Crop Profile for Tomatoes in North Carolina

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General Production Information

- North Carolina ranked seventh nationally in the production of tomatoes in 2003, representing 2.7 percent of U. S. production.
- In 2003, 2,800 acres of tomatoes were harvested in North Carolina.
- In 2003, a total of 896,000 cwt. of tomatoes were produced in North Carolina for a value of $26,880,000.
- All North Carolina tomato production is destined for fresh market.

Production Regions

The two major production areas for fresh-market tomatoes in the state are western North Carolina (Henderson, Buncombe, Haywood, Macon, Polk, and Rutherford counties) and the Piedmont (Rowan, Cleveland, and Lincoln counties). Some tomato production is scattered in the Coastal Plain (particularly Sampson County).

Production Practices

Tomatoes are grown on a wide range of soil types in North Carolina, from rich, silty loams in river bottoms in the western part of the state to red clays in the Piedmont to sands in the Coastal Plain. Standard production practices include use of methyl bromide fumigation, raised beds, black polyethylene mulch, and drip-irrigation. Rows are usually spaced 5 feet apart, and plants are usually 18 inches apart in the row. Most growers produce their own transplants. Tomatoes are staked, pruned, and tied using the Florida string-weave system. Varieties are determinate, most commonly of the *Mountain* series developed at North Carolina State University.

Early season production takes place in the Piedmont and foothills, with planting in mid-April. Main season production takes place in the western counties, with mid-May to mid-June plantings. Late season production, using heat-tolerant varieties, is practiced in the piedmont, with late-June plantings. Most production is for vine-ripe tomatoes, although there is some mature green production in all areas. Tomatoes are hand-harvested and often field-packed.

Worker Activities

(The following information was taken from the August 2003 Arkansas Tomato Crop Profile and adapted for North Carolina tomato production.)

Tomatoes are planted in spring through early summer into raised plastic covered beds that are usually fumigated with methyl bromide and chloropicrin before planting. Fields should be fumigated at least 14 days prior to planting, although 21 days or more is recommended to limit residual activity in the soil. Fumigation, plastic mulch, and drip-irrigation tape are all applied in a single process using a tractor-mounted machine. Transplanting is done with tractor-mounted transplanter, usually a water-wheel type. Hand labor is used to drive stakes into the beds shortly after transplanting. Drip-irrigation tape is connected to lay-flat by hand.

Preemergent herbicide applications are applied to the row middles in early spring, primarily with tractor-mounted spray equipment. Postemergence herbicide applications are made to the row middles in early summer and as needed with tractor-mounted sprayers although backpack sprayers are occasionally used. Hand labor is used to stake, tie and prune the plants beginning approximately two weeks after transplanting and continuing every few weeks throughout the season.

Insecticides and fungicides are applied from early spring up to harvest on a 7 to 10 day schedule primarily with airblast or boom sprayers.

Virtually the entire tomato crop is hand-harvested from June till frost. Many operations field pack their fruit. The tomato plants, stakes, and string are removed after harvest usually by hand. The plastic mulch and drip tape are removed with tractor-mounted equipment. The beds are renovated in preparation for fumigation before replanting in the spring.

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. At least 14 species of insects and mites can infest tomatoes in North Carolina. However, only five of these insects (tomato fruitworm, stink bugs, thrips, aphids, and flea beetles) are common in the majority of fields throughout the state, while the remaining nine insects occur more sporadically.

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 North Carolina. 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 mountain 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 (*Campletis 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. Some growers practice augmentative release of *Trichogramma*, but the poor quality of commercially available *Trichogramma* makes this approach questionable. Applications of *Bacillus thuringiensis* (*Bt*) products (Dipel, Xentari, Javelin, Biobit HP or Mattch) provide good control of fruitworms, but *Bt*s are less effective than many synthetic insecticides against high-density populations.

Cultural control:

Early plantings of tomatoes suffer considerably less fruitworm pressure than later plantings. However, simply planting earlier does not eliminate the need for supplemental control, and climatic conditions and market considerations limit the overall utility of this management approach.

Chemical control:

The use of insecticides is essential for profitable production of tomatoes in North Carolina. Historically pyrethroid insecticides, including esfenvalerate (Asana XL), cyfluthrin (Baythroid), lambda-cyhalothrin (Warrior), bifenthrin (Capture) and zeta-cypermethrin (Mustang Max) were commonly used for fruitworm control. However, the increased importance of twospotted spider mites, combined with the fact that pyrethroids aggravate mite problems, has resulted in the increased use of indoxacarb (Avaunt) and spinosad (SpinTor) for fruitworm control. *Bacillus thuringiensis* products (Dipel, Crymax) are also applied for fruitworm control. Methomyl (Lannate) is an important material because it is the most effective insecticide for killing large fruitworms in tomatoes.

Stink bugs

Acrosternum hilare

The brown (*E. servus*) and green (*A. hilare*) stink bug are common pests of tomatoes, although the severity of damage varies considerably among fields. Adults and immatures feed on developing fruit with their piercing mouthparts, 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.

Chemical control:

Insecticides are currently the only method of effectively controlling stink bugs. Endosulfan (Thiodan, Phaser) is the most effective insecticide, but label restrictions related to applications near water resources has decreased its use in favor of the pyrethroids fenpropathrin (Danitol) and zeta-cypermethrin (Mustang Max), and to a lesser extend methomyl (Lannate) and methamidophos (Monitor) are sometimes applied for stink bugs.

Thrips

Franklinellia fusca, *F. occidentalis*, and *F. tritici*

Thrips cause damage directly by ovipositing and/or feeding in small, developing fruit before stamens have been shed and indirectly by transmitting tomato spotted wilt virus (TSWV). Western flower thrips *(F. occidentalis)* and flower thrips *(F. tritici*) are most important as direct pests. Both *F. fusca* and *F. occidentalis* are vectors of TSWV, and transmit the virus when feeding on foliage shortly after planting. Thrips and other pests with sucking mouthparts, are also suspected of contributing to gold flecking disorder.

Chemical control:

For flower infestations of *F. occidentalis*, methomyl (Lannate), methamidophos (Monitor), and dimethoate (Dimethoate) are the only effective options. *F. occidentalis* infestations on tomato have an aggregated distribution on a statewide basis. 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), which control foliar infestations of thrips, may be useful in protecting plants from TSWV transmission.

Spider Mites

Tetranychus urticae, T. cinnabarinus

Spider mites have become a common problem of field-grown tomatoes in recent years. Twospotted spider mite, *T. urticae,* is most common, but the carmine mite (*T. cinnabarinus*) can also build to damaging levels. Spider mites overwinter on weeds surrounding fields and certain winter crops such as strawberry, and migrate to tomatoes when overwintering hosts senesce or are destroyed in the spring. Mites indirectly damage tomatoes by feeding on foliage, reducing the rate of photosynthesis, and, thus, reducing overall yields. Feeding on fruit is also suspected of contributing to gold fleck. Populations build to high densities under hot and dry conditions, and are also aggravated by certain pesticides applied for insect control, particularly pyrethroid insecticides.

Chemical control:

The most common acaricides applied for mite control are abamectin (Agri-Mek) and bifenazate (Acramite). Because of a 7-day preharvest interval, Agri-Mek is used most often for early season infestations, while Acramite is used as the crop approaches harvest. The pyrethroid fenpropathrin (Danitol) is also used for mite control, although populations often rebound following application. Dicofol (Kelthane) and oxamyl (Vydate) are sometimes use for mite control, but resistance has limited their usefulness. Horticultural oils are also used on a preventative basis for suppression of mite populations. Twospotted spider mite can quickly develop resistance to acaricides, and rotation of products is important to delay or prevent resistance development.

Aphids

Macrosiphum euphoribae, Myzus persicae

Potato aphid (*M. euphoribae)* is a common pest of tomatoes in North Carolina, while the green peach aphid (*M. persicae*) is of relatively minor importance. 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 North Carolina 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 check). 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:

Potato 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. When supplemental control is necessary, esfenvalerate (Asana XL), lambda-cyhalothrin (Warrior), imidacloprid (Admire, Provado) all provide excellent control with 1 or 2 applications per season. Soil applications of imidacloprid (Admire) also provide excellent aphid control.

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 damage.

Chemical control:

Making a single application of insecticide when 50 percent of leaves show feeding damage effectively controls flea beetles. Control can be achieved with a wide range of insecticides, including esfenvalerate (Asana XL), cyfluthrin (Baythroid), lambda-cyhalothrin (Warrior), dimethoate, and carbaryl (Sevin). In most instances, imidacloprid (Admire) applied for thrips also controls flea beetles.

Whiteflies

Trialeurodes vaporariorum, Bemisia argentifolii, Bemisia tabaci

Greenhouse whitefly (*T. vaporariorum*) is the most common species infesting tomatoes in North Carolina, 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 North Carolina; less than 10 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. The most important damage is sooty mold growth on whitefly honeydew, which accumulates on fruit and leaves.

Chemical control:

When whitefly populations build to high densities, control can be difficult with even the most effective insecticides. Soil applications of imidacloprid (Admire) are most effective against whiteflies. In the absence of imidacloprid or for late-season infestations, pyriproxifen (Knack), buprofezin (Courier), pymetrozine (Fulfill), and acetamiprid (Assail) are effective options.

Armyworms

Spodoptera spp.

Armyworms are sporadic pests of tomatoes in North Carolina, but when infestations occur, they can cause extensive damage and be difficult to control. Three species occur on North Carolina 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. Spinosad (SpinTor), *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:

Indoxacarb (Avaunt), spinosad (SpinTor), methoxyfenozide (Intrepid) and emamectin benzoate (Proclaim) all provide rapid and excellent control of armyworms.

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) are recommended. Options for curative control of cutworm include carbaryl (Sevin), esfenvalerate (Asana XL), cyfluthrin (Baythroid), lambda-cyhalothrin (Warrior), and zeta-cypermethrin (Mustang Max).

Tomato pinworm

Keiferia lycopersicella

Tomato pinworm is a sporadic pest that is usually imported with transplants from southern production regions. Occasionally, populations develop late in the season in eastern North Carolina, and migrating moths may be the source of these infestations.

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:

Because this insect does not overwinter in North Carolina and because infestations are usually isolated, they often can be eliminated with two or three applications of an appropriate insecticide applied every week. There area a wide array of insecticides effective against pinworm, including esfenvalerate (Asana XL), cyfluthrin (Baythroid), lambda-cyhalothrin (Warrior), abamectin (Agri-Mek), indoxacarb (Avaunt), spinosad (SpinTor), emamectin benzoate (Proclaim), and zeta-cypermethrin (Mustang Max).

Alternative control:

Although pheromone-mediated mating disruption is registered and useful in areas where pinworms are a common pest, it is not recommended in North Carolina 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 North Carolina. The insecticide methomyl is particularly toxic to these parasites.

Chemical control:

Chemical control of leafminers on tomatoes is rarely necessary. Registered insecticides that control this insect include abamectin (Agri-Mek), spinosad (SpinTor), and zeta-cypermethrin (Mustang Max).

Hornworms

Manduca spp.

The tobacco hornworm, *Manduca sexta*, and the less common 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 insecticide applications 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, Crymax) 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.

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 are highly effective against cabbage looper larvae.

Colorado potato beetle

Leptinotarsa decemlineata

This insect is a minor pest of tomatoes in North Carolina. Although Colorado potato beetle (CPB) larvae can rapidly defoliate small plants, this insect is rarely encountered in commercial fields.

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.

Chemical control:

Although CPB has developed resistance to many insecticides in commercial potato production regions of North Carolina, resistance has not occurred in tomato systems. Consequently, many commonly used insecticides control CPB in tomatoes. The most effective include imidacloprid (Admire, Provado), spinosad (SpinTor) and indoxacarb (Avaunt).

Insecticide and Miticide Use Estimates for Tomatoes

While pyrethroids were once used extensively for tomato insect control, concerns about twospotted spider mite problems have contributed to a decline in their use. Although esfenvalerate (Asana), lambda cyhalothrin (Warrior) and fenpropathrin (Danitol) are still used on considerable acreage, spinosad (SpinTor) and indoxacarb (Avaunt) use has increased considerably in recent years. Transplant applications of imidacloprid (Admire) are used on the majority of field-grown tomatoes for early season thrips, aphid and flea beetle control, and one or two applications of dimethoate are often applied to supplement thrips control. Abamectin (Agri-Mek) and bifenazate (Acramite) are most commonly used for mite control.

Current Insecticide and Miticide Recommendations for Tomatoes

Current North Carolina Cooperative Extension Service recommendations for insecticide and miticide use on tomatoes (including information on formulations, application rates, and precautions/limitations) are provided in the following table from the *North Carolina Agricultural Chemicals Manual*:

Table 5-10: Insect Control for Commercial Vegetables (http://ipm.ncsu.edu/agchem/chptr5/510.pdf)

Diseases and Nematodes

Tomato diseases can be the most important limiting factor in tomato production in North Carolina. Without adequate 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 have been documented in North Carolina. Fourteen of the most common and destructive diseases are described below.

Generally, soilborne diseases (e.g., bacterial wilt, root-knot, and southern blight) are more prevalent and cause greater losses in the coastal plain and piedmont than in the mountains, and foliar diseases (e.g., early blight and late blight) are more serious in the mountains than in the coastal plain and piedmont. Success in tomato production in North Carolina depends on knowing which diseases can be present in a region or on a given farm at a particular time during the season and taking the necessary measures to prevent those diseases from occurring.

Early blight

Alternaria solani

Early blight is the most common foliar disease in North Carolina, occurring in all production regions. The causal fungus overwinters in crop debris; thus, the disease is worst in fields cropped continuously to tomatoes. Early blight tends to show up early in the season, although despite its name it can occur at any time. It causes leafspotting and blight, which progress over the season from lower leaves to upper leaves. The fungus can also affect tomato stems and fruit. In non-sprayed 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. Some recent varieties (e.g., *Mountain Supreme* and *Plum Dandy*) from the North Carolina breeding program have moderate levels of 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 include preventative fungicide applications every seven days in the coastal plain and piedmont and every five days in the mountains. The strobilurin fungicides give excellent control, mancozeb provides good control and chlorothalonil gives only fair control of early blight. Mancozeb (e.g., Dithane, Manzate, Penncozeb) is applied at 1.2 to 2.4 pounds of active ingredient per acre and has a 5-day preharvest interval (phi), so applications must occur before harvest. Chlorothalonil (e.g., Bravo), with a zero-day phi, is recommended at 1.1 to 2.2 pounds of active ingredient per acre during harvest. A new class of fungicides called the strobilurins (Quadris, Amistar, Cabrio) provide excellent activity against early blight and are registered for use beginning 21 days postplanting with restrictions of five total applications ranging from 0.08 to 0.1 pounds, 0.1 to 0.25 pounds, and 1.6 to 3.2 ounces (respectively) of active ingredient per acre. Some pathogens have developed insensitivity (resistance) to the strobilurins when used too frequently; therefore, rotating applications are required.

Septoria leaf spot

Septoria lycopersici

Septoria leaf spot is common in eastern North Carolina and rare in the mountains, being favored by the higher temperatures in the east. Leaf spot can be a very destructive disease on tomatoes, developing rapidly during rainy weather. The fungus is seedborne and can overwinter on debris and on equipment such as 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. Equipment should be cleaned in between crops. 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, routine fungicide sprays are the most effective means of controlling Septoria leaf spot. Fungicides and application intervals recommended for early blight are also effective for Septoria leaf spot, in particular the strobilurin fungicides

Late blight

Phytophthora infestans

During certain years, late blight has the potential to 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 on both crops and fruit rot in tomatoes. It is favored by cool temperatures and wet weather and thus is more problematic in the mountains than in the Coastal Plain or Piedmont. The disease is typically more damaging in home gardens, where fungicides are rarely used in comparison to commercial fields.

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 (Ridomil); 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.

Cultural control:

Overhead irrigation can spread late blight spores and provide conditions favorable to sporulation and infection; this type of irrigation should be avoided. Progress is being made in the tomato-breeding program at North Carolina State University to develop varieties with resistance to late blight, but none are presently available for commercial use.

Chemical control:

The preventative fungicide application schedule described for early blight also protects against late blight. Growers who wait to apply fungicides until after late blight appears usually fail to control the disease. In commercial plantings, the mancozeb fungicides used early in the season provide good protection against foliar blighting, and chlorothalonil used later in the season gives excellent control of the fruit rot phase. The strobilurin fungicides are less effective for control of late blight than for early blight. The zoxamide component of Gavel (mancozeb plus zoxamide) provides improved control of late blight over mancozeb. In tests at Fletcher, North Carolina, Gavel has performed as well as chlorothalonil (Bravo and Equus) in preventing late blight on tomatoes and has been superior to straight mancozeb in preventing fruit infection. Tomato producers could substitute Gavel for either mancozeb or chlorothalonil products in their spray programs during late blight favorable periods. However, Gavel has a 5-day preharvest interval (PHI), the same as for mancozeb. Chlorothalonil products, with 0-day PHI, are preferred during harvest. Copper materials used for bacterial diseases and used by organic producers provide only moderate protection against late blight. The best fungicides to use on tomatoes already infected with late blight are Tanos or Curzate; check the labels for the specific directions on rotating and tank mixing. Note that either Tanos or Curzate, but not both, should be used in one field. Ridomil products are no longer recommended for control of late blight due to the increase in metalaxyl resistant populations of the pathogen in North Carolina.

Gray mold

Botrytis cinerea

Gray mold occurs sporadically in the mountains and rarely in the other production regions of North Carolina. It can be a very damaging disease, causing blighting and fruit rot. Botrytis disease development is dependent upon a very strict set of weather conditions, in particular, during cool, moist conditions and in plantings with dense foliage. In the field the fungus appears as a gray, velvety covering of spores on dying flowers and the calyx of fruit.

Cultural control:

Growers should avoid excessive fertilization, which promotes a dense canopy favorable to the disease. Wide plant spacing in the row also creates conditions less favorable to the disease than close plant spacing.

Chemical control:

The product boscalid (Endura) has excellent activity against Botrytis gray mold. Due to the cost of application, Endura is only necessary if conditions are conducive for gray mold (wet and cool) shortly before and during harvest).

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 bacterium is seedborne and can cause serious loss when seed lots are infested. Bacterial populations 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. It enters the plant through pruning wounds and hydathodes, causing necrosis, blighting, and wilting. The disease can also cause fruit spotting, making the fruit unmarketable.

Cultural control:

Buying disease-free seed or transplants 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. For the same reason, it is also important to avoid working in fields when the foliage is wet. Sources of genetic resistance to bacterial canker have been identified and are being incorporated into advanced breeding lines in the North Carolina State University tomato breeding program.

Chemical control:

Since seeds may or may not be contaminated with *C. michiganensis*, it is best to assume the seed is contaminated and take preventative measures. A three-step approach for preventing bacterial canker has been developed and used successfully by North Carolina growers since the mid 1970s. These steps are: 1) soak seed in a 20 percent bleach solution (1.05 percent NaOCl) for 40 minutes before sowing; 2) spray young seedlings with streptomycin (Agri-Mycin 17) (200 ppm) during transplant production; and 3) use copper materials (e.g., 1.5 to 2.5 pounds copper hydroxide active ingredient per acre) and/or Actigard (e.g., 0.75 ounce per acre) with the fungicide spray before harvest. Actigard, a plant protection compound in a new class of chemicals called "plant activators", has been shown to significantly reduce bacterial spot, speck and canker in field trials when used preventatively. Such measures reduce the possibility that bacterial canker will reach damaging levels. Chemical controls are ineffective if initiated after symptoms appear. Although Tanos (famoxadone plus cymoxanil) is also labeled for canker, research in North Carolina indicates this product is ineffective against the disease.

Bacterial spot

Xanthomonas campestris pv. *vesicatoria*

Bacterial spot is an occasional problem in the coastal plain and piedmont and rare in the mountains. The disease causes spots on leaves and fruit, which can result in severe blighting and defoliation. 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 or symptomatic 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 will also reduce bacterial spot. However, some bacterial strains have been identified that are insensitive to either streptomycin or copper or both; therefore, applications of Actigard are recommended when bacterial spot is a concern.

Bacterial speck

Pseudomonas syringae pv.*tomato*

Bacterial speck has been a troublesome disease in all North Carolina 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. Actigard is effective when used preventatively, although other preventative applications such as copper formulations do not appear to be as effective due to the development of resistance among speck populations. It is important that seed companies provide seeds free of *P. syringae* pv. *tomato.*

Verticillium wilt

Verticillium dahliae

Verticillium wilt is a soilborne disease that is very common in the mountains and rare in other production regions of North Carolina. The disease causes stunting, moderate wilting, and a slow plant decline that results in moderate to heavy yield losses. Both known races of the pathogen have been found 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 is present throughout the mountain tomato production region, and no genes producing effective resistance to this race 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 a viable option for mountain producers, due to the long persistence of the fungus in the soil and the very limited land available for production. Certain weed species (nightshade family) can harbor the pathogen; therefore, managing weeds within infected fields can help reduce build up of the pathogen.

Chemical control:

Soil fumigation is the only effective means for controlling Verticillium wilt in infested fields. 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 recommended at 250 pounds active ingredient per acre for Verticillium control in the mountains. With the expected phasing out of methyl bromide registration, chloropicrin would still be a viable alternative for control.

Bacterial wilt

Pseudomonas solanacearum

Bacterial wilt can be found in all tomato production areas of North Carolina, but it is more common in the coastal plain and piedmont than in the mountains. 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 soil.

Cultural control:

Crop rotation is not effective due to persistence of the causal bacterium. Once infested sites are identified, growers should avoid planting in affected areas.

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. Once tomato roots penetrate nontreated soil, they become infected and the plant dies— slightly later than it would without fumigation.

Southern blight

Sclorotium rolfsii

Southern blight occurs sporadically in the coastal plain and piedmont, but is very rare in the mountains. 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.

Cultural control:

Crop rotation with corn and small grains 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 the soil with PCNB (Terraclor) only at planting. Soil fumigation with methyl bromide and chloropicrin, as for Verticillium wilt, can also reduce disease incidence. However, the fungus can be very aggressive if treated areas are later contaminated with nontreated soil.

Fusarium wilt

Fusarium oxysporium

Fusarium wilt can be a problem throughout North Carolina. 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 other equipment. The fungus is very destructive, causing wilt and eventual death of infected plants. Three races of the pathogen 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 North Carolina. *Floralina* was the first variety with race 3 resistance, released jointly by the Florida and North Carolina State University tomato breeding programs in 1998.

Cultural control:

The only effective control is the use of Fusarium wilt-resistant varieties.

Root-knot

Meloidogyne spp.

Root-knot occurs in all tomato production regions of the state but is most severe in the Coastal Plain and Piedmont. This soilborne disease is caused by at least three species of *Meloidogyne* nematodes 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 North Carolina Department of Agriculture and Consumer Services provides a nematode assay service in its soil-testing division. 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.

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 oxamyl (Vydate) can also be used effectively for nematode control.

Pith necrosis

Pseudomonas corrugata

Pith necrosis occurs sporadically in all tomato production areas of North Carolina. In field surveys conducted in 1986 and 1987, disease incidence in individual fields was as much as 11 percent, but the average incidence was approximately 1 percent. 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. 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. Crop rotation has no influence on disease appearance, and there are no effective chemical controls.

Tomato spotted wilt, Tomato spotted wilt virus (TSWV)

Tomato spotted wilt occurs sporadically on several North Carolina crops, including tomatoes, across the state. Disease incidence is related to the survival of the overwintering vector, various thrips species, and to the occurrence and distribution of various alternate weed hosts of the virus. To reduce the source of infection, manage weeds adjacent to the field. (TSWV can overwinter in weeds.) Remove and destroy infected plants as soon as symptoms appear, to further reduce virus spread.

The conventional insecticide program for thrips consists of broad-spectrum insecticides (namely methamidophos), although the use of insecticides to control thrips has not been very effective in preventing tomato spotted wilt.

Fungicide and Nematicide Use Estimates for Tomatoes

The most common fungicides used on fresh market tomatoes in North Carolina include: Acidbenzolar-S-methyl (Actigard), chlorothalonil, copper hydroxide, mancozeb, maneb, Streptomycin (as transplants), and the strobilurins. In addition, combinations of methyl bromide and chlorothalonil are commonly used as preplant treatments against nematodes and Verticillium wilt.

Current Fungicide and Nematicide Recommendations for Tomatoes

Current North Carolina Cooperative Extension Service recommendations for fungicide and nematicide use on tomatoes (including information on formulations, application rates, and precautions/limitations) are provided in the following tables from the *North Carolina Agricultural Chemicals Manual*:

Table 6-17: Vegetable Crop Disease Control Schedule
(http://ipm.ncsu.edu/agchem/chptr6/612.pdf)

Table 6-24: Nematode Control in Vegetable Crops
(http://ipm.ncsu.edu/agchem/chptr6/617.pdf)

Weeds

Weeds that infest tomatoes in North Carolina include annual grasses (broadleaf signalgrass, large crabgrass, goosegrass, and fall panicum), perennial grasses (Johnsongrass), 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. The largest tomato fruit are the ones that are commonly affected. The size of these fruit are often reduced in size. 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, napropamide, s-metolachlor, trifluralin) are incorporated to suppress weed emergence. Preemergence herbicides (halosulfuron, s-metolachlor, metribuzin, napropamide) are applied after tomato transplanting and before weed emergence. Postemergence weed control is achieved by using either postemergence herbicides (halosulfuron, metribuzin, paraquat (row middles only), rimsulfuron, trifloxysulfuron, clethodim, 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 cultivated twice during the season. Weeds that emerge near the tomato plants are generally hand-removed.

Preplant Herbicides

Methyl bromide
Methyl bromide 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.

Paraquat (Gramoxone Max)
This non-selective herbicide is applied to control emerged annual weeds before tomato transplanting.

Metribuzin (Sencor)
Metribuzin is applied preplant incorporated. This material 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.

Napropamide (Devrinol)
Napropamide is applied preplant incorporated, this material is used to control annual grasses and broadleaf weeds, including common purslane, pigweeds, and hairy galinsoga.

S-Metolachlor (Dual MAGNUM)
S-Metolachlor may be applied preplant incorporated, or preplant before transplanting. This material gives good control of many annual grass species, nightshade, groundcherry and pigweed.

Trifluralin (Treflan)
Trifluralin is applied pretransplant and incorporate. It provides good control of annual grass weeds and small seeded broadleaf weeds such at pigweed

Preemergence Herbicides

Metribuzin (Sencor)
Metribuzin 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.

Napropamide (Devrinol)
Napropamide is applied preemergence, this material controls annual grasses and broadleaf weeds, including common purslane, pigweeds, and hairy galinsoga.

Halosulfuron-methyl (Sandea)
Halosulfuron-methyl is applied preemergence after transplanting over the top of crop or post directed. This herbicide controls galinsoga, wild radish, jimsonweed, common lambsquarters, redroot and smooth pigweed and common cocklebur.

S-Metolachlor (Dual MAGNUM)
S-Metolachlor is applied post directed to transplants after first settling rain or irrigation. This material gives good control of many annual grass species, nightshade, groundcherry and pigweed.

Postemergence Herbicides

Paraquat (Gramoxone Max)
Paraquat is applied as a shielded, postdirected application to emerged weeds. It is most effective on small, actively growing broadleaf weeds.

Metribuzin (Sencor)
This postemergence herbicide is used to control small weeds. It is most effective for controlling broadleaf weeds. Sencor is sometimes applied with sethoxydim (Poast) to broaden their control.

Sethoxydim (Poast) or Clethodim (Select)
These herbicides are applied postemergence, and control annual and perennial grasses.

Halosulfuron-methyl (Sandea)
Halosulfuron-methyl can be applied over the top or the crop or post directed. It gives excellent control of yellow and purple nutsedge, common cocklebur, galinsoga, wild radish, common ragweed and redroot and smooth pigweed.

Rimsulfuron (Matrix)
Rimsulfuron is applied postemergence. It controls common chickweed, redroot and smooth pigweed, common purslane, wild radish and certain grass and other broadleaf weeds.

Trifloxysulfuron (Envoke)
This herbicide is post directed in tomato. It gives control of common cocklebur, Florida beggarweed, certain morningglory species, common lambsquarters, common ragweed and sicklepod.

Herbicide Use Estimates for Tomatoes

The predominant herbicides used in North Carolina tomatoes are clethodim, metribuzin, metolachlor, paraquat, napropoamide, and/or sethoxydim post directed to the middles. Paraquat and metribuzin are most commonly used followed by halosulfuron for nutsedge control, and clethodim or sethoxydim for grass control.

Current Herbicide Recommendations for Tomatoes

Current North Carolina Cooperative Extension Service recommendations for herbicide use on tomatoes (including information on formulations, application rates, and precautions/limitations) are provided in the following table from the *North Carolina Agricultural Chemicals Manual*:

Table 8-15: Chemical Weed Control in Vegetable Crops
(http://ipm.ncsu.edu/agchem/chptr8/817.pdf)

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On-Line Resources

Commercial Vegetables Recommendations for the Southeastern U. S. (http://ipm.ncsu.edu/vegetables/CommercialVegetables/SECommercialVegGuide.pdf)

Sustainable Practices for Vegetable Production in the South (http://www.cals.ncsu.edu/sustainable/peet/)

North Carolina Pest News (http://ipm.ncsu.edu/current_ipm/pest_news.html)

Insects and Related Pests of Vegetables

(http://ipm.ncsu.edu/AG295/html/index.htm)

Insect Pests of Vegetables
(http://ipm.ncsu.edu/vegetables/pests_vegetables.html)

Insect Notes – Vegetables
(http://www.ces.ncsu.edu/depts/ent/notes/Vegetables/vegetable_contents.html)

Plant Disease Information – Vegetables
(http://www.ces.ncsu.edu/depts/pp/notes/Vegetable/vegetable_contents.html)

Tomatoes, Horticultural Commodity of North Carolina
(http://www.agr.state.nc.us/markets/commodit/horticul/tomatoes/)

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