidentalis infestations on tomato have an aggregated distribution on a statewide basis, and these insecticides are used on a combination of 25 percent of tomato acreage. The value of chemical control of F. fusca and F. occidentalis to prevent the spread of TSWV is questionable; however, recent research has shown that transplant water applications of imidacloprid (Admire 2F @ 0.12 lb active ingredient/acre), which control foliar infestations of thrips, may be useful in protecting plants from TSWV transmission.

**Alternative chemical controls:**
Dimethoate (Dimethoate 4EC@ 0.5 lb active ingredient/acre with a 7-day PHI) at a cost of $4.54 per application.

Cyfluthrin (Baythroid 2 is a restricted use pesticide with a 0-day PHI to be used at a rate range of 0.0328 – 0.0437 lbs ai per acre) at a cost of $5.73 – 7.61 per application.
Fenpropathrin (Danitol 2.4EC) is a restricted use pesticide with a 3-day PHI, rate of 0.2 lbs ai per acre and no more than 0.8 lbs ai per acre per season. Cost of $11.42 per acre per application.

Carbaryl (Sevin 80SP or XLR) has some suppression activity against this pest at a rate range of 1 – 2 lbs active ingredient per acre. Cost of $7.82 – 15.75 per application.

Aphids, *Macrosiphum euphoribae, Myzus persicae*

Potato aphid (*M. euphoribae*) is a common pest of tomatoes in Tennessee, while the green peach aphid (*M. persicae*) is of relatively minor importance in tomato production. Winged aphids infest tomatoes from weed habitats and reproduce parthenogenetically. Although the potato aphid is kept at low densities by insecticides applied for other insects, in the absence of insecticides, it is the most common and abundant pest on Tennessee tomatoes. Aphid feeding causes leaves to be stunted and increases the plant’s susceptibility to early blight. The stunting of leaves and increased levels of early blight reduce the leaf area, which can lower yields and cause more weather-related physiological disorders of fruit (i.e., sunscald and weather fleck). Also, aphids attract an array of generalist predators, some of which (leaf-footed bugs) may also feed on and damage fruit.

**Biological control:**
On tomatoes grown with minimal broad-spectrum insecticides, natural populations of generalist predators can sometimes control potato aphid infestations. Common predators include lady beetles, syrphid flies, lacewing larvae, and predatory midges.

**Cultural control:**
Aphid infestations are often delayed and reduced when tomatoes are grown on black plastic. However, this practice alone does not eliminate the need for supplemental control.

**Chemical control:**
Many of the insecticides applied for control of other insects also control potato aphid. Consequently, insecticides are rarely used specifically for potato aphid. Dimethoate (Dimethoate 2.67EC or Digon 4004EC) has a 7-day PHI and used at a rate range of 0.25- 0.5 lbs active ingredient per acre. At a cost of $2.27 – 4.54 per application. Excessive rates of dimethoate have been reported to cause plant damage. Methamidophos (Monitor 4EC) has a 7-day PHI with a rate range of 0.75 - 1 lb active ingredient per acre. This product has a state 24(c) label for fresh fruit only. Cost of $15.54 – 20.72 per acre per application.

Endosulfan (Phaser or Thiodan 3EC or 50WP) has a 2-day PHI and a rate range of 0.5 - 1.0 lbs active
ingredient per acre. Cost varies depending on rate and formulation which ranges from $4.93 – 9.87 per application for the EC and $6.75 – 13.5 for the WP formulation.

Imidacloprid (Admire 2F or Provado 1.6F) has a use rate of 0.25 lb active ingredient for Admire and 0.047 lbs active ingredient for Provado. Admire is used as a soil application and has a 21-day PHI and Provado is used as a foliar application with a 0-day PHI. Admire cost is $72.38 per acre and Provado is $13.33 per acre.

Fenpropathrin (Danitol 2.4EC) has a 7-day PHI and used at a rate of 0.2 lbs active ingredient/acre. At a cost of $11.43 per application. This product is often used in conjunction with methamidophos.

Alternative chemical controls:

When supplemental control is necessary, esfenvalerate (Asana XL @ 0.025 lb active ingredient/acre) at a cost of $3.58 per application, and lambda-cyhalothrin (Warrior 1EC @ 0.025 lb active ingredient/acre) at a cost of $6.60 per application, all provide excellent control with 1 or 2 applications per season.

Flea beetles, Epitrix cucumeris, Exitrix hirtipennis, Aystena blanda

Flea beetles are a common but rarely injurious pest of tomatoes. Infestations are most common within three weeks after transplanting, when adult beetles feed on foliage, leaving small round holes in the leaves. Larvae feed on the roots of plants, but cause no losses.

Chemical control:
Making a single application of insecticide when 50 percent of leaves show feeding damage effectively controls flea beetles.

Azinophos-methyl (Guthion 50WP) has a 14-day PHI and is used at a rate range of 0.5 - 0.75 lbs active ingredient per acre. At a cost of $10.80 – 21.60 per acre per application.

Carbaryl (Sevin 50WP or 80WP) has a 0-day PHI and a use rate range of 0.5 - 1 lb active ingredient per acre. At a cost of $3.91 – 7.88 per acre depending on rate and formulation used.

Imidacloprid (Admire 2F) has a 21-day PHI with a use range of 0.25 - 0.375 lb active ingredient per acre. Imidacloprid is applied to the soil. At a cost of $72.38 – 108.56 per acre depending on rate used.

Alternative chemical controls:

Control can be achieved with a wide range of insecticides, including esfenvalerate, endosulfan,
cyfluthrin, lambda-cyhalothrin, sodium aluminofluoride and diazinon. Rates and cost vary for each alternative.

**Whiteflies, *Trialeurodes vaporariorum, Bemisia argentifolii, Bemisia tabaci***

Greenhouse whitefly (*T. vaporariorum*) is the most common species infesting tomatoes in Tennessee, while silverleaf whitefly (*B. argentifolii*) and, to a lesser extent, the sweetpotato whitefly (*B. tabaci*) sometimes infest greenhouse-grown tomatoes. However, whitefly infestations on field-grown tomatoes have been sporadic in Tennessee; less than 5 percent of fields have problems in any given year. Damage results from adults and nymphs feeding on leaves, which can reduce the rate of photosynthesis and stunt growth. However, the most important damage is sooty mold growth on whitefly honeydew, which accumulates on fruit and leaves reducing photosynthesis.

**Chemical control:**

When whitefly populations build to high densities, control can be difficult with even the most effective insecticides. Imidacloprid (Admire 2F @ 0.25 lb active ingredient/acre soil applied, Provado 1.6F @ 0.05 lb active ingredient/acre) is most effective against whitefly, while methomyl (Lannate 90SP @ 0.45 lb active ingredient/acre) is effective against populations that have not developed resistance to this chemical. To reduce established infestations with either Provado or Lannate, multiple applications at weekly intervals are often necessary. Insecticidal soap (M-Pede at 1 % solution) is also effective when applied on weekly intervals.

Imidacloprid (Admire 2F) is applied to the soil at a rate range of 0.25-0.375 lbs active ingredient/acre with a 21-day PHI. Cost of this product is $72.38 – 108.56 per acre.

Endosulfan (Phaser or Thiodan in 3EC or 50WP) at 0.5 lbs active ingredient per acre with a 2-day PHI. At a cost of $6.75 for the WP formulation and $4.93 for the EC formulation.

Methomyl (Lannate 90SP or 2.4LV) at 0.45 - 0.9 lbs active ingredient per acre with a 1-day PHI and a cost per acre per application of $11.18 - 22.35 for the WP formulation and $10.31 – 20.62 per acre for the LV formulation.

Methamidophos (Monitor 4EC) at 0.75 - 1.0 lb active ingredient per acre with a 7-day PHI. This product has a state 24(c) label for fresh fruit only. At a cost of $15.54 – 20.72 per acre per application.

Fenpropathrin (Danitol 2.4EC) at a 0.15- 0.2 lb active ingredient per acre with a 7 day PHI. This product is normally used with methamidophos. At a cost of $8.56 – $11.43 per acre per application.
Armyworms, *Spodoptera* spp.

Armyworms are sporadic pests of tomatoes in Tennessee, but when infestations occur, they can cause extensive damage and be difficult to control. Three species occur on Tennessee tomatoes, including the southern armyworm, *S. eridania*; yellowstriped armyworm, *S. ornithogalli*; and beet armyworm, *S. exigua*. The beet armyworm is the most difficult to control because of its high reproductive capacity and resistance to many common insecticides.

Larvae of all three species feed on foliage and fruit, but only the fruit feeding damages the crop.

**Biological control:**
Predators and parasites do not provide effective control of infestations in tomato, but biologically based insecticides do. *Bacillus thuringiensis* products (e.g., Dipel, Javelin, and Xentari) and nuclear polyhedrosis virus (Spod-X) are especially good.

**Cultural control:**
Controlling weeds in and adjacent to tomato fields can help minimize infestations because weeds often serve as oviposition hosts for armyworms. However, weed control alone will not eliminate the potential for infestations.

**Chemical control:**
Most chemical insecticides provide poor control of armyworms, particularly beet armyworm. Methomyl (Lannate 90SP @ 0.9 lb active ingredient/acre) at a cost of $22.35 per application is sometimes effective against armyworms, but biologically derived insecticides are generally most satisfactory. Certain new insecticides for which manufacturers are seeking registration on tomato are very effective, including spinosad (SpinTor @ 0.07 lb active ingredient/acre) and tebufenozide (Confirm 2F @ 0.125 lb active ingredient/acre) at a cost of $10.38 per application.

Cutworms, *Agrotis ipsilon, Peridroma saucia*

The black cutworm (*Agrotis ipsilon*) and variegated cutworm (*Peridroma saucia*) can both cause damage in the larval stage when they sever newly set transplants. Variegated cutworms can also be a problem later when they feed on foliage and fruit. Cutworms are often a problem where grass has previously been grown or in conservation-tillage systems.

**Cultural control:**
Conservation-tillage systems provide an excellent habitat for cutworm larvae. Hence, cutworms can be avoided by using conventional-tillage systems and avoiding fields previously in grass.

**Chemical control:**
When planting into fields where cutworms are suspected of overwintering (e.g., fields previously planted to grass or fallow fields), preplant broadcast applications of diazinon (Diazinon 14G @ 3 lb active ingredient/acre) at a cost of $32.90 per acre are recommended. Options for curative control of cutworm include carbaryl (Sevin 50WP or XLR @ 1 lb active ingredient/acre at a cost of $7.83 per application), esfenvalerate (Asana XL @ 0.025 lb active ingredient/acre at a cost of $3.58 per application), cyfluthrin (Baythroid 2E @ 0.03 lb active ingredient/acre at a cost of $5.44 per application), and lambda-cyhalothrin (Warrior 1EC @ 0.025 lb active ingredient/acre at a cost of $6.60 per application).

Carbaryl (Sevin 50WP, 80WP or 4XLR) 2 lbs active ingredient per acre with a 0-day PHI at a cost of $7.83 - 15.76 per application.

Terbufenozide (Confirm 2F) early season with a 0.09 - 0.12 lb active ingredient per acre at a cost of $7.78 – 10.38 per application, late season applications would have higher rates of 0.12 - 0.25 lbs active ingredient per acre at a cost of $10.38 – 20.75 per application in heavier infestations and when more foliage occurs.

Cyfluthrin (Baythroid 2EC) 0.033 - 0.044 lbs active ingredient per acre with a 0-day PHI. At a cost of $5.73 – 7.61 per application.

**Tomato pinworm, Keiferia lycopersicella**

Tomato pinworm is a sporadic pest that is usually imported with transplants from southern production regions or greenhouses. Occasionally, populations develop late in the season in eastern Tennessee, and migrating moths may be the source of these infestations. Growers are advised to completely destroy all tomato plants and tomatoes in a greenhouse before setting a summer crop in the field.

Moths deposit eggs on leaves, and the first two larval instars mine in leaves. Subsequent instar larvae bore into fruit, usually under the calyx. Infested fruit is not marketable.

**Chemical control:**

This insect generally does not overwinter in Tennessee, however can occasionally overwinter in greenhouse tomato production. Normally in field grown tomatoes, infestations are usually isolated, they often can be eliminated with two or three applications of an appropriate insecticide is applied on a weekly schedule. Effective insecticides include methomyl (Lannate 90SP @ 0.9 lb active ingredient/acre), esfenvalerate (Asana XL @ 0.025 lb active ingredient/acre at a cost of $3.58 per application), cyfluthrin (Baythroid 2E @ 0.03 lb active ingredient/acre at a cost of $5.44 per application), lambda-cyhalothrin (Warrior 1EC @ 0.025 lb active ingredient/acre at a cost of $6.60 per application), abamectin (Agri-Mek 0.15EC @ 0.01 lb active ingredient/acre), and endosulfan (Thiodan/Phaser 3EC and 50WP @ 1 lb active ingredient/acre at a cost of 9.87 for the EC and 13.50 for the WP formulation.
Methomyl (Lannate 90SP or 2.4LV) rates range from 0.45 - 0.9 lbs active ingredient per acre with a 1-day PHI with a cost of $10.30 – 22.35 per application.

Methamidophos (Monitor 4EC) rates range from 0.75 - 1.0 lbs active ingredient per acre with a 7-day PHI with a cost of $15.54 – 20.72 per application. This product has a state 24(c) label.

Azinophos-methyl (Guthion 50WP) rates range from 0.75 - 1.5 lbs active ingredient per acre with a 14-day PHI with a cost of $8.10- 10.80 per application.

Spinosad (SpinTor 2SC) rates range from 0.062 - 0.125 lbs active ingredient per acre with a 1-day PHI.

Abamectin (Agri-Mek 0.15EC) rate of 0.019 lbs active ingredient per acre with a 7-day PHI.

Cyfluthrin (Baythroid 2EC) rates range from 0.033 - 0.044 lbs active ingredient per acre with a 0-day PHI with a cost of $2.25 – 7.16 per application.

**Alternative control:**
Although pheromone-mediated mating disruption is registered and useful in areas where pinworms are a common pest, it is not recommended in Tennessee because of the sporadic nature of the pest.

**Vegetable leafminer, Liriomyza sativae**

Vegetable leafminer is a minor pest that develops to large densities only when methomyl is sprayed extensively. Adults are small black flies that insert eggs into leaves. Larvae feed between the upper and lower leaf surface and create mines.

**Biological control:**
A complex of at least five different parasitic wasps of the vegetable leafminer occurs in Tennessee. The insecticide methomyl is particularly toxic to these parasites and populations may be reduced when methomyl applications are made for other pests.

**Chemical control:**
Chemical control of leafminers on tomatoes is rarely necessary. Registered insecticides that control this insect include abamectin (Agri-Mek 0.15EC @ 0.01 lb active ingredient/acre), diazinon (Diazinon 50WP @ 0.25 lb active ingredient/acre), and dimethoate (Dimethoate 4EC @ 0.25 lb active ingredient/
Esfenvalerate (Asana XL) has a 1-day PHI and a rate range of 0.03 – 0.05 lbs active ingredient per acre with a cost of $4.32 - 7.16 per application.

Dimethoate (Dimethoate or Digon 400 in 4EC or 2.67EC) have a 7-day PHI with a rate range of 0.25 – 0.5 lbs active ingredient per acre at a cost of $2.27 – 4.53 per application.

Methamidophos (Monitor 4EC) 0.75 - 1.0 lb active ingredient per acre with a 7-day PHI. This product has a state 24(c) label. At a cost of $15.54 – 20.72 per application.

Azinophos-methyl (Guthion 50WP) rate range of 0.37 - 0.5 lbs active ingredient per acre with a 14-day PHI. At a cost of 4.05 - $7.00 per application.

Cyromazine (Trigard 75WP) rate of 0.125 lbs active ingredient per acre with a 7-day PHI. No more than 6 applications can be made to one crop of tomatoes. At a cost of $28.26 per application.

Spinosad (SpinTor 2SC) 0.094. 0.125 lbs active ingredient per acre with a 1-day PHI.

**Hornworms, *Manduca spp.***

Tobacco hornworm, *Manduca sexta*, and, less commonly, the tomato hornworm, *M. quinquemaculata*, are minor pests of tomatoes. Larvae of both species can cause extensive defoliation of tomatoes and also feed on fruit. However, these insects are rarely found in commercial tomatoes because they are controlled by insecticides applied for other insect pests.

**Biological control:**
*Cotesia congregatus* is a common and very effective parasitic wasp of hornworm larvae. In the absence of broad-spectrum insecticide applications, these wasps can maintain hornworm populations at subeconomic levels. Also, *Bacillus thuringiensis* materials (i.e., Dipel, Javelin, Xentari, Mattch) are very effective.

**Chemical control:**
Hornworm larvae are highly sensitive to a broad range of insecticides, including most applied to tomatoes for control of other insects. Esfenvalerate applied at the same rate for tomato fruitworms can give helpful control if this pest is present, however is not recommended in Tennessee's recommendations.

Carbaryl (Sevin 50WP, 80WP or 4XLR) rate of 2 lbs active ingredient per acre with a 0-day PHI at a cost of $15.75 per application.
Endosulfan (Phaser or Thiodan 3EC or 50WP) rates range from 0.5 - 1 lb active ingredient per acre with a 2-day PHI at a cost of $6.75 – 13.50 for the WP formulation and $4.94 – 9.87 for the EC formulation per application.

Terbufenozide (Confirm 2F) rates range from 0.09 - 0.25 lbs active ingredient per acre with a 7-day PHI at a cost of $7.78 – 20.75 per application.

Spinosad (SpinTor 2SC) rates range from 0.047 - 0.094 lbs active ingredient per acre with a 1-day PHI.

Azinophos-methyl (Guthion 50WP) rates range from 0.75 - 1.5 lbs active ingredient per acre with a 14-day PHI at a cost of $8.10 – 10.80 per application.

**Cabbage looper, *Trichoplusia ni***

The cabbage looper is a minor pest of tomatoes that is controlled with insecticides applied for other insects. Consequently, it is infrequently encountered in commercial operations. Although most of the larval feeding is confined to foliage, it also feeds on fruit.

**Biological control:**
*Copidosoma truncatellum* is a common parasitic wasp of cabbage looper larvae. However, they have limited potential as biological control agents because parasitized larvae consume more foliage than healthy larvae, and the larvae are not killed until late in their development. *Bacillus thuringiensis* products (i.e., Dipel, Javelin, Xentari, Mattch) provide excellent control.

**Chemical control:**
The pyrethroid insecticides used for tomato fruitworm control include esfenvalerate and lambda-cyhalothrin are both highly effective against cabbage looper larvae. Other products commonly used are listed below.

Methomyl (Lannate 90SP or 2.4LV) rates range from 0.45 - 0.9 lbs active ingredient per acre and have a 1-day PHI. This product may induce outbreaks of leafminers. Cost of this material ranges from $10.30 – 22.35

Esfenvalerate (Asana XL 0.66EC) rates range from 0.03 - 0.05 lbs active ingredient per acre with a 1-day PHI at a cost of $4.32 – 7.16 per application.

Endosulfan (Phaser or Thiodan, 3EC or 50WP) rate of 1 lb active ingredient per acre with a 2-day PHI at a cost of $9.87 for the EC formulation and $13.50 for the WP formulation.
Spinosad (SpinTor 2SC) rate range of 0.047 - 0.094 lb active ingredient per acre with a 1-day PHI.

Tebufenozide (Confirm 2F) 0.09 - 0.25 lbs active ingredient per acre with a 7 day PHI. Higher rates are recommended in the latter portion of the season due to heavy foliage and to obtain thorough coverage. At a cost of $7.78 - 20.75 per application.

**Colorado potato beetle, *Leptinotarsa decemlineata***

This insect is a minor pest of tomatoes in Tennessee. Colorado potato beetle (CPB) larvae can rapidly defoliate small plants, this insect is commonly encountered in commercial fields. There have been several reports by home gardeners that this insect has developed resistance to many of the commonly used products such as carbaryl and endosulfan.

**Biological control:**
A number of common predators attack CPB eggs and larvae, but the level of control achieved is not adequate for commercial tomato production. *Bacillus thuringiensis* var. san diego (M-Trak @ 2 qt/acre) and var. tenebrionus (Trident II @ 4 qt/acre) are effective against CPB larvae.

**Chemical control:**
Although CPB has developed resistance to many insecticides in commercial potato production regions of Tennessee, resistance has not been reported in Tennessee's commercial tomato systems. Consequently, many commonly used insecticides control CPB in tomatoes. The most effective include imidacloprid (Admire 2F @ 0.125 lb active ingredient/acre and Provado 1.6F @ 0.04 lb active ingredient/acre) and esfenvalerate (Asana XL @ 0.05 lb active ingredient/acre).

Azinphos-methyl (Guthion 50WP) rate of 0.37 lbs active ingredient per acre with a 14-day PHI at a cost of $4.05 per application.

Spinosad (SpinTor 2SC) 0.035 - 0.070 lbs active ingredient per acre with a 1-day PHI.

Endosulfan (Phaser/Thiodan 3EC or 50WP) rate of 1 lb active ingredient per acre with a 2-day PHI at a cost of $13.50 for the WP formulation and $9.87 for the EC formulation.

Esfenvalerate (Asana XL 0.66EC) at a rate range of 0.03 - 0.05 lbs active ingredient per acre with a 1-day PHI and a cost of $4.32 – 7.16 per application.

Imidacloprid (Admire 2E or Provado 1.6F) Admire has a 2-day PHI and is applied to the soil at a rate range of 0.25 - 0.375 lbs active ingredient at a cost of $72.38 – 108.56 for an application and Provado is applied to the foliage at 0.047 lb active ingredient per acre with a 0-day PHI at a cost of $13.33 per application.
Alternative chemical control:

Cyromazine (Trigard) 75% has a 0-day PHI, rate of 0.1249 lbs ai/acre. No more than 6 applications per crop. A cost of $28.26 per acre per application.

Mites, *Tetranychus urticae, T. cinnabarinus*

Two-spotted spider mites (*T. urticae*) and carmine spider mites (*T. cinnabarinus*) are sporadic pests of tomatoes in Tennessee. Although only 15 percent of tomato fields were infested with mites in 2001, infestations can be difficult to control. Mites indirectly damage tomatoes by feeding on foliage, reducing the rate of photosynthesis, and, thus, reducing overall yields. High populations and damage is often observed during hot dry weather.

Chemical control:

Before 1997, dicofol (Kelthane 4MF @ 0.5 lb active ingredient/acre, and a cost of $4.75 per application) was the only miticide registered for use on tomatoes, and it was applied by approximately 15 percent of growers. In 1997, abamectin (Agri-Mek 0.15EC @ 0.015 lb active ingredient/acre) was registered and is the most effective miticide available to growers. Other chemicals that generally provide fair control include dimethoate (Dimethoate 4EC @ 0.5 lb active ingredient/acre, at a cost of $4.54 per application) and oxamyl (Vydate L @ 0.05 lb active ingredient/acre at a cost of $1.76 per application).

Abamectin (Agri-mek 0.15EC) 0.009-0.019 lb active ingredient per acre with a 7 day PHI. This product is not to be applied in less than 20 gallons of water per acre.

Fenpropathrin (Danitol 2.4EC) has a rate of 0.2 lbs active ingredient per acre with a 3-day PHI and a cost of $11.43 per application.

Diseases

Tomato diseases can be the most important limiting factor in tomato production in Tennessee. Without proper preventative measures, some diseases (e.g., late blight) can destroy a crop within two to three weeks. Other diseases (e.g., pith necrosis) are minor in occurrence and cause little loss. More than 20
tomato diseases are often found in Tennessee. Fourteen of the most common and destructive are described below.

Generally, soilborne diseases (e.g., Pythium root rot, bacterial wilt, root-knot, and southern blight) are more prevalent and cause greater losses in areas where production occurs year after year and foliar diseases (e.g., early blight and late blight) are more serious in the Plateau region and East Tennessee. Success in tomato production in Tennessee depends on knowing which diseases can be present in a region or on a given farm and taking the necessary measures to prevent those diseases from occurring. When acreage is sprayed with a fungicide, growers generally spray on schedule to reduce losses from disease.

**Fungicides used during 2001 tomato production season**

<table>
<thead>
<tr>
<th>Product</th>
<th>Ave. number of apps.*</th>
<th>Percent acreage sprayed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorothalonil</td>
<td>8</td>
<td>50</td>
</tr>
<tr>
<td>Copper</td>
<td>8</td>
<td>90</td>
</tr>
<tr>
<td>Mancozeb</td>
<td>8</td>
<td>50</td>
</tr>
<tr>
<td>Maneb</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Mefanoxam</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Azoxystrobin</td>
<td>5</td>
<td>80</td>
</tr>
<tr>
<td>Aluminum-tris</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Acibenzolar-S-Methyl</td>
<td>6</td>
<td>5</td>
</tr>
</tbody>
</table>

* Average number of applications when used.

**Early blight, Alternaria solani**
Early blight is the most common foliar disease in Tennessee, occurring in all production regions. The causal fungus overwinters in crop debris, and in other crops. The disease is worst in fields cropped continuously to tomatoes. It causes leafspotting and blight, which progress over the season from lower leaves to upper leaves. In nonsprayed research plots, the disease often causes up to 50 percent yield losses.

**Cultural control:**
Crop rotation is very effective in reducing and avoiding overwintering sources of the fungus that causes early blight. The disease appears much later and is easier to control in fields that were in sod or small grains, rather than in fields that were in tomatoes the previous year. A three-year rotation will help reduce early blight and several other diseases that affect tomatoes. In the mountains, however, suitable land for tomato production is limited, and crop rotation is not an option. There are no commercially acceptable varieties with resistance to early blight.

**Chemical control:**
Traditionally, farmers have relied heavily on fungicides to prevent and control early blight as well as other foliar diseases. Recommendations have been to spray with fungicides preventatively every seven-ten days during normal growing conditions; however if wet conditions persist a 5 to 7 day spray schedule may be needed. There are several rates for products used to control early blight. Each product is applied at different rates depending on plant maturity. Prior to fruit set normally has a lower amount of product used than after the fruit set application. Standard fungicides for early blight have been mancozeb, chlorothalonil, azoxystrobin and manebo. Chlorothalonil is more effective against early blight than mancozeb.

Chlorothalonil (Bravo, Chlorothalonil) has a zero-day PHI is applied at rate ranges of 1.073 to 1.5 pounds active ingredient per acre prior to fruit set at a cost of $8.59 – $12.20 and a rate range of 1.5 – 2.25 lbs active ingredient per acre after fruit set at a cost of $11.45 – 17.18. Not to exceed 15.1 lbs active ingredient per acre per year. This product should not be applied within 150 feet of large areas of water.

Azoxystrobin (Quadris 2L), has excellent activity against early blight, but is at risk to the development of fungicide resistance in the pathogen population. It is registered for use in tomatoes however is restricted to five total applications at 0.08 to 0.1 pound active ingredient per application per acre and not to exceed 0.52 lbs active ingredient per acre per season. Azoxystrobin has a zero-day preharvest interval. Cost per application ranges from $11.02 – 13.66 depending on rate used.

Mancozeb (Dithane DF and Manex II) fungicides have a 5-day PHI are used at rate ranges of 1.2 to 2.4 lbs a.i. and are used early in the season and provide fair to moderate protection against foliar blighting. Do not to exceed more than 16.8 lbs active ingredient of mancozeb per acre per season. Cost range of $4.40 – 8.80 per acre per application.

Manebo (Manex, Maneb 80WP) has a 5-day PHI and is applied at 1.2 – 2.4 lbs active ingredient per acre with a cost of $3.40- 6.80 per application. No more than 16.8 lbs active ingredient per acre per season.
Normally a higher rate (2.4 lbs ai) of maneb is used after fruit set and lower rates (1.2 –2.4 lbs ai) are applied prior to fruit set. Copper materials are often applied with products containing maneb or mancozeb.

Basic copper sulfate (Basicop 57%) has a 0-day PHI, and a rate range of 2-4 lbs/acre of formulation at a cost of $3.12 - 6.24 per acre.

Copper hydroxide (Kocide 101) has a 0-day PHI and has a use rate of 1.54 – 2.31 lbs active ingredient per acre per application at a cost of $6.50 – 11.50.

**Septoria leaf spot, *Septoria lycopersici***

Septoria leaf spot is common during wet weather in Tennessee, being favored by the higher temperatures. It can be a very destructive disease on tomatoes, developing rapidly during rainy weather. The fungus can be seedborne and can become established in a field on debris and on stakes used to support plants. Fungal spores are readily spread by splashing rain and also can be spread by workers and equipment moving through a tomato field when the foliage is wet.

**Cultural control:**
Growers should use clean seed from a reputable source and avoid planting tomatoes in fields where the disease was present the previous year. Various field operations such as cultivating, pruning, and stringing should not be performed when foliage is wet. No commercial varieties are presently resistant to Septoria leaf spot.

**Chemical control:**
Preventative, regular spraying with fungicides is the most effective means of controlling Septoria leaf spot. The fungicides and application intervals for early blight are also effective for Septoria leaf spot.

**Alternative Chemical Control:**
Chlorothalonil (Bravo, Chlorothalonil) has a zero-day PHI is labeled at 1.125 to 1.5 pounds active ingredient per acre prior to fruit set at a cost of $8.59 – 12.20 and a rate range of 1.5 – 2.88 lbs active ingredient per acre after fruit set at a cost of $12.20 – 21.98 per acre depending on rate used. This product is effective for Septoria control.

**Late blight, *Phytophthora infestans***

Late blight can be the most destructive disease affecting tomatoes, capable of causing complete loss in
unprotected crops. The disease affects both tomatoes and potatoes, causing blighting of foliage, fruit rot in tomatoes and tuber rot of potatoes. It is favored by cool temperatures and wet weather and thus is more of a problem in higher elevations. The disease is usually more damaging in home gardens, where fungicide is used less, than in commercial crops, where farmers spray preventatively for early blight.

Different strains of the late blight fungus have been collected and characterized in North Carolina, including A1 and A2 mating types; strains resistant to metalaxyl and mefenoxam (Ridomil Gold); and genotypes US1, US7, US8, and NC1, a previously undescribed genotype. The fungus may overwinter on unharvested potato tubers, or it can be introduced each year on potato seed, on tomato transplants, and via airborne spores which is the most common mode of transport in Tennessee.

**Cultural control:**
Overhead irrigation can spread late blight spores and provide conditions favorable to sporulation and infection; this type of irrigation should be avoided. Several states have breeding programs to develop varieties with resistance to late blight, but none is presently available for commercial use at this time.

**Chemical control:**
The preventative fungicide application schedule described for early blight also protects against late blight. Home gardeners who wait to apply fungicides until after late blight appears usually fail to control the disease. In commercial plantings, the mancozeb (Dithane DF and Manex II) fungicides have a 5-day PHI are used at rate ranges of 1.2 to 2.4 lbs a.i. and are used early in the season and provide fair to moderate protection against foliar blighting. Do not to exceed more than 16.8 lbs active ingredient of mancozeb per acre per season. If late blight is present, the fungicide of choice is chlorothalonil, which gives excellent control of the fruit rot phase of this disease. Chlorothalonil has a zero-day PHI is recommended at 1.125 to 1.5 pounds active ingredient per acre at a cost of $8.69 – 12.20 prior to fruit set and a rate range of 1.5 – 2.268 lbs active ingredient per acre at a cost of $12.20 – 17.18 after fruit set. Azoxystrobin (Quadris), has less activity against late blight, and is at risk to the development of fungicide resistance in the pathogen population. It is registered for use in tomatoes however is restricted to five total applications at 0.08 to 0.1 pound active ingredient per application per acre and not to exceed 0.52 lbs active ingredient per acre per season. Azoxystrobin has a zero-day preharvest interval. Copper materials used for bacterial diseases and used by organic producers provide only moderate protection against late blight. Basicop 57% (basic copper sulfate) 0-day PHI, rate range of formulation 2-4 lbs/acre at a cost of $3.12 – 6.24 per acre. Control of late blight with fungicides can be improved by the use of high pressure sprayers for thorough coverage of the foliage and by adding copper material to the mix. Copper hydroxide (Kocide 101) is applied at the rate range of 1.54 – 2.31 lbs active ingredient per acre per application and cost approximately $6.50 – 11.50 per acre.

**Alternative chemical control:**
Mefanoxam (Ridomil Gold) can be used to aid in control of this disease however, is no longer recommended because of widespread resistance to it. Therefore, most growers have not been using this product for late blight control.
Dimethomorph (Acrobat 50WP) with mancozeb recently received federal registrations for late blight control on tomatoes, but usage is expected to be very low in Tennessee because of low risk of late blight.

**Gray mold, Botrytis cinerea**

Gray mold occurs sporadically in field tomato production regions of Tennessee. It can be a very damaging disease, causing blighting and fruit rot. It is much worse under cool, moist conditions and in plantings with dense foliage. This disease is most often observed in greenhouse operations, where stem cankers can cause serious plant losses.

**Cultural control:**
In greenhouse production, ventilation practices to reduce humidity, and sanitation practices to reduce available food sources are a key to gray mold control. Growers should avoid excessive fertilization, which promotes a dense canopy favorable to the disease in field grown tomatoes. Wide plant-spacing in the row also creates conditions less favorable to the disease than close plant-spacing.

**Chemical control:**
In greenhouse production Exotherm termil (chlorothalonil) and Botran are often used. Dichloran (Botran 75W) has a 10-day PHI, a rate of 0.75 lbs active ingredient per acre with no more than 4 applications per crop, generally used in greenhouse transplant production. This material must be directed from soil line to first 18-24 inches height of stem to satisfy the label requirements.

In field production, Benomyl (Benlate) has a 1-day PHI and is applied at 0.5 pound active ingredient per acre suppresses sensitive strains of B. cinerea. However, benomyl-resistant strains exist and are widespread and this product should be alternated with other fungicides. Benomyl production has been cancelled and the food-use tolerance (Federal Register: January 15, 2002 (Volume 67, Number 10, Page 1976-1977). Benomyl is limited to 2.5 lbs active ingredient per acre per crop. The cost of an application of this product was $18.90 per acre. Other currently registered fungicides for tomatoes are ineffective in controlling gray mold. Chlorothalonil has a 0-day PHI and is used at the rate of 2.268 lbs a.i. per acre and may give some additional control of gray mold but it is recommended to be applied with benomyl for best results.

**Bacterial canker, Clavibacter michiganensis subspecies michiganensis**

Bacterial canker has been a sporadic but devastating disease in all tomato production areas of the state. The causal agent is seedborne and has caused serious losses when seed lots have been infested. The
Bacteria can develop epiphytically on leaf surfaces and spread from plant to plant by splashing rain and by workers pruning or tying when foliage is wet. The bacteria enter the plant through pruning wounds and hydathodes, causing necrosis, blighting, and wilting. The disease can also cause fruit spotting, which makes the fruit unmarketable.

Cultural control:
Buying disease-free seed is the best guarantee against bacterial canker. However, most hybrid tomato seed is produced in developing countries where there are often inadequate controls to prevent seed contamination. Heating seeds in water to 56°C for 30 minutes reduces seed infestation, but most growers lack the means to do this. Growers should avoid overhead watering of seedlings during transplant production in order to prevent secondary spread of the bacteria. It is important to avoid working in fields when the foliage is wet.

Chemical control:
Since seeds may or may not be contaminated with *C. michiganensis*, it is best for growers to assume the seed is contaminated and take preventative measures. Several steps may be taken to prevent disease have been suggested by other state extension specialists. The steps are: 1) soak seed in a 20 percent bleach solution (1.05 percent NaOCl) for 40 minutes before sowing; 2) spray seedlings with streptomycin sulfate (200 ppm) during transplant production; and 3) mix a copper material (Kocide 101, e.g., 1.5-2.5 lbs copper hydroxide active ingredient/acre) with maneb or mancozeb at each application before harvest. These measures may reduce the possibility that bacterial canker will reach damaging levels. Chemical controls are ineffective if initiated after symptoms appear.

**Bacterial spot, Xanthomonas campestris pv. vesicatoria**

Bacterial spot is an occasional problem across the state. The disease causes spots on leaves and fruit, which can result in severe blighting and defoliation. Diseased fruit is not marketable. Disease development is favored by moderately high temperatures and frequent and heavy rainfall. The bacteria can overwinter on crop debris and can be introduced on seeds and transplants.

Cultural control:
Growers should avoid southern-grown transplants, avoid planting in fields where the disease was present the previous year, and avoid working in fields when foliage is wet.

Chemical control:
The three-step approach for preventing bacterial canker may also reduce bacterial spot. However, some bacterial strains have been identified that are insensitive to either streptomycin or copper or both. Benzothiadiazole or acibenzolar-S-methyl (Actigard) has a 14-day PHI. Actigard is a plant resistance activator. Under certain conditions, Actigard may lead to reductions in yield. Applications may be made 1 week after transplanting. Up to 6 applications on weekly intervals may be made. Actigard is
applied at 0.01-0.023 lbs. active ingredient / acre. Cost of an application ranges from $17.16 – 38.63 per acre per application. Basicop 57% (basic copper sulfate) has a 0-day PHI, rate range of formulation between 2 - 4 lbs/acre, Copper hydroxide (Kocide 101) has a 0-day PHI and a rate range of 1.54 – 3.08 lbs active ingredient per acre per application. Kocide DF or Kocide 2000 both have a 0-day PHI have varying rates which depend on number of plants per acre and row spacing. These copper products are normally applied with mancozeb products.

**Bacterial speck, *Pseudomonas syringae pv. tomato***

Bacterial speck has been a troublesome disease in all Tennessee production regions in recent years. The disease has been most prevalent on the *Mountain Spring* cultivar, apparently due to infested seed. The disease develops under relatively cool temperatures early in the season, causing leaf and fruit spotting. Preventative measures used to reduce bacterial canker have not appeared to be as effective in reducing bacterial speck. It is important that seed companies provide seeds free of *P. syringae pv. tomato*.

**Chemical control:**

The three-step approach for preventing bacterial canker may also reduce bacterial spot. However, some bacterial strains have been identified that are insensitive to either streptomycin or copper or both. Benzothiadiazole or acibenzolar-S-methyl (Actigard) has a 14-day PHI. Actigard is a plant resistance activator. Under certain conditions, Actigard may lead to reductions in yield. Applications may be made 1 week after transplanting. Up to 6 applications on weekly intervals may be made. Actigard is applied at 0.01-0.023 lbs. active ingredient / acre. Cost of an application ranges from $17.16 – 38.63 per acre per application. Basicop 57% (basic copper sulfate) has a 0-day PHI, rate range of formulation between 2 - 4 lbs/acre, Copper hydroxide (Kocide 101) has a 0-day PHI and a rate range of 1.54 – 3.08 lbs active ingredient per acre per application. Kocide DF or Kocide 2000 both have a 0-day PHI have varying rates which depend on number of plants per acre and row spacing. These copper products are normally applied with mancozeb products.

**Verticillium wilt, *Verticillium dahliae***

Verticillium wilt is a soilborne disease that is occasionally reported in Tennessee. The disease causes stunting, moderate wilting, and a slow plant decline that results in moderate to heavy yield losses. There are two races of this organism, both known races have been reported in North Carolina. Race 1 of *V. dahliae* can reduce yields on susceptible varieties by as much as 50 percent and is effectively controlled by varieties with the *Ve*-gene. Race 2 overcomes the *Ve*-gene resistance and can cause yield losses of 30 percent on both resistant and susceptible varieties. Race 2 has not been confirmed in Tennessee. No genes producing effective resistance to Race 2 have been found. The causal fungus produces resting
structures called microsclerotia, which can survive in the soil for up to eight years.

**Cultural control:**
Crop rotation for Verticillium management is not always a viable option for most producers, due to the long persistence of the fungus in the soil and the very limited land available for production. Resistant varieties may help reduce problems from this disease but is not always the cure.

**Chemical control:**
Soil fumigation with methyl bromide is the only effective means for controlling Verticillium wilt in infested fields where susceptible varieties are grown. In research tests, yields were increased 30 to 50 percent in fumigated plots compared to nontreated controls. Methyl bromide 67 percent plus chloropicrin 33 percent is used at 250 pounds mixture of these active ingredients per acre for Verticillium control. The U.S. Clean Air Act required the Environmental Protection Agency (EPA) to take action on any substance with an Ozone Depleting Potential (ODP) of 0.2 or greater by listing it as class I substance, and phasing methyl bromide out in the United States within seven years. In 1992, atmospheric scientists had reached a global consensus that methyl bromide depletes stratospheric ozone, with evidence estimating that bromine from this material is 50 times more effective at destroying ozone than chlorine from CFCs on a per atom basis. The Ozone Depletion Potential of methyl bromide at that time was 0.7. With the expected phasing out of methyl bromide registration by 2005, chloropicrin would still be a viable alternative for control, however is not as effective.

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**Bacterial wilt, *Pseudomonas solanacearum***

Bacterial wilt can be found in all tomato production areas of Tennessee. The causal bacteria are soilborne, infect through the roots, and cause wilting and rapid collapse of the plant. High soil temperature and moisture favor disease development. The organism is very persistent in the soil.

**Cultural control:**
Crop rotation is not effective because of the persistence of the causal bacterium. Once infested sites are identified, growers should avoid planting in those sites. Resistant varieties are reaching the market, but their horticultural qualities have not been evaluated.

**Chemical control:**
Soil fumigation with methyl bromide plus chloropicrin is lethal to the causal bacterium but does not provide effective control in infested fields. Because fumigation treats only the top 6 to 9 inches of soil, the procedure only delays the appearance of the disease.

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**Southern blight, *Sclerotium rolfsii***
Southern blight occurs sporadically across the state. The causal fungus is soilborne and can cause damping-off of seedlings and stem rot and death of older plants. The fungus has a wide host range and survives between crops as sclerotia in the soil and on debris. Rotation of the field in non-susceptible crops will help eliminate this pathogen.

**Cultural control:**
Crop rotation with corn, small grains or sod reduces the population of the fungus in the soil. Most vegetable crops are susceptible, and growers should not plant tomatoes following other vegetables. Deep plowing to bury sclerotia reduces disease incidence.

**Chemical control:**
In sites where the disease has occurred previously, growers can treat with quintozene (PCNB or Terraclor 75WP at a cost of $80.53 per acre). Terraclor is available in various formulations. Most commonly used is the WP formulation. This product is added to transplant water and applied at the time of transplanting. No more than 7.5 lbs a.i per acre in any one season may be applied (based on 5000 plants/acre) or 16.5 lbs a.i. (based on 11,733 plants per acre). Soil fumigation with methyl bromide and chloropicrin, as for Verticillium wilt, can also reduce disease incidence from southern blight. However, the fungus can be very aggressive if treated areas are later contaminated with this organism.

**Fusarium wilt, *Fusarium oxysporium***

Fusarium wilt can be a problem throughout Tennessee. It is a soilborne disease that has been effectively controlled in the past by use of resistant varieties. The fungus can remain in infested soil for several years and can be transmitted by seed, transplants, soil, tomato stakes, and equipment. The disease is very destructive, causing wilt and death of infected plants. Three races have been identified, and most commercial varieties are resistant to races 1 and 2. Race 3 is more recent in occurrence and in the 1990s has been found scattered throughout Tennessee. *Floralina* was the first variety with race 3 resistance, released jointly by the Florida and North Carolina tomato breeding programs in 1998.

**Cultural control:**
The only effective control is to use Fusarium wilt-resistant varieties. The number of race 3-resistant varieties is very limited.

**Chemical control:**
Soil fumigation is effective in reducing losses from this disease. Methyl bromide with chloropicrin applied 2 - 4 weeks prior to planting.

Root-knot occurs primarily on the Plateau and in the eastern production regions of the state. The disease is caused by at least two species of *Meloidogyne* and is most destructive in sandy soils during drought. Root-knot can cause severe stunting and more than 50 percent yield loss on affected plants.

**Cultural control:**
Crop rotation with non-host plants such as grasses and corn reduces soil populations of *Meloidogyne*. The University of Tennessee Agricultural Extension Service, Entomology and Plant Pathology Department provides a nematode assay service of $5.00 per sample. Growers should have the soil assayed for root-knot nematodes in fields where they plan to plant tomatoes and take necessary control actions based on the results. Resistant varieties are available but not often used due to fruit quality and plant habit (indeterminate growth).

**Chemical control:**
Soil fumigation with methyl bromide and chloropicrin, as for Verticillium wilt, is very effective for root-knot control. Where broad-spectrum fumigation is not needed, nematicides such as dichloropropene and oxamyl can also be used effectively for nematode control. Methyl bromide will no longer be available for use as of 2005. Products such as Telone II, Telone C-17, Chloropicrin, SMDC (Busan 1020 or Vapam) may be used as alternatives.

Telone C-35 contains 6.84 lbs of 1,3-dichloropropene and 3.89 lbs of chloropicrin per gallon of formulation. Telone C-35 may be applied at 13 (88.92 + 50.57 lbs ai) – 20.5 (140.22 + 79.745 lbs. ai) gallons of formulation per acre in mineral type soils of Tennessee.

1,3-dichloropropene (Telone II) is used at a rate range of 90.9 – 121.2 lbs active ingredient per acre.

**Pith necrosis, *Pseudomonas corrugata***

Pith necrosis occurs sporadically in all tomato production areas of Tennessee. The pith in affected plants is brown and necrotic, which is often accompanied by stunting, wilting, and yield reduction. The causal bacterium is a common soil inhabitant, causing disease at random in the field usually entering the plant through wounds. Disease development appears to be associated with rapid growth following high nitrogen fertilization and high moisture.

**Cultural control:**
Growers should avoid excess nitrogen fertilization early in the season. Suckers should be removed while small. Crop rotation has no influence on disease appearance, and there are no effective chemical controls.
**Tomato spotted wilt, (TSWV)**

Tomato spotted wilt occurs sporadically across the state on several Tennessee crops, including tomatoes. Serious losses sometimes occur. Disease incidence is related to the survival of the overwintering vector, to various thrips species, and to the occurrence and distribution of various alternate weed hosts of the virus. Use of insecticides to control thrips has not been effective in preventing tomato spotted wilt. A new product known as Actigard has recently been reported to control TSWV. Several growers use products containing the insecticide imadacloprid to suppress this disease.

**Cultural control:** Often growers will cut grass that surrounds the field to help reduce possible spread from weed species that may harbor this disease.

**Chemical control:**

The University of Tennessee does not recommend chemical control for TSWV. The University of Tennessee does recommend insecticides to help reduce spread of this disease. Insecticides recommended which may aid in the control of TSWV include; Spintor, Lannate, Monitor and Admire.

**Buckeye rot, Phytophthora parasitica**

Buckeye rot of tomato rarely results in large losses in the yield of harvestable fruit. The fungus also causes a fruit rot of pepper and eggplant. It can also cause damping-off of seedlings, stem cankers near the soil line, or leaf blight, but these symptoms are not as common as the fruit rot. Fruit infected with buckeye rot are not marketable.

**Chemical control:**

Mefanoxam (Ridomil Gold or Ultra Flourish) may be used to control spread of this disease. Mefanoxam may also be used in combination with other products such as chlorothalonil (Ridomil Gold/Bravo at a cost of $34.40 per acre) or copper (Ridomil Gold Copper at a cost of $23.00 per acre). In instances where mefanoxam is used by itself as a soil application, it has a 28-day PHI. When mefanoxam is used in combination with products as a foliar application it has a 14-day PHI.

(Quadris 2L) has a 0-day PHI and is used at the rate of 0.08 – 0.10 lbs active ingredient per acre, at a cost of $11.01 – 13.65 per acre per application.
**Sclerotinia / timber rot, Sclerotinia sclerotiorum**

The disease is caused by the fungus, *Sclerotinia sclerotiorum*, and it attacks over 170 species of plants. Vegetables, especially susceptible include tomatoes, beans, cabbage and other crucifers, carrot, cucumber, eggplant, Irish potato, lettuce, pepper and squash. Many other crops such as clover, soybean and peanuts are susceptible. The fungus overwinters (or oversummers) as sclerotia in the soil and may survive up to 7 years in dry soil. However, if the soil is maintained warm and moist, following a dormant period when the moisture and temperature are suitable, the sclerotia in the greenhouse or the field germinate by resuming vegetative growth. Benlate will no longer be available for use to control this disease. Benomyl (Benlate) has a 1-day PHI and is applied at 0.5 pound active ingredient per acre. Benomyl is limited to 2.5 lbs active ingredient per acre per crop. The cost of an application of this product was $18.90 per acre.

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**Weeds**

Weeds that infest tomatoes in Tennessee include annual grasses (broadleaf signalgrass, large crabgrass, goosegrass, and fall panicum), perennial grasses (Johnsongrass, sedges), and broadleaf weeds (common cocklebur, groundcherry, hairy galinsoga, jimsonweed, common lambsquarters, morningglory, nightshade, pigweed, common ragweed, Pennsylvania smartweed, sicklepod, and velvetleaf). Weeds, if uncontrolled, can cause as much as 50 to 70 percent reduction in tomato yield. Tomatoes must be nearly weed-free from transplanting to flowering for optimum yield and quality.

In bareground (no plastic) tomatoes, weeds must be managed with preplant or preemergence herbicides. Preplant herbicides are applied before transplanting. Certain preplant herbicides (paraquat) kill emerged weeds and do not suppress weed germination, while others (metribuzin, pebulate, or napropamide) are incorporated to suppress weed emergence. Preemergence herbicides (metribuzin, napropamide) are applied after tomato transplanting and before weed emergence. Postemergence weed control is achieved by using either postemergence herbicides (metribuzin, paraquat, sethoxydim) or hand removal and early cultivation.

In tomatoes grown using black plastic, preemergence and postemergence herbicides are used to control weeds in middles between the plastic rows. Cultivation (between plastic rows) is not used because the cultivators may damage the plastic and increase erosion.

**Mechanical control:**
Tomatoes grown on bare ground are generally cultivated twice during the season. Weeds that emerge near the tomato plants are often hand-removed.
Chemical Control:

Preplant herbicides

- **Methyl bromide**
  This material (240 lb active ingredient/acre) is injected into the soil under plastic for disease control. An additional benefit is that it prevents weeds from emerging through the same hole that the tomato plant uses to grow through the plastic. It was used on approximately 20 percent of the tomato acreage during 2001. Cost of approximately $300 per acre.

- **Paraquat**
  This non-selective herbicide (Gramoxone Extra 2.5L@0.5 lbs active ingredient/acre) is applied to control emerged annual weeds before tomato transplanting. It is used on approximately 25 percent of the acreage. Cost of $7.41 per acre.

- **Metribuzin**
  Applied preplant incorporated, this material (Lexone or Sencor 75DF@0.25-1.0 lb active ingredient/acre) targets annual grasses and broadleaf weeds. It gives excellent control of common lambsquarters, common ragweed, hairy galinsoga, jimsonweed, most pigweeds, purslane, sicklepod, and certain annual grasses. It is used on approximately 20 percent of the tomato acreage. Cost of $6.54 – 26.07 per acre.

- **Pebulate**
  This material (Tillam 6E@3 lbs active ingredient/acre) is applied preplant incorporated primarily for controlling yellow nutsedge. It also controls several annual grasses and broadleaf weeds. Tillam is used on approximately 13 percent of the tomato acreage. Cost of $29.40 per acre.

- **Napropamide**
  Napropamide is applied as a preplant incorporated into the first 1 – 2 inches of soil, this material (Devrinol 50DF@1-2 lbs active ingredient/acre) is used to control annual grasses and broadleaf weeds, including common purslane, pigweeds, and hairy galinsoga. This product may also be applied over the top after transplanting as a preemergent herbicide to weed free soil, however must be irrigated in within 24 hours. It is applied to approximately 7 percent of the tomato acreage as a preplant herbicide. Cost of $19.12 – 38.28 per acre.

Preemergence herbicides

- **Metribuzin**
  This material (Lexone or Sencor 75DF@ 0.5 -1 lb active ingredient/acre) is applied preemergence for controlling annual grasses and broadleaf weeds. It gives excellent control of common lambsquarters, common ragweed, hairy galinsoga, jimsonweed, most pigweeds, purslane, sicklepod, and certain annual grasses. It is used on approximately 45 percent of the tomato acreage. Cost of $14.70 – 26.14 per acre.

- **Napropamide**
  Applied preemergence, this material (Devrinol 50DF@1-2 lbs active ingredient/acre) controls annual grasses and broadleaf weeds, including common purslane, pigweeds, and hairy galinsoga.
It is applied to approximately 5 percent of the tomato acreage as a preemergent herbicide. Cost of $19.12 – 38.24 per acre.

**Postemergence herbicides**

- **Paraquat**
  Paraquat (Gramoxone Extra 2.5L@0.5 lb active ingredient/acre) is applied as a shielded, postdirected application to emerged weeds. It is most effective on small, actively growing broadleaf weeds. It is applied to approximately 65 percent of the acreage an average of three times per season. Cost of $7.40 per acre.

- **Metribuzin**
  This postemergence material (Lexone or Sencor 75DF @ 0.5 -1 lb active ingredient/acre) is used to control small weeds. It is most effective for controlling broadleaf weeds. It is applied to approximately 60 percent of the tomato acreage. Lexone or Sencor are sometimes applied with sethoxydim (Poast) a grass herbicide, to broaden their control. Cost of $14.70 – 26.14 per acre.

- **Sethoxydim**
  Applied postemergence, this material (Poast 1.53EC@0.2-0.3 lb active ingredient/acre) controls annual and perennial grasses. It is used on approximately 40 percent of the tomato acreage. This product is often spot sprayed in areas of sporadic infestations. Cost of $8.50 – 12.75 per acre.

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1. USDA - National Agricultural Statistics Service.


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