

Crop Profile for Tomatoes in New Jersey

Production Facts

- As of 2006 New Jersey ranked 9th in United States for fresh market tomato production and acres harvested and 11th in production value (41). New Jersey ranked 5th in production, acreage, and value for processing tomatoes.
- New Jersey supplies 2.4% of the total US fresh market tomato production and less than 1% of the processing tomato production (40, 41).
- New Jersey fresh market tomato growers planted 3,100 acres and harvested 2,900 acres for a cash value of \$19,627,000 (40). Processing acreage was 1,200 acres with a cash value of \$1,700,000 (56).
- There are no current costs of production studies for New Jersey fresh market or processing tomatoes.
- The major portion of the New Jersey tomato crop is destined for fresh market (72%); the remainder (27%) is grown for processing.

Production Regions

Fresh market tomatoes are grown in almost all counties in New Jersey. The majority of the wholesale production and acreage is located in southern New Jersey in the counties of Gloucester, Cumberland, Salem, and Atlantic. There are smaller wholesale production areas in northwest and central New Jersey. All counties produce tomatoes for the retail trade, with the largest concentration in northern and central New Jersey. Wholesale fresh market tomatoes are shipped throughout the eastern United States and Canada, depending on the time of year. Processing tomatoes are grown primarily in Cumberland and Salem counties for one processing company in New Jersey and one in Pennsylvania.

Cultural Practices

Types Grown. Tomatoes are a member of the nightshade family and related to pepper, eggplant, and white potato. Most of the tomatoes produced in the state are picked for fresh market between the pink and vine-ripe stage, depending on the distance to market. There are some growers producing gas green round and plum tomatoes. The majority of the acreage is dedicated to round red tomatoes followed by plums, grapes, heirlooms, and cherries.

Variety selection depends on market demand, yield, disease tolerance, and plant type. The wholesale trade grows many of the same varieties grown in Florida while the retail trade grows a mixture of varieties that are less adapted to shipping. Varieties grown in New Jersey include:

Round: Sunshine, Sunbrite, Applause, Biltmore, Debut, Sunbeam, Sunstation, Florida 47, Florida 91, Crista, BHN 589, Indy, Mountain Spring, Mountain Fresh, SunPride

Plums: Plum Crimson, BHN 411, Sonoma, Marianna, Heinz H-132, Daiquiri
Grapes: Santa, Juliete, St. Nick, Smarty
Heirlooms: Mortgage Lifter, Prudens Purple, Mister Stripy, Eva Purple Ball, Arkansas Traveler, Brandywine, Lemon Boy, Snow White
Cherries: Mountain Bell, Sweet Chelsea, Sugar Snack
Processing: TSH4, H-3402, H-9704, H-9423, H-9997

Transplant Production. All tomatoes are produced from transplants. Most fresh market tomatoes are transplanted from locally grown plants. Processing tomato plants are produced locally and in Pennsylvania. Tomatoes are seeded in greenhouses from February through April for transplanting April through June. Growers start seeds in 72 to 200 cell trays for fresh market tomatoes and 200 to 338 for processing varieties. Plants are grown using a standard soilless mix (i.e. Promix) and the fertility level is supplemented with either a continual feed program or two to three applications of a complete liquid fertilizer. Growers harden off plants before transplanting by withholding water and placing plants in a protected area.

Land Preparation. Tomatoes grow best on well-drained sandy-loam and loamy sand soils with a pH of 6.0-6.5. A wheat or rye fall cover crop is planted the year before. Growers prefer wheat since it does not seem to hold as much moisture, because grain rye may grow too tall to incorporate. In the spring, the cover crop is plowed down using either a moldboard or chisel plow. Some fields are fumigated in the fall before the cover crop is planted. For growers who fumigate, the main fumigant used in New Jersey is metam-sodium at the rate of 45 to 70 gal/A. The fumigant is applied using a shank applicator and the soil is sealed behind.

Nutrients are broadcast based on the soil test. Boron may be applied with the other nutrients at the rate of 1.0 lbs/A. The fertilizer is incorporated and the soil prepared before bed making. High raised, dome shaped beds are recommended for disease control and water management. Drip tape and plastic mulch are applied as the raised beds are being made. Some growers apply herbicides as the plastic is being laid. Others lay the plastic without any herbicide, then band apply between the rows before transplanting. In bare ground culture, herbicides are applied pre-transplant and additional weed control is maintained through cultivation and post emergent herbicides.

Field Planting. For early fresh market production, growers begin transplanting April 10 to 20 in the southern areas and May 10 to 25 in the cooler, northern areas. Early plantings may be covered with a row cover to speed growth and reduce the chance of frost injury. The cover remains in place until the temperature warms or when the plants start to flower. The plants are then suckered and staked. The number of suckers removed depends on the variety and maturity. Processing tomatoes are transplanted starting April 15 to 20 in the warmer, southern counties to May 5 to 10 in the cooler areas. Successive plantings are made through early June.

Most fresh market tomato plants are set into black plastic with drip irrigation for early production. Determinate varieties are spaced in rows 4 to 5 feet apart with plants 15 to

24 inches apart in the row. The indeterminate varieties are spaced in rows 5 to 6 feet apart with 24 to 36 inches in-row plant spacing. Staked tomatoes are spaced in row widths of 5 to 6 feet with in-row spacing from 18 to 24 inches. Most processing tomatoes are transplanted 9 to 12 inches apart in single rows 5 feet apart or to accommodate machine harvester. There are some processing tomatoes now being grown in double rows.

Transplants are set with a water wheel, mechanical transplanter, or by hand when the plants are at least six inches tall. All growers plant with water and many use a transplant solution. When transplanting, growers take care to set the plants straight in the transplant plant hole to avoid stem burn when the black plastic becomes too hot. In addition, some growers fill the hole around the plant with soil to reduce the chance of water collecting around the base of the plant, which can lead to disease.

Most fresh market tomatoes are grown on plastic and staked using a basket weave system to increase yield and fruit quality. Tomato stakes (4 to 5 ft) are placed between every other plant and strings are woven around them. Vigorous cultivars may require larger and longer stakes. Three to 4 strings are required for most varieties. Heirloom and some grape tomato varieties require taller stakes (7-8 ft.) and may be tied 5 to 6 times.

In plastic mulch culture, additional soluble fertilizer (complete fertilizer including boron) is applied through the drip system at intervals throughout the growing season. The first application is generally applied one week after transplanting, followed with either weekly applications (12 total) or every three weeks for a total of six applications. Some growers use plant tissue testing to adjust their fertility program. Most fungicides and insecticides are applied with boom or air blast type sprayers, and some materials are applied through the trickle irrigation system.

Irrigation Fresh market tomatoes in New Jersey are irrigated primarily with a drip/trickle irrigation system either on top of beds or under black plastic mulch. A few growers use plastic mulch, but overhead irrigate. Processing tomatoes are irrigated with center pivot or traveling guns.

Harvesting Fresh market varieties are ready to harvest in 70 to 80 days and are hand harvested every 10 to 14 days through frost (mid-October). Fruit are snapped from the plant above the calyx as they approach a marketable size and the fruit is firm. Fruit that are allowed to stay on the plant too long will reduce total yield. Fruit are picked in plastic $\frac{5}{8}$ or 1 bushel containers and transported to packing sheds. Most round and plum tomatoes are washed, sorted into U.S. Fancy, No. 1, No. 2, and field run grades, and packed in 25 lbs waxed cardboard cartons and forced-air cooled or placed in refrigerated rooms with pre cooling. Cherry and grape tomatoes are packed in 1 pint containers; heirloom tomatoes are packed in single layer containers. Processing growers begin harvesting by machine (e.g. Pik Rite) in August and finish in October. Most harvesters have electronic sorters to reduce green fruit.

Worker Activities

Worker activities in the greenhouse include seeding, spotting transplants, and watering. Fungicide treated seed is handled by workers who use the required personal protection equipment. Most growers make several greenhouse pesticide applications during transplant production, but the existing reentry intervals (REI's) for greenhouse materials do not currently interfere with worker activity.

Field activities include transplanting, suckering, staking and tying plants, occasional hoeing for bare ground culture, scouting, and harvesting. At the end of the season workers remove plastic mulch and stakes. Workers risk potential exposure to pesticides during these activities and should follow all safety procedures determined by the label. These procedures include wearing proper personal protective equipment (PPE) and strictly following restricted-entry intervals (REIs). These activities are conducted within the REI restrictions that currently exist for the materials growers are using for pest control. When harvesting begins, growers choose the most effective insecticides and fungicides with the minimum pre-harvest intervals (PHI), preferably a PHI less than 3 days, to accommodate harvest schedules. For the major tomato insect and disease pests, there are sufficient choices in effective materials with low (less than 3 days) PHI's and REI's. Most of these activities can be easily conducted within the REI restrictions that currently exist for the materials growers are using for pest control.

Scouting activities typically occur once a week throughout the season. The farms that employ a scouting service are visited once or twice weekly for all crops, although individual fields are usually checked on a 7-10 day schedule. Since scouts will be returning to the farm between 48-72 hours, REI's of 48 hours or less are sufficiently short that major pest outbreaks will not occur within a field during the period of no reentry. In general, extending REI's and PHI's for current or new materials has the potential to be detrimental to tomato production in New Jersey.

Insect and Mite Control

Tomatoes are attacked by as many as 16 insect species. Most of the insecticides target the primary pests (Colorado potato beetles, stinkbugs, thrips, aphids, mites, tomato fruitworms, and armyworms) that occur every year. Secondary pests are managed as a result of primary pest control measures, although some years the secondary pest levels may change pest management decisions. Occasionally insect pests like corn borers, leafminers, whiteflies, pinworms, and cutworms may be a problem, but these pests are not typically managed every year like the primary and secondary pests.

Most fresh market and processing growers use the neonicotinoid insecticides at transplanting for thrips, aphid, Colorado potato beetle, and flea beetle management. Subsequent foliar insecticide applications follow the fungicide schedule and depend on scouting and local pest populations. The tolerance for insect damage on fresh market tomatoes, especially staked tomatoes, is less than for processing tomatoes due to the high value of the crop. Insecticide applications are generally applied during flowering

through fruit maturation to prevent fruit injury by direct feeding insects like thrips, stinkbugs, and the later season caterpillars (tomato fruitworm, fall and beet armyworms). The secondary and occasional pests are usually controlled as a result of broad-spectrum insecticide applications for the primary pests. As the control options have become more pest-specific, formerly secondary pests like stinkbugs have become primary pests.

The main processing tomato insect pests are Colorado potato beetles early in the season and the caterpillars in the later season, including tomato fruitworm and fall armyworm. In areas of high Colorado potato beetle populations, preventative treatments are applied at planting. Most of the foliar insecticide use on processing tomatoes occurs later in the season to prevent fruit injury.

Insecticide Resistance Management Insecticides have been classified by the Insecticide Resistance Action Committee (IRAC) by their mode of action (MoA) (23). Insecticides within a given IRAC MoA group usually target the same site within a pest, have a similar mode-of-action, control similar types of insects, and thus share the same risk for resistance development. The concept of cross resistance of chemicals within the same mode of action group/subgroup is the basis of the IRAC classification. The overuse or misuse of some insecticides may result in the development of resistant populations not only of the specific insecticide but to all insecticides within its IRAC group. This classification scheme has been developed to aid those in the crop protection business (including farmers, extension staff, consultants, advisors, etc.) in selecting insecticides for resistance management. In the following section insecticides listed for the control of specific insects are listed according to active ingredient followed by trade name and IRAC MoA group in parentheses. Where appropriate, guidelines for specific use according to resistance management are included.

Colorado Potato Beetle, *Leptinotarsa decemlineata*

Description and Damage: Colorado potato beetle (CPB) adults are oval-shaped and have an orange or light brown head and thorax with wing covers that are yellow with black stripes. Females lay an average of 25 yellow elliptical eggs in a cluster or mass on the undersides of tomato leaves. An individual female deposits approximately 500 eggs over a period of about 3 weeks. Larvae hatch in 4 to 8 days, are convex in shape and look like grubs. They have two rows of black spots down each side, a black head and black legs. The early instars are typically darker orange or red and turn a lighter orange color as they develop through four instars. Mature larvae drop to the ground and burrow into the soil to pupate into adults in 5 to 10 days. Larvae hatch and feed in groups, spreading out on an individual plant as they develop and feed. Both larvae and adults feed on all parts of the plant.

The Colorado potato beetle (CPB) has historically been the main insect pest of tomatoes and other solanaceous crops in New Jersey. Adults and larvae attack foliage, flowers, and young fruit, and have the potential to defoliate these crops each year. Adult beetles overwinter in the soil in and near infested fields from the previous season. In

May and early June, overwintering adults emerge and walk to host plants to feed, mate and lay eggs. The adults defoliate newly transplanted fields, especially those located close to last year's fields, and may cause complete yield loss. Infestations are typically clumped in a field, especially for the first generation. Early infestations may be controlled with spot or edge treatments. Severe defoliation can occur if larvae and adults are not controlled. Two generations occur annually and occasionally a partial third generation may develop. CPB occur throughout the state every year in areas where solanaceous plants are grown.

Since the advent of the neonicotinoid (IRAC group 4A) materials, CPB control has become less of a problem in tomato production. The use of these materials at planting has reduced broad spectrum foliar insecticide use overall. However, pests that were less commonly seen (e.g., stinkbugs) due to broad spectrum insecticide use are now necessitating management every year. Also, insecticide resistance is a major concern for CPB management. CPB has developed resistance to at least 49 active ingredients and all major insecticide groups (54). Imidacloprid (IRAC group 4A) has been an effective choice for control on tomatoes in the last decade; however, tolerance and resistance has been documented (7). Future pest management with regard to CPB must include resistance management planning and implementation.

Monitoring and Thresholds: The recommended procedure is to check newly transplanted fields weekly for overwintered adult populations. Inspect field edges closest to where a host crop was grown the previous year. The insect will move over or through another crop to infest tomatoes. Treat transplants when 15 CPB adults are found on 10 plants (16). If early treatments are not applied, wait for egg hatch and start spray program when larvae are young and exceed the threshold of 20 larvae or adults per 10 plants. Reassess after each treatment to determine the need and timing of next spray. Avoid the application of IRAC Group 4A insecticides on second and third generations for resistance management.

Chemical Controls:

1. abamectin (Agri-Mek, IRAC Group 6)
 - Percent acres treated: 15.8% (42)
 - Typical rates and frequency of application: 8.0-16.0 fl oz 0.15 EC/A, 1-2 applications. Do not exceed 48 fl oz/A per growing season. Do not make more than 2 sequential applications.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 7 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Treat at threshold levels of CPB. For resistance management, do not apply on tomatoes being grown for transplanting (see label). This material has high toxicity to some natural enemies, especially predatory mites (51).

2. acetamiprid (Assail, IRAC Group 4A)
 - Percent acres treated: 0.1% (42)
 - Typical rates and frequency of application: 1.5-2.5 oz 30SG/A, 1 application.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 7 days
 - Efficacy: Very good.
 - Use in IPM and resistance management: Treat at threshold levels of CPB. Rotate with non IRAC Group 4A insecticides. Lower rates preserve beneficial insect and spider populations and allow for faster rebound of the beneficial populations.

3. azadirachtin (Azatin, Ecozin, Neemix, etc.; IRAC Group 26)
 - Percent acres treated: 9.6% (42)
 - Typical rates and frequency of application: 8.0-16.0 fl oz EC/A or other labeled formulation (OLF), 2-3 applications.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 0 days
 - Efficacy: Fair to good.
 - Use in IPM and resistance management: Compatible with the use of most beneficial insects. Apply when pests first appear and are in their early larval stages (16). Use lower rate as a preventative when populations are low or if used in combination with other adulticides. For high pest populations use the higher rate and treat more frequently (see label).

4. *Bacillus thuringiensis tenebrionis* (Novodor, IRAC Group 11C)
 - Percent acres treated: 0.1% (42)
 - Typical rates and frequency of application: 1-3 qts FC/A for light to moderate infestations of small larvae; 2-3 qts FC/A heavy infestations of small larvae; 3-4 qts FC/A for mixed populations of early and later instar larvae; 2-3 applications.
 - Method of application: Foliar application with ground equipment.
 - REI: 4 hours PHI: 0 days
 - Efficacy: Good on small or newly hatched larvae.
 - Use in IPM and resistance management: Begin treatments at early egg hatch and repeat applications 5-7 day intervals if small larvae are present. *Bt* is not effective on medium larvae and adults. If rainfall occurs within 24 hours of the application, reapplication may be needed (16).

5. dinotefuran (Venom, IRAC Group 4A)
 - Percent acres treated: New material; data not available.
 - Typical rates and frequency of application: 5.0-6.0 oz (soil); 1.0-4.0 oz (foliar) 70SG/A, 1-3 applications. Do not apply to varieties less than 2 inches in size (cherry or grape varieties). Do not apply more than 6.0 oz (foliar) or 12 oz (soil) per acre per season.
 - Method of application: Do not combine applications; use either a foliar application with ground or aerial equipment or a soil application applied as a transplant drench, in-furrow, side-dressed, or drip-irrigated.

- Typical rates and frequency of application: 1-2 qts 2L/A, 1-2 applications. Do not apply more than 24 pts per acre per season.
 - Method of application: Foliar application with ground equipment.
 - REI: 48 hours PHI: 1 day
 - Efficacy: Fair to good. Most effective when the plant has adequate foliage and is actively growing. Applications under other conditions may be ineffective (16).
 - Use in IPM and resistance management: Treat at threshold levels of CPB and rotate with materials in other IRAC groups. This broad spectrum material has high toxicity and moderate duration of activity against beneficial insects (51).
9. spinosad (SpinTor 2SC, Entrust; IRAC Group 5)
- Percent acres treated: 22.3% (0% Entrust) (42)
 - Typical rates and frequency of application:
 - SpinTor 2SC: 3.0-6.0 fl oz 2SC/A, 2-3 applications. Do not exceed 29 total fl oz per acre per season.
 - Entrust: 1.0-2.0 oz 80W/A, 2-3 applications. Do not apply more than 9 oz per acre per crop.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 4 hours PHI: 1 day
 - Efficacy: Good.
 - Use in IPM and resistance management: Treat at threshold levels of CPB and rotate with materials in other IRAC groups. Since spinosad (IRAC Group 5) does not impact certain predators and parasites, secondary pest outbreaks are minimized. Use a higher rate for heavy infestations or advanced growth stages. For resistance management do not apply more than 3 times in any 21 day period; rotate to another insecticide class or do not use spinosad for the next 21 days.
10. thiamethoxam (Platinum, IRAC Group 4A)
- Percent acres treated: 0.4% (42)
 - Typical rates and frequency of application: 5.0-8.0 oz 2SC/A, 1 application. Lower rates provide a shorter residual control.
 - Method of application: Soil application may be applied as a transplant drench, in-furrow, side-dressed, or drip-irrigated.
 - REI: 12 hours PHI: 30 days
 - Efficacy: Very good.
 - Use in IPM and resistance management: Thiamthoxam is applied as a preventative treatment for CPB. For resistance management, if the soil treatment is applied, subsequent foliar applications should be made with materials in different insecticide groups.

Alternatives: There are effective materials that are alternatives to the EPA targeted materials endosulfan (IRAC Group 2A) and oxamyl (IRAC Group 1A), including acetamiprid, imidacloprid, and thiamethoxam (IRAC Group 4A), and spinosad (IRAC Group 5). However, the first three active ingredients are in the same chemical group

and should be rotated with materials in other groups for resistance management. There are several IRAC Group 3 materials that are labeled but are not effective; permethrin and esfenvalerate may be effective as an alternative if applied with a synergist such as piperonyl butoxide.

Cultural Control Practices: The key cultural control for CPB is rotation from previous host crops (tomato, eggplant, and potato), especially for control of the overwintered population. Control solanaceous weeds such as horse nettle. Plastic-lined trenches to trap the overwintering population have been shown to reduce early adult populations (37); however, growers have not adopted this method. Trap cropping and/or trenching between last year's and this year's fields may also be effective in combination with flaming of adults (4).

Biological Controls: Numerous natural enemies including ladybug larvae, lacewing larvae, predatory stinkbugs, and others feed on all stages of the CPB.

Other Issues: Abamectin (IRAC Group 6), acetamiprid (IRAC Group 4A), and esfenvalerate (IRAC Group 3) may not be used during harvest due to the 7-day PHI.

Thrips, *Frankliniella* spp., *Thrips* spp.

Description and Damage: Several species of thrips occasionally infest tomatoes as well as numerous other host plants. Adult thrips are small, less than $\frac{1}{10}$ inch long, and may be black, yellow, or banded yellow and black. Eggs are produced sexually or asexually, and wingless nymphs develop into winged adults within 2 weeks. Thrips pierce plant tissue and extract sap, causing white streaks on the leaves and giving the leaves a silvery appearance. Direct feeding on the fruit results in a small dimple surrounded by a white halo. Thrips feeding scars reduce the marketability of fruit. In addition to direct feeding damage, certain species vector tomato spotted wilt virus and impatiens necrotic spot virus. Viral transmission usually occurs in the greenhouse during transplant production.

Thrips move into tomato fields from adjacent weed or crop hosts, and their development, like spider mites, is favored by prolonged warm and dry conditions. Thrips can be found every year in most fields, but the development to pest status is mainly dependent on the environmental conditions (long periods of hot and dry weather). Cool wet weather conditions slow thrips development.

Monitoring and Thresholds: Inspect plants for evidence of thrips and thrips damage and consider treating if significant fruit damage is occurring and weather conditions are favorable for continued development.

Chemical Controls:

1. acetamiprid (Assail, IRAC Group 4A)

- Percent acres treated: 0.1% (42)
 - Typical rates and frequency of application: 4.0 oz 30SG/A, 1 application.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 7 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Rotate with non IRAC Group 4A insecticides. Lower rates preserve beneficial insect and spider populations and allow for faster rebound of the beneficial populations.
2. dinotefuran (Venom, IRAC Group 4A)
- Percent acres treated: New material; data not available.
 - Typical rates and frequency of application: 5.0-6.0 oz (soil); 1.0-4.0 oz (foliar) 70SG/A, 1-3 applications. Do not apply to varieties less than 2 inches in size (cherry or grape varieties). Do not apply more than 6.0 oz (foliar) or 12 oz (soil) per acre per season.
 - Method of application: Do not combine applications; use either a foliar application with ground or aerial equipment or a soil application applied as a transplant drench, in-furrow, side-dressed, or drip-irrigated.
 - REI: 12 hours PHI: 1 day foliar; 21 days for soil application
 - Efficacy: Good.
 - Use in IPM and resistance management: Time applications before damaging populations become established, and use higher rates when pest pressure is severe. The rate applied affects the length of control. Rotate with non-IRAC Group 4A insecticides.
3. gamma-cyhalothrin (Proaxis, IRAC Group 3)
- Percent acres treated: Newer material, data not available.
 - Typical rates and frequency of application: 2.56-3.84 fl oz/A, 1-2 applications. Do not apply more than 2.88 pts per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 24 hours PHI: 5 days
 - Efficacy: Good.
 - Use in IPM and resistance management: This material has broad-spectrum activity so that it may be used when multiple pests are present. Overuse of IRAC Group 3 insecticides impacts predators and parasites and may cause secondary pest outbreaks.
4. imidacloprid (Admire, IRAC Group 4A)
- Percent acres treated: 25.7% (42)
 - Typical rates and frequency of application: 16-24 fl oz 2F/A, 1 application (lower rates provide a shorter residual control). Do not exceed 24 fl oz/A per season.
 - Method of application: Soil application applied as a transplant drench, in-furrow, side-dressed, or drip-irrigated.
 - REI: 12 hours PHI: 21 days
 - Efficacy: Good.

- Use in IPM and resistance management: Growers apply imidacloprid (IRAC Group 4A) primarily as a drench application to transplants 3-4 days before transplanting as a preventative treatment for early season control of CPB. Other pests controlled include early season aphids, thrips, and flea beetles. Admire provides control of foliar feeding thrips and does not control thrips infesting flowers or blooms (see label).
5. lambda-cyhalothrin (Warrior, IRAC Group 3)
- Percent acres treated: 36.5% (42)
 - Typical rates and frequency of application: 2.56-3.84 fl oz/A, 1-2 applications.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 24 hours PHI: 5 days
 - Efficacy: Fair to good.
 - Use in IPM and resistance management: Lambda-cyhalothrin (IRAC Group 3) has broad-spectrum activity for multiple pest species, and would likely be used when thrips are present and the lepidopteran larvae were at threshold levels. Rotate with materials from other insecticide groups for resistance management. Overuse of pyrethroid (IRAC Group 3) related materials impacts predators and parasites and may cause secondary pest outbreaks.
6. methamidophos (Monitor, IRAC Group 1B)
- Percent acres treated: 0.9% (42)
 - Typical rates and frequency of application: 1.5-2.0 pts 4EC/A, 1-2 applications. Do not exceed 4 applications per crop per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 4 days PHI: 7 days
 - Efficacy: Very good.
 - Use in IPM and resistance management: This material is primarily recommended for stinkbug control, although due to the broad spectrum activity it is effective on many tomato insects. However, it has a high toxicity and long duration of impact on natural enemy populations (51).
7. spinosad (SpinTor 2SC, Entrust; IRAC Group 5)
- Percent acres treated: 22.3% (0% Entrust) (42)
 - Typical rates and frequency of application:
 - SpinTor 2SC: 4.0-8.0 fl oz 2SC/A, 1-2 applications. Do not exceed 29 total fluid ounces per acre per season.
 - Entrust: 1.25-2.25 oz 80W/A, 1-2 applications. Do not apply more than 9 oz per acre per crop.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 4 hours PHI: 1 day
 - Efficacy: Good.
 - Use in IPM and resistance management: Spinosad (IRAC Group 5) is more frequently used for control of lepidopterous larvae and would be used for thrips at

the time these pests are active. Since spinosad does not impact certain predators and parasites, secondary pest outbreaks are minimized.

Alternatives: There are effective alternatives to methamidophos (IRAC Group 1B) for thrips control. Gamma-cyhalothrin and lambda-cyhalothrin (IRAC Group 3), spinosad (IRAC Group 5), and imidacloprid (IRAC Group 4A) are materials recommended for control of thrips in New Jersey. Other materials labeled but not typically recommended are azadirachtin (IRAC Group 26), and bifenthrin, cyfluthrin, and zeta-permethrin (IRAC Group 3). Newer materials fenproparthrin (IRAC Group 3) and pyriproxyfen (IRAC Group 7C) are labeled for control with methamidophos (IRAC Group 1B).

Cultural Control Practices: Avoid growing tomatoes next to onions, garlic, or cereals because thrips often build up to large numbers on these crops. Do not grow transplants in or near greenhouses with ornamentals (cut flowers, impatiens) as these plants serve as host for the virus and thrips. Beware of highly susceptible species such as New Guinea impatiens and gloxinia which are common source of tomato spotted wilt virus. Control weeds in and around the greenhouse which could harbor tomato spotted wilt virus. If the virus is suspected, rogue out the infected material as quickly as possible. Use resistant cultivars if available. Avoid southern transplants.

Biological Controls: No effective and reliable biological control is available, although numerous naturally occurring predators will feed on thrips.

Other Issues: Methamidophos (IRAC Group 1B) may not be used during harvest due to the 7-day PHI.

Green Peach Aphid, *Myzus persicae*
Potato Aphid, *Macrosiphum euphorbiae*

Description and Damage: Aphids are occasional pests of tomatoes. The species commonly found infesting tomatoes include the green peach aphid (GPA) and the potato aphid (PA). Although similar in size, about 1/8 inch, they vary in appearance. The potato aphid is pear-shaped and may be solid pink, green and pink mottled, or light green with a dark stripe. The green peach aphid is pear shaped and pale yellow to green in color. Both species have a slender pair of tail-like appendages (cornicles). The cornicles are much shorter on the GPA than the PA.

Aphids migrate from overwintering sites on wild host plants in the spring and establish colonies. They feed on plants by injecting piercing sucking mouthparts into the plant tissue and removing plant juices. Aphids are usually found on the undersides of the leaves, and as they feed they excrete excess plant sap that accumulates on the plant surfaces below the infested leaves. A black to grayish sooty mold fungus grows on the sap, discoloring the leaves and fruit. The sooty mold is difficult to wash off and may result in unmarketable fruit. Heavy infestations on the leaves cause leaf curling and yellowing, stunting, and reduced plant vigor.

Aphids are controlled effectively most years by naturally occurring predators and parasites. Broad-spectrum and pyrethroid (IRAC Group 3) insecticide treatments, which impact natural enemy populations, can increase the potential for aphid outbreaks.

Monitoring and Thresholds: The typical method includes checking transplants prior to planting for infestations and monitoring for aphids when scouting other insect pests. Scouts check the undersides of the leaves for aphids and look on leaf surfaces for the presence of sooty mold. Treatment may be needed when infestations are increasing or when sooty mold appears.

Chemical Controls:

1. acetamiprid (Assail, IRAC Group 4A)
 - Percent acres treated: 0.1% (42)
 - Typical rates and frequency of application: 2.0-4.0 oz 30SG/A, 1 application.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 7 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Although this material is primarily used for CPB control it will also control aphids. Rotate with non IRAC Group 4A insecticides. Lower rates preserve beneficial insect and spider populations and allow for faster rebound of the beneficial populations.

2. diazinon (Diazinon, IRAC Group 1B)
 - Percent acres treated: 1.1% (42)
 - Typical rates and frequency of application: 0.5 lb 50WP/A or OLF, 1-2 applications. Do not make more than 5 applications per season.
 - Method of application: Foliar application with ground equipment.
 - REI: 24 hours PHI: 1 day
 - Efficacy: Poor. Not listed in the 2007 New Jersey Commercial Vegetable Production Recommendations manual for this pest.
 - Use in IPM and resistance management: Rotate with materials in other IRAC groups.

3. dimethoate (Dimethoate, IRAC Group 1B)
 - Percent acres treated: 4.1% (42)
 - Typical rates and frequency of application: 0.5-1.0 pt 4EC/A or OLF, 1-2 applications.
 - Method of application: Foliar application with ground equipment.
 - REI: 48 hours PHI: 7 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Rotate with materials in other IRAC groups. This material has high toxicity and long duration of activity against beneficial insects (51).

4. dinotefuran (Venom, IRAC Group 4A)

- Percent acres treated: New material; data not available.
 - Typical rates and frequency of application: 5.0-6.0 oz (soil); 1.0-4.0 oz (foliar) 70SG/A, 1-3 applications. Do not apply to varieties less than 2 inches in size (cherry or grape varieties). Do not apply more than 6.0 oz (foliar) or 12 oz (soil) per acre per season.
 - Method of application: Do not combine applications; use either a foliar application with ground or aerial equipment or a soil application applied as a transplant drench, in-furrow, side-dressed, or drip-irrigated.
 - REI: 12 hours PHI: 1 day foliar; 21 days for soil application
 - Efficacy: Good.
 - Use in IPM and resistance management: Time applications before damaging populations become established, and use higher rates when pest pressure is severe. The rate applied affects the length of control. Rotate with non-IRAC Group 4A insecticides.
5. endosulfan (Thionex, Thiodan, Phaser, etc.; IRAC Group 2A)
- Percent acres treated: 3.7% (42)
 - Typical rates and frequency of application: 1.0-1.33 qts 3EC/A, 1-2 applications. Do not make more than 6 applications per year; do not exceed 4.0 qts per acre per year.
 - Method of application: Foliar application with ground equipment.
 - REI: 24 hours PHI: 2 days
 - Efficacy: Good.
 - Use in IPM and resistance management: The broad-spectrum activity of this material results in its use when multiple pests are present. Rotate with materials in other IRAC groups.
6. gamma-cyhalothrin (Proaxis, IRAC Group 3)
- Percent acres treated: New material; data not available.
 - Typical rates and frequency of application: 2.56-3.84 fl oz/A, 1-2 applications. Do not apply more than 2.88 pts per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 24 hours PHI: 5 days
 - Efficacy: Good.
 - Use in IPM and resistance management: This material has broad-spectrum activity so that it may be used when multiple pests are present. Overuse of IRAC Group 3 insecticides impacts predators and parasites and may cause secondary pest outbreaks.
7. imidacloprid (Admire, Admire Pro, Provado; IRAC Group 4A)
- Percent acres treated: 43.7% (25.7% Admire; 18.0% Provado) (42)
 - Typical rates and frequency of application:
 - Admire: 16-24 fl oz 2F/A, 1 application. Lower rates provide a shorter residual control. Do not exceed 24 fl oz per acre per season.

- Provado: 3.75 fl oz 1.6F/A, 1-2 applications. Do not exceed 19.2 fl oz per acre per season.
 - Method of application:
 - Admire: Soil application applied as a transplant drench, in-furrow, side-dressed, or drip-irrigated.
 - Provado: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 21 days (Admire)
 - REI: 12 hours PHI: 0 days (Provado)
 - Efficacy: Good.
 - Use in IPM and resistance management: Growers apply imidacloprid (IRAC Group 4A) primarily as a preventative treatment for early season control of CPB. Aphids will also be controlled under this use. Growers should follow the resistance management practices for CPB for this material.
8. methamidophos (Monitor, IRAC Group 1B)
- Percent acres treated: 0.9% (42)
 - Typical rates and frequency of application: 1.5-2.0 pts 4EC/A, 1-2 applications. Do not exceed 4 applications per crop per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 4 days PHI: 7 days
 - Efficacy: Good to very good.
 - Use in IPM and resistance management: This material is primarily recommended for stinkbug control, although due to the broad spectrum activity it is effective on many tomato insects. However, it has a high toxicity and long duration of impact on natural enemy populations (51).
9. methomyl (Lannate, IRAC Group 1A)
- Percent acres treated: 6.6% (42)
 - Typical rates and frequency of application: 1.5-3.0 pts LV/A, 1-2 applications. Do not apply more than 16 applications or 2.7 gal per acre per crop.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 48 hours PHI: 1 day
 - Efficacy: Good.
 - Use in IPM and resistance management: This broad spectrum material has high toxicity and moderate duration of activity against beneficial insects (51). Use in rotation with materials from other insecticide groups for resistance management.
10. oxamyl (Vydate L, IRAC Group 1A)
- Percent acres treated: 6.8% (42)
 - Typical rates and frequency of application: 1-2 qts 2L/A, 1-2 applications. Do not apply more than 24 pts per acre per season.
 - Method of application: Foliar application with ground equipment.
 - REI: 48 hours PHI: 1 day
 - Efficacy: Fair to good. Most effective when the plant has adequate foliage and is actively growing. Applications under other conditions may be ineffective (16).

- Use in IPM and resistance management: This material would primarily be used to control CPB, and would also control aphids. This broad spectrum material has high toxicity and moderate duration of activity against beneficial insects (51).

11. pymetrozine (Fulfill, IRAC Group 9B)

- Percent acres treated: Newer material; data not available.
- Typical rates and frequency of application: 2.75 oz 50W/A, 1-2 applications. Do not exceed a total of 5.5 oz/A per crop per season. Allow a minimum of 7 days between applications.
- Method of application: Foliar application with ground equipment.
- REI: 12 hours PHI: 0 days
- Efficacy: Very good.
- Use in IPM and resistance management: This material selectively controls aphids. Upon application feeding will cease, but aphids may not die right away. Should be applied when aphids first appear and before populations build to damaging levels. Low toxicity to beneficial insect populations. Rotate with products with different modes of action for resistance management.

12. thiamethoxam (Platinum, IRAC Group 4A)

- Percent acres treated: 0.4% (42)
- Typical rates and frequency of application: 5.0-8.0 oz 2SC/A, 1 application. Lower rates provide a shorter residual control.
- Method of application: Soil application may be applied as a transplant drench, in-furrow, side-dressed, or drip-irrigated.
- REI: 12 hours PHI: 30 days
- Efficacy: Very good.
- Use in IPM and resistance management: Growers apply thiamethoxam (IRAC Group 4A) primarily as a preventative treatment for early season control of CPB. Aphids will also be controlled under this use. Growers follow the resistance management practices for CPB for this material.

13. zeta-cypermethrin (Mustang Max, IRAC Group 3)

- Percent acres treated: 2.0% (42)
- Typical rates and frequency of application: 3.2-4.0 fl oz/A, 1-2 applications.
- Method of application: Foliar application with ground or aerial equipment.
- REI: 12 hours PHI: 1 day
- Efficacy: Fair to good.
- Use in IPM and resistance management: Zeta-cypermethrin (IRAC Group 3) has broad-spectrum activity for multiple pest species. Rotate with materials from other insecticide groups for resistance management.

Alternatives: The materials that are alternatives to methomyl and oxamyl (IRAC Group 1A), diazinon and methamidophos (IRAC Group 1B), and endosulfan (IRAC Group 2A) include the IRAC Group 4A insecticides (acetamiprid, imidacloprid, and thiamthoxam) and pymetrozine (IRAC Group 9B). Both of these insecticide groups would be applied

as a preventative in the early stages of aphid population development. In the case of an aphid population outbreak, there are no effective alternatives. The pyrethroids (bifenthrin, gamma-cyhalothrin, and zeta-cypermethrin; IRAC Group 3) and azadirachtin (IRAC Group 26) are labeled but are not recommended in New Jersey for aphid control.

Cultural Control Practices: Destroy weed populations around the field. Incorporate crop residue as soon as possible after the last harvest.

Biological Controls: Numerous natural enemies help keep aphid populations under control, including lacewing larvae, syrphid fly larvae, lady beetle adults and larvae, true bugs and other predators. Parasites and a fungal disease are also important biological control agents. Overuse of certain broad spectrum insecticides has been shown to cause aphid outbreaks due to their detrimental impact on predators and parasites. Conservation of natural enemies in tomato fields is important for aphid control.

Other Issues: During harvesting, acetamiprid (IRAC Group 4A), dimethoate (IRAC Group 1B), and methamidophos (IRAC Group 1B) may not be used due to the PHI.

Stinkbugs

Euschistus servus, *E. variolarius*, & *E. tristigmus*

Description and Damage: Three species of stinkbugs are associated with tomatoes in New Jersey: *Euschistus servus*, *E. variolarius*, and *E. tristigmus* (25). Stinkbugs are shield-shaped with a large triangle on the thorax and green or brown in color. Eggs are barrel-shaped and stand on end in double rows. Nymphs are similar to adults in appearance, but smaller. They overwinter in debris and other protected areas, emerging in the spring to lay eggs on plant leaves. The adults and nymphs pierce plant tissue with needle-like mouthparts and remove plant juices from all parts of the plant, including fruit. Immature fruit may become deformed and drop off the plant. Mature fruit will have a white to yellow stippled area under the surface of the tomato skin associated with dark pinprick or small dimple at the feeding site. Although the damage is cosmetic it does reduce the marketability of the fruit.

Damage from stinkbugs has been increasing as insecticides have become more selective. Injury occurs sporadically in tomatoes and is usually limited to field margins where they migrate from other hosts such as brambles or legumes, especially during dry weather when adjacent forage crops are harvested. In some years the injury can significantly impact yield since the damage directly affects the marketability of the fruit. As a result, preventative treatments are usually applied during fruit development since detection is difficult.

Monitoring and Thresholds: Stinkbugs are difficult to monitor due to their mobility and ability to hide in the plant. The threshold in New Jersey is to treat when levels exceed 1 stinkbug damaged fruit per 40 plants or 1 stinkbug per 6 plants when fruit are present or if fruit damage is increasing (18).

Chemical Controls:

1. bifenthrin (Capture, IRAC Group 3)
 - Percent acres treated: 9.7% (42)
 - Typical rates and frequency of application: 2.1-5.2 fl oz 2EC/A, 1-2 applications. Do not make applications less than 10 days apart. A maximum of 4 applications may be applied per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 1 day
 - Efficacy: Good. Not listed in the 2007 New Jersey Commercial Vegetable Production Recommendations manual for this pest.
 - Use in IPM and resistance management: Treat at threshold levels and rotate with materials in other IRAC groups. Overuse of pyrethroid (IRAC Group 3) related materials impacts predators and parasites and may cause secondary pest outbreaks.

2. cyfluthrin (Baythroid, IRAC Group 3)
 - Percent acres treated: 11.3% (42)
 - Typical rates and frequency of application: 2.8 fl oz 2E/A, 2-3 applications. Do not exceed 16.8 total fluid ounces per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 0 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Treat at threshold levels and rotate with non IRAC group 3 insecticides. The broad-spectrum activity results in its use when multiple pests are present. Overuse of pyrethroid (IRAC Group 3) related materials impacts predators and parasites and may cause secondary pest outbreaks.

3. endosulfan (Thionex, Thiodan, Phaser, etc.; IRAC Group 2A)
 - Percent acres treated: 3.7% (42)
 - Typical rates and frequency of application: 1.0-1.33 qts 3EC/A, 1-2 applications. Do not make more than 6 applications per year; do not exceed 4.0 qts per acre per year.
 - Method of application: Foliar application with ground equipment.
 - REI: 24 hours PHI: 2 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Treat at threshold levels and rotate with materials in other IRAC groups. The broad-spectrum activity of this material results in its use when multiple pests are present.

4. fenproparthrin (Danitol, IRAC Group 3)
 - Percent acres treated: 11.7% (42)
 - Typical rates and frequency of application: 10.67 fl oz 2.4EC/A, 1-2 applications. Do not exceed 42.67 fl oz per acre per season. Do not tank mix with any copper formulations.

- Method of application: Foliar application with ground or aerial equipment.
 - REI: 24 hours PHI: 3 days
 - Efficacy: Very good.
 - Use in IPM and resistance management: This material is primarily used as a miticide for two-spotted spider mites, but it also controls other tomato pests that may be active at the same time. However, the broad spectrum activity results in high toxicity to beneficial insects (51). Treat at threshold levels and use in rotation with other insecticides.
5. gamma-cyhalothrin (Proaxis, IRAC Group 3)
- Percent acres treated: Newer material, data not available.
 - Typical rates and frequency of application: 2.56-3.84 fl oz/A, 1-2 applications. Do not apply more than 2.88 pts per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 24 hours PHI: 5 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Treat at threshold levels and rotate with materials in other IRAC groups. This material has broad-spectrum activity so that it may be used when multiple pests are present. Overuse of IRAC Group 3 insecticides impacts predators and parasites and may cause secondary pest outbreaks.
6. lambdacyhalothrin (Warrior, IRAC Group 3)
- Percent acres treated: 36.5% (42)
 - Typical rates and frequency of application: 2.56-3.84 fl oz/A, 2-3 applications.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 24 hours PHI: 5 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Lambdacyhalothrin (IRAC Group 3) has broad-spectrum activity for multiple pest species, and would be used when both stinkbugs and the lepidopterous larvae are at threshold levels. Rotate with materials from other insecticide groups for resistance management. Overuse of pyrethroid (IRAC Group 3) related materials impacts predators and parasites and may cause secondary pest outbreaks.
7. methamidophos (Monitor, IRAC Group 1B)
- Percent acres treated: 0.9% (42)
 - Typical rates and frequency of application: 1.5-2.0 pts 4EC/A, 1-2 applications. Do not exceed 4 applications per crop per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 4 days PHI: 7 days
 - Efficacy: Very good.
 - Use in IPM and resistance management: This material is primarily recommended for stinkbug control, although due to the broad spectrum activity it is effective on

many tomato insects. However, it has a high toxicity and long duration of impact on natural enemy populations (51).

8. zeta-cypermethrin (Mustang Max, IRAC Group 3)
 - Percent acres treated: 2.0% (42)
 - Typical rates and frequency of application: 3.2-4.0 fl oz/A, 1-2 applications.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 1 day
 - Efficacy: Good.
 - Use in IPM and resistance management: Zeta-cypermethrin (IRAC Group 3) has broad-spectrum activity for multiple pest species. Rotate with materials from other insecticide groups for resistance management.

Alternatives: The pyrethroids (cyfluthrin, fenproparthrin, zeta-permethrin, gamma-cyhalothrin, and lambda-cyhalothrin; IRAC Group 3) are alternatives to methamidophos (IRAC Group 1B) and endosulfan (IRAC Group 2A). However, they are all in the same IRAC group. Methamidophos and endosulfan provide longer residual control and are needed for resistance management.

Cultural Control Practices: Maintain good weed control in and around the field and avoid planting near other host crops, especially forage crops.

Biological Controls: No effective natural enemies are known.

Other Issues: Methamidophos (IRAC Group 1B) may not be used during harvest due to the 7-day PHI.

Two Spotted Spider Mite, *Tetranychus urticae*

Description and Damage: Adult two spotted spider mites (TSSM) overwinter in the soil, on tree bark, in debris, and in sheltered areas. They become active in early spring, but usually reach peak abundance in mid to late July, and are active through frost. Mites are very small ($1/60$ inch in length) and difficult to see with the naked eye; a 10x hand lens facilitates identification. Adults have eight legs, are oval shaped, and are various shades of green, yellow, or pink, with a characteristic dark spot on each side of the body.

Females deposit individual spherical eggs on the undersides of the leaves or in sheltered areas on the plant. Immature mites molt three times and reach adulthood in less than a week depending on environmental conditions. Adults and nymphs feed on the undersides of the leaves, extracting plant sap and causing whitish spots or stippling damage that results in leaf yellowing on the upper leaf surface. As populations increase, the leaves turn brown, the fruit may become injured from mite feeding, and leaves and fruit become covered in fine webbing. Heavy infestations may result in leaf drop and unmarketable fruit.

Hot dry weather promotes mite development. Infestations generally begin around field margins, grassy areas, and windbreaks, or from other hosts like soybean, small grains, or other solanaceous crops. Mites disperse through wind, worker, and equipment movement. Rain and overhead irrigation help to hinder outbreaks. The use of certain pesticides that impact the natural enemy complex (pyrethroid sprays in particular) are known to cause spider mite outbreaks (21). Infestations may go undetected until population levels are high and difficult to control since mites are small and the damage may be mistaken for nutrient deficiency. If left untreated, mites will cause yield losses of 50% or more depending on the time of infestation.

Mites are found most years in tomato fields in the southern region of the state (Atlantic, Camden, Salem, Gloucester, and Cumberland counties), but they do not typically reach economically damaging levels except during long periods of hot dry weather. Tomatoes grown in high tunnels throughout the state do experience more frequent problems with mites since the greenhouse conditions favor population outbreaks. Population explosions in high tunnels have resulted in abandonment of harvesting toward the end of the high tunnel season.

Monitoring and Thresholds: The typical scouting method includes observing plants near field edges, especially next to dusty roads. A 10X hand lens or shaking leaves over white paper helps in identification. Fields should be monitored weekly especially during dry periods. Spot treatments may be effective for early infestations. There are no thresholds determined for tomatoes in New Jersey. Consider treatment if the mite population is increasing and/or if significant plant injury is evident (29).

Chemical Controls:

1. abamectin (Agri-Mek, IRAC Group 6)
 - Percent acres treated: 15.8% (42)
 - Typical rates and frequency of application: 8.0-16.0 fl oz 0.15EC/A, 1-2 applications. Do not apply more than 48 fl oz per acre per season, and do not make more than 2 consecutive applications.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 7 days
 - Efficacy: Very good.
 - Use in IPM and resistance management: Apply when mites first appear and use in rotation with other groups of miticides for resistance management. This material has high toxicity to some natural enemies, especially predatory mites (51).

2. bifenazate (Acramite, IRAC Group 25)
 - Percent acres treated: Newer material, data not available.
 - Typical rates and frequency of application: 0.75-1.0 lb 50WS/A, 1 application. Use only on tomato plants that will produce fruit greater than 1 inch in diameter (see label).
 - Method of application: Foliar application with ground equipment.
 - REI: 12 hours PHI: 3 days

- Efficacy: Very good.
 - Use in IPM and resistance management: Treat as mite levels increase and use in rotation with other miticides. Bifenazate (IRAC Group 25) is selective for two-spotted spider mites and is relatively inactive against populations of beneficial insects and predatory mites (see label).
3. dicofol (Kelthane, IRAC Group 20)
- Percent acres treated: 16.3% (42)
 - Typical rates and frequency of application: 0.75-1.5 pt EC/A, 1 application. Do not exceed 1.6 pts per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 2 days
 - Efficacy: Very good.
 - Use in IPM and resistance management: Apply at first signs of mite buildup. For resistance management do not apply more than 1 application per year and use in rotation with other miticides. If two applications are made in a single growing season, no applications should be made the following year (see label).
4. fenproparthrin (Danitol, IRAC Group 3)
- Percent acres treated: 11.7% (42)
 - Typical rates and frequency of application: 10.67 fl oz 2.4EC/A, 1-2 applications. Do not exceed 42.67 fl oz per acre per season. Do not tank mix with any copper formulations.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 24 hours PHI: 3 days
 - Efficacy: Poor to fair.
 - Use in IPM and resistance management: Treat when mite populations are just beginning to build (less than 5 mites/leaf) (see label). Repeat as needed to maintain control but not more often than every 7 days. Use in rotation with other miticides. The broad spectrum activity results in high toxicity to beneficial insects (51).
5. spiromesifen (Oberon, IRAC Group 23)
- Percent acres treated: New material; data not available.
 - Typical rates and frequency of application: 7.0-8.5 2SC/A, 1-2 applications. Do not apply more than 3 applications or 25.5 fl oz per acre per season, and do not apply more than 8.5 fl oz per acre per 7-day interval.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 7 days
 - Efficacy: Very good.
 - Use in IPM and resistance management: Applications should be timed to coincide with the early developing mite population. Use in rotation with other groups of miticides for resistance management.

Alternatives: There are alternatives to dicofol (IRAC Group 20) for mite control, including bifenthrin and fenproparthrin (IRAC Group 3), abamectin (IRAC Group 6), spiromesifen (IRAC Group 23), and bifenazate (IRAC Group 25).

Cultural Control Practices: Destroy weeds around the field in the fall or early spring to reduce overwintering populations. Populations generally decline after periods of heavy rainfall, and overhead irrigation may have the same effect. Avoid planting near alfalfa, small grains, and hay. Maintain mowed areas next to fields, or avoid mowing overgrown weedy areas after midseason and/or especially during dry periods.

Biological Controls: Mite natural enemies like minute pirate bugs, predatory thrips, and predatory mites usually keep populations under control. Outbreaks have been associated with the use of broad spectrum insecticides that impact natural enemy populations (21). In high tunnels in New Jersey, two species of predatory mites are being used to control TSSM effectively (20).

Other Issues: Abamectin (IRAC Group 6) and spiromesifen (IRAC Group 23) may not be used during harvest due to the 7-day PHI.

Tomato Fruitworm, *Helioverpa zea*

Description and Damage: The tomato fruitworm (TFW), adult moth is yellowish-tan with a characteristic dark spot near the middle of the wing. Females deposit individual spherical eggs on the leaves and blossoms of tomato plants. Eggs hatch in 3-5 days depending on environmental conditions, and larvae move to the fruit to feed. Larval color varies from light green to pink, yellow, and brown. Adult moths are active at dusk through early morning, laying eggs on susceptible host plants like sweet corn, peppers, tomatoes, lettuce, and weeds. As the larvae mature they bore into the fruit to feed, usually leaving obvious entry and exit holes. Occasionally they will enter under the calyx. Fruit may rot in the field prior to harvest or may go undetected through the packing line only to be rejected at the market.

Tomato fruitworm pupae overwinter in the soil throughout New Jersey in mild winters, although survival is usually not successful north of 39° latitude. Adults typically appear in July in New Jersey. Adults are highly migratory, and move from other areas into New Jersey especially associated with weather systems of southern origin. During the fall hurricane season (late August through September), large influxes of moths may occur. Tomatoes are not a favored host, but in the absence of other host plants (especially sweet corn), and in combination with high populations, tomatoes may sustain fruit loss. In southern New Jersey, TFW are present most years but do not usually reach economically damaging levels due to preventative treatments. Northern counties rarely have problems with TFW on tomatoes.

Monitoring and Thresholds: Rutgers Cooperative Extension publishes a statewide Plant & Pest Advisory newsletter that contains maps of adult black light trap population levels. The maps are useful for growers to determine area population levels and

possible risk of fruit infestations. A threshold of 20 moths per night is the general guideline used for assessing risk of infestation.

Chemical Controls:

1. bifenthrin (Capture, IRAC Group 3)
 - Percent acres treated: 9.7% (42)
 - Typical rates and frequency of application: 2.1-5.2 fl oz 2EC/A, 1-2 applications. Do not make applications less than 10 days apart. A maximum of 4 applications may be applied per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 1 day
 - Efficacy: Very good.
 - Use in IPM and resistance management: Treat at threshold levels and rotate with materials in other IRAC groups. Overuse of pyrethroid (IRAC Group 3) related materials impacts predators and parasites and may cause secondary pest outbreaks.

2. cyfluthrin (Baythroid, IRAC Group 3)
 - Percent acres treated: 11.3% (42)
 - Typical rates and frequency of application: 1.6-2.8 fl oz 2E/A, 1-2 applications. Do not exceed 16.8 total fl oz per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 0 days
 - Efficacy: Very good.
 - Use in IPM and resistance management: Treat at threshold levels and rotate with non IRAC group 3 insecticides. The broad-spectrum activity results in its use when multiple pests are present. Overuse of pyrethroid (IRAC Group 3) related materials impacts predators and parasites and may cause secondary pest outbreaks.

3. emamectin (Proclaim, IRAC Group 6)
 - Percent acres treated: Newer material; data not available.
 - Typical rates and frequency of application: 2.4-4.8 fl oz 5WDG/A, 1-2 applications. Do not exceed 4.8 fl oz/A per application or 28.8 fl oz ounces per acre per season. Do not make subsequent applications less than 7 days apart.
 - Method of application: Foliar application with ground equipment.
 - REI: 48 hours PHI: 7 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Emamectin (IRAC Group 6) is recommended for use on small larvae when larvae first appear and before populations reach damaging levels. The lower rate is used for low to moderate populations, and the high rate for high infestations. The product needs to be ingested so coverage is important. Rotate with materials from other insecticide groups for resistance management.

4. esfenvalerate (Asana, IRAC Group 3)
 - Percent acres treated: 3.6% (42)
 - Typical rates and frequency of application: 5.8-9.6 fl oz 0.66EC/A, 1-2 applications. Do not exceed 96 fl oz per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 1 day
 - Efficacy: Good.
 - Use in IPM and resistance management: Due to lower residual activity, this material is used every 5-7 days during the period of threshold levels of TFW. The broad-spectrum contact activity results in its use when multiple pests are present. Rotate with materials from other insecticide groups for resistance management. Overuse of pyrethroid (IRAC Group 3) related materials impacts predators and parasites and may cause secondary pest outbreaks.

5. fenproparthrin (Danitol, IRAC Group 3)
 - Percent acres treated: 11.7% (42)
 - Typical rates and frequency of application: 10.67 fl oz 2.4EC/A, 1-2 applications. Do not exceed 42.67 fl oz per acre per season and maintain at least 7 days between applications. Do not tank mix with any copper formulations.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 24 hours PHI: 3 days
 - Efficacy: Good.
 - Use in IPM and resistance management: This material is primarily used as a miticide for two-spotted spider mites, but it also controls other tomato pests that may be active at the same time. However, the broad spectrum activity results in high toxicity to beneficial insects (51). Treat at threshold levels and use in rotation with other insecticides.

6. gamma-cyhalothrin (Proaxis, IRAC Group 3)
 - Percent acres treated: Newer material, data not available.
 - Typical rates and frequency of application: 2.56-3.84 fl oz/A, 1-2 applications. Do not apply more than 2.88 pts per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 24 hours PHI: 5 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Treat at threshold levels and rotate with materials in other IRAC groups. This material has broad-spectrum activity so that it may be used when multiple pests are present. Overuse of IRAC Group 3 insecticides impacts predators and parasites and may cause secondary pest outbreaks.

7. indoxacarb (Avaunt, IRAC Group 22)
 - Percent acres treated: 2.6% (42)

- Typical rates and frequency of application: 3.5 oz 30WDG/A, 1-2 applications. Do not apply more than 14 oz per acre per crop. Allow at least 5 days between applications.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 3 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Use at threshold levels and rotate with materials from other insecticide groups for resistance management. This product is useful in an IPM program for conserving certain beneficial insect populations.
8. lambda-cyhalothrin (Warrior, IRAC Group 3)
- Percent acres treated: 36.5% (42)
 - Typical rates and frequency of application: 2.56-3.84 fl oz/A, 2-4 applications.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 24 hours PHI: 5 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Lambda-cyhalothrin (IRAC Group 3) has broad-spectrum activity for multiple pest species. Rotate with materials from other insecticide groups for resistance management. Overuse of pyrethroids (IRAC Group 3) impacts predators and parasites and may cause secondary pest outbreaks.
9. methomyl (Lannate, IRAC Group 1A)
- Percent acres treated: 6.6% (42)
 - Typical rates and frequency of application: 1.5-3.0 pts LV/A, 1-2 applications. Do not apply more than 16 applications or 2.7 gal per acre per crop.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 48 hours PHI: 1 day
 - Efficacy: Good.
 - Use in IPM and resistance management: This broad spectrum material has high toxicity and moderate duration of activity against beneficial insects (51). Treat at threshold levels and reapply on a 5-7 day spray schedule to maintain control. Use in rotation with materials from other insecticide groups for resistance management.
10. methoxyfenozide (Intrepid, IRAC Group 18)
- Percent acres treated: Newer material, data not available.
 - Typical rates and frequency of application: 10-16 fl oz/A 1-2 applications. Do not apply more 16.0 fl oz per acre per application, and no more than 64 fl oz per acre per season.
 - Method of application: Foliar application with ground equipment.
 - REI: 12 hours PHI: 1 day
 - Efficacy: Good.
 - Use in IPM and resistance management: Since larvae must ingest the material, reapplications may be needed to protect new growth until moth flights and/or infestations subside. This material selectively controls multiple lepidopteran

species but does not impact beneficial insect populations and bees (see label). Rotate with materials from other insecticide groups for resistance management.

11. permethrin (i.e., Ambush, Pounce; IRAC Group 3)

- Percent acres treated: 2.5% (42)
- Typical rates and frequency of application: 2.0-8.0 fl oz 3.2EC/A or OLF. Do not apply more than 24 oz per acre per season. Do not apply on cherry tomatoes or other varieties with fruit less than one inch in diameter.
- Method of application: Foliar application with ground or aerial equipment.
- REI: 24 hours PHI: 0 days
- Efficacy: Fair to good. Not listed in the 2007 New Jersey Commercial Vegetable Production Recommendations manual for control of this pest.
- Use in IPM and resistance management: Use in rotation with other groups of insecticides. Overuse of permethrin (IRAC Group 3) will impact predators and parasites and may cause secondary pest outbreaks.

12. spinosad (SpinTor 2SC, Entrust; IRAC Group 5)

- Percent acres treated: 22.3% (0% Entrust) (42)
- Typical rates and frequency of application:
 - SpinTor 2SC: 3.0-6.0 fl oz 2SC/A, 2-3 applications. Do not exceed 29 fl oz per acre per season.
 - Entrust: 1.0-2.0 oz 80W/A, 2-3 applications. Do not apply more than 9 oz per acre per crop.
- Method of application: Foliar application with ground or aerial equipment.
- REI: 4 hours PHI: 1 day
- Efficacy: Good.
- Use in IPM and resistance management: Treat at threshold levels and/or time applications to peak egg hatch. Use a higher rate for heavy infestations or advanced growth stages. Since spinosad (IRAC Group 5) does not impact certain predators and parasites, secondary pest outbreaks are minimized. For resistance management, use in rotation with other groups of insecticides and do not apply more than 3 times in any 21 day period; rotate to another insecticide class or do not use spinosad for the next 21 days (see label).

13. zeta-cypermethrin (Mustang Max, IRAC Group 3)

- Percent acres treated: 2.0% (42)
- Typical rates and frequency of application: 2.24-4.0 fl oz/A, 1-2 applications.
- Method of application: Foliar application with ground or aerial equipment.
- REI: 12 hours PHI: 1 day
- Efficacy: Good.
- Use in IPM and resistance management: Zeta-cypermethrin (IRAC Group 3) has broad-spectrum activity for multiple pest species. Rotate with materials from other insecticide groups for resistance management. Overuse of pyrethroid (IRAC Group 3) related materials impacts predators and parasites and may cause secondary pest outbreaks.

Alternatives: Carbaryl (IRAC Group 1A) and endosulfan (IRAC Group 2A) are labeled for TFW on tomatoes but are not listed in the New Jersey Commercial Vegetable Recommendations manual. Although methomyl (IRAC Group 1A) and methamidophos (IRAC Group 1B) are recommended in New Jersey, there are effective alternative materials available including cyfluthrin, gamma-cyhalothrin, lambda-cyhalothrin, and zeta-permethrin (IRAC Group 3), emamectin (IRAC Group 6), indoxacarb (IRAC Group 22), methoxyfenozide (IRAC Group 18), spinosad (IRAC Group 5).

Cultural Control Practices: Effective weed control may help reduce TFW damage by improving spray coverage within the field.

Biological Controls: There are many general predators like lady beetles, syrphid fly larvae, lacewings, spiders, and minute pirate bug, which feed on TFW eggs and small larvae. However, when populations of TFW are high, natural control is not reliable.

Other Issues: Esfenvalerate and cyfluthrin (IRAC Group 3), emamectin (IRAC Group 6), and methamidophos (IRAC Group 1B) may not be used during harvest due to the 7-day PHI.

Fall Armyworm, *Spodoptera frugiperda*

Description and Damage: Fall armyworms (FAW) migrate from the southern states and appear in New Jersey in July, and are attracted to tomato fields as sweet corn fields mature in late August through September. FAW females deposit fuzzy light brown egg masses on the undersides of leaves. Larvae are light to dark brown with a dark stripe along each side, and have a pattern of four black dots on each segment down the back, and a characteristic inverted 'Y' shape on the head capsule. Larvae emerge and disperse throughout the plant to feed on both the leaves and the fruit. As they mature they bore into the fruit and usually leave obvious large entry holes. They cause direct damage to the fruit, and can be a contaminant as well as cause significant fruit rot. Early fruit infestations may go undetected. Under high populations many fruit may turn prematurely red and rot in the field. Populations in New Jersey depend on southern survivorship and migration, and vary year to year. Yield losses can be significant on fall tomatoes.

Monitoring and Thresholds: Pheromone traps can be used to track the adult male populations to determine influxes of moths. Trap captures of 10-20 per night in the green unitraps, in combination with presence of egg masses and/or evidence of larvae in the field, signal that FAW is a target pest for fall fruit cover sprays.

Chemical Controls:

1. bifenthrin (Capture, IRAC Group 3)
 - Percent acres treated: 9.7% (42)
 - Typical rates and frequency of application: 2.1-5.2 fl oz 2EC/A, 1-2 applications.

Do not make applications less than 10 days apart. A maximum of 4 applications may be applied per season.

- Method of application: Foliar application with ground or aerial equipment.
- REI: 12 hours PHI: 1 day
- Efficacy: Good.
- Use in IPM and resistance management: Treat at threshold levels and rotate with materials in other IRAC groups. Overuse of pyrethroid (IRAC Group 3) related materials impacts predators and parasites and may cause secondary pest outbreaks.

2. emamectin (Proclaim, IRAC Group 6)

- Percent acres treated: Newer material; data not available.
- Typical rates and frequency of application: 2.4-4.8 fl oz 5WDG/A, 1-2 applications. Do not exceed 4.8 fl oz/A per application or 28.8 total fluid ounces per acre per season. Do not make subsequent applications less than 7 days apart.
- Method of application: Foliar application with ground equipment.
- REI: 48 hours PHI: 7 days
- Efficacy: Good.
- Use in IPM and resistance management: Emamectin (IRAC Group 6) is recommended for use on small larvae when larvae first appear and before populations reach damaging levels. The lower rate is used for low to moderate populations, and the high rate for high infestations. Since the product needs to be ingested, coverage is important. Rotate with materials from other insecticide groups for resistance management.

3. gamma-cyhalothrin (Proaxis, IRAC Group 3)

- Percent acres treated: Newer material, data not available.
- Typical rates and frequency of application: 2.56-3.84 fl oz/A, 1-2 applications. Do not apply more than 2.88 pts per acre per season.
- Method of application: Foliar application with ground or aerial equipment.
- REI: 24 hours PHI: 5 days
- Efficacy: Good.
- Use in IPM and resistance management: Treat at threshold levels and rotate with materials in other IRAC groups. This material has broad-spectrum activity so that it may be used when multiple pests are present. Overuse of IRAC Group 3 insecticides impacts predators and parasites and may cause secondary pest outbreaks.

4. lambdacyhalothrin (Warrior, IRAC Group 3)

- Percent acres treated: 36.5% (42)
- Typical rates and frequency of application: 2.56-3.84 fl oz/A, 2-4 applications.
- Method of application: Foliar application with ground or aerial equipment.
- REI: 24 hours PHI: 5 days
- Efficacy: Good for first and second instar larvae.

- Use in IPM and resistance management: Labeled for control of first and second instar larvae only. Lambdacyhalothrin (IRAC Group 3) has broad-spectrum activity for multiple pest species. Rotate with materials from other insecticide groups for resistance management. Overuse of pyrethroids (IRAC Group 3) impacts predators and parasites and may cause secondary pest outbreaks.
5. methomyl (Lannate, IRAC Group 1A)
- Percent acres treated: 6.6% (42)
 - Typical rates and frequency of application: 2.0 pts 2.4LV/A, 1-2 applications. Do not apply more than 16 applications or 2.7 gal per acre per crop.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 48 hours PHI: 1 day
 - Efficacy: Good.
 - Use in IPM and resistance management: This broad spectrum material has high toxicity and moderate duration of activity against beneficial insects (51). Treat at threshold levels and reapply on a 5-7 day spray schedule to maintain control. Use in rotation with materials from other insecticide groups for resistance management.
6. methoxyfenozide (Intrepid, IRAC Group 18)
- Percent acres treated: Newer material, data not available.
 - Typical rates and frequency of application: 4-8 fl oz 2F/A early season, 8-16 fl oz 2F/A late season; 1-2 applications. Do not apply more 16.0 fl oz per acre per application, and no more than 64 fl oz per acre per season.
 - Method of application: Foliar application with ground equipment.
 - REI: 12 hours PHI: 1 day
 - Efficacy: Good.
 - Use in IPM and resistance management: Since larvae must ingest the material additional applications may be needed to protect new growth until moth flights and/or infestations subside. Methoxyfenozide (IRAC Group 18) selectively controls multiple lepidopteran species but does not impact beneficial insect populations or bees. Rotate with materials from other insecticide groups for resistance management.
7. spinosad (SpinTor 2SC, Entrust; IRAC Group 5)
- Percent acres treated: 22.3% (0% Entrust) (42)
 - Typical rates and frequency of application:
 - SpinTor 2SC: 4.0-8.0 fl oz 2SC/A, 1-2 applications. Do not exceed 29 fl oz per acre per season.
 - Entrust: 1.0-2.0 oz 80W/A, 1-2 applications. Do not apply more than 9 oz per acre per crop.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 4 hours PHI: 1 day
 - Efficacy: Good.

Other Issues: Tebufenozide (IRAC Group 18) and emamectin (IRAC Group 6) may not be used during harvest due to the 7-day PHI.

Potato Flea Beetle, *Epitrix cucumeris*
Tobacco Flea Beetle, *E. hirtipennis*
Palestriped Flea Beetle, *Systema blanda*

Description and Damage: Flea beetles are occasional pests of tomatoes. Most flea beetles are tiny, darkly colored beetles 2.5 to 4.5 mm long. The body is usually a shiny black or duller brown color, or dark with pale yellow stripes on each wing cover. Flea beetles overwinter as adults in protected areas like hedgerows and emerge in mid-May into June to lay eggs in the soil. Eggs hatch in the soil and larvae feed on plant roots and pupate in 3 to 4 weeks. Adults appear in late June and July. A second generation of beetles matures in August or September.

Flea beetles have large hind legs that allow them to jump from plant to plant. Beetles damage tomato plants by chewing tiny round holes in the foliage, resulting in a 'shot-hole' appearance. Seedling or newly transplanted plants are more susceptible to damage at lower population levels, as the loss of leaf tissue will stunt plant growth. The larvae may also feed on the roots but generally do not cause significant damage.

Monitoring and Thresholds: The typical scouting method is to check fields shortly after transplanting for the appearance of the adults and/or flea beetle damage. Beetles are more easily found on warm, calm, sunny days. Monitor field borders since beetles move into the crop during the day and take shelter in hedgerows and weeds at night. Fields should be monitored weekly for the first 3 weeks following transplanting (29). Treat if defoliation exceeds 30% (12). Once plants are established they can withstand flea beetle feeding injury without loss to yield or quality.

Chemical Controls:

1. bifenthrin (Capture, IRAC Group 3)
 - Percent acres treated: 9.7% (42)
 - Typical rates and frequency of application: 2.1-5.2 fl oz 2EC/A, 1-2 applications. Do not make applications less than 10 days apart. A maximum of 4 applications may be applied per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 1 day
 - Efficacy: Very good.
 - Use in IPM and resistance management: Treat at threshold levels and rotate with materials in other IRAC groups. Overuse of pyrethroid (IRAC Group 3) related materials impacts predators and parasites and may cause secondary pest outbreaks.

2. cyfluthrin (Baythroid, IRAC Group 3)
 - Percent acres treated: 11.3% (42)

- Typical rates and frequency of application: 2.8 fl oz 2E/A, 1-2 applications. Do not exceed 16.8 total fluid ounces per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 0 days
 - Efficacy: Good. Not listed in the 2007 New Jersey Commercial Vegetable Production Recommendations manual for this pest.
 - Use in IPM and resistance management: Treat at threshold levels and rotate with non IRAC group 3 insecticides. The broad-spectrum activity results in its use when multiple pests are present. Overuse of pyrethroid (IRAC Group 3) related materials impacts predators and parasites and may cause secondary pest outbreaks.
3. dinotefuran (Venom, IRAC Group 4A)
- Percent acres treated: New material; data not available.
 - Typical rates and frequency of application: 5.0-6.0 oz (soil); 1.0-4.0 oz (foliar) 70SG/A, 1-3 applications. Do not apply to varieties less than 2 inches in size (cherry or grape varieties). Do not apply more than 6.0 oz (foliar) or 12 oz (soil) per acre per season.
 - Method of application: Do not combine applications; use either a foliar application with ground or aerial equipment or a soil application applied as a transplant drench, in-furrow, side-dressed, or drip-irrigated.
 - REI: 12 hours PHI: 1 day foliar; 21 days for soil application
 - Efficacy: Good.
 - Use in IPM and resistance management: Time applications before damaging populations become established, and use higher rates when pest pressure is severe. The rate applied affects the length of control (label). Rotate with non-IRAC Group 4A insecticides.
4. endosulfan (Thionex, Thiodan, Phaser, etc.; IRAC Group 2A)
- Percent acres treated: 3.7% (42)
 - Typical rates and frequency of application: 0.67-1.33 qts 3EC/A, 1-2 applications. Do not make more than 6 applications per year; do not exceed 4.0 qts per acre per year.
 - Method of application: Foliar application with ground equipment.
 - REI: 24 hours PHI: 2 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Treat at threshold levels and rotate with materials in other IRAC groups. The broad-spectrum activity of this material results in its use when multiple pests are present.
5. esfenvalerate (Asana, IRAC Group 3)
- Percent acres treated: 3.6% (42)
 - Typical rates and frequency of application: 5.8-9.6 fl oz EC/A, 1-2 applications.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 1 day

- Efficacy: Good.
 - Use in IPM and resistance management: Treat at threshold levels and rotate with materials in other IRAC groups. The broad-spectrum activity of this material results in its use when multiple pests are present. Overuse of IRAC Group 3 materials may impact predators and parasites and cause secondary pest outbreaks.
6. gamma-cyhalothrin (Proaxis, IRAC Group 3)
- Percent acres treated: New material; data not available.
 - Typical rates and frequency of application: 2.56-3.84 fl oz/A, 1-2 applications. Do not apply more than 2.88 pts per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 24 hours PHI: 5 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Treat at threshold levels and rotate with materials in other IRAC groups. This material has broad-spectrum activity so that it may be used when multiple pests are present. Overuse of IRAC Group 3 insecticides impacts predators and parasites and may cause secondary pest outbreaks.
7. imidacloprid (Admire, IRAC Group 4A)
- Percent acres treated: 25.7% (42)
 - Typical rates and frequency of application: 16-24 fl oz 2F/A, 1 application (lower rates provide shorter residual control). Do not exceed 24 oz per acre per season.
 - Method of application: Soil application applied as a transplant drench, in-furrow, side-dressed, or drip-irrigated.
 - REI: 12 hours PHI: 21 days
 - Efficacy: Very good.
 - Use in IPM and resistance management: Growers apply imidacloprid (IRAC Group 4A) primarily as a drench application to transplants 3-4 days before transplanting as a preventative treatment for early season control of CPB. Other pests controlled include early season aphids, thrips, and flea beetles.
8. lambdacyhalothrin (Warrior, IRAC Group 3)
- Percent acres treated: 36.5% (42)
 - Typical rates and frequency of application: 2.56-3.84 fl oz/A, 1-2 applications.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 24 hours PHI: 5 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Lambdacyhalothrin (IRAC Group 3) has broad-spectrum activity for multiple pest species, including the lepidopteran tomato pests. Rotate with materials from other insecticide groups for resistance management. Overuse of pyrethroid (IRAC Group 3) related materials impacts predators and parasites and may cause secondary pest outbreaks.
9. thiamethoxam (Platinum, IRAC Group 4A)

- Percent acres treated: 0.4% (42)
- Typical rates and frequency of application: 5.0-8.0 oz 2SC/A, 1 application.
- Method of application: Soil application may be applied as a transplant drench, in-furrow, side-dressed, or drip-irrigated.
- REI: 12 hours PHI: 30 days
- Efficacy: Very good.
- Use in IPM and resistance management: Growers apply thiamethoxam (IRAC Group 4A) primarily as a drench application to transplants 3-4 days before transplanting as a preventative treatment for early season control of CPB. Other pests controlled include early season aphids and flea beetles. Lower rates provide a shorter residual control.

10. zeta-cypermethrin (Mustang Max, IRAC Group 3)

- Percent acres treated: 2.0% (42)
- Typical rates and frequency of application: 3.2-4.0 fl oz/A, 1-2 applications.
- Method of application: Foliar application with ground or aerial equipment.
- REI: 12 hours PHI: 1 day
- Efficacy: Good.
- Use in IPM and resistance management: Zeta-cypermethrin (IRAC Group 3) has broad-spectrum activity for multiple pest species. Rotate with materials from other insecticide groups for resistance management.

Alternatives: The recommended materials that are alternatives to carbaryl (IRAC Group 1A) and endosulfan (IRAC Group 2A) include bifenthrin, esfenvalerate, gamma-cyhalothrin and zeta-permethrin (IRAC Group 3), imidacloprid and thiamethoxam (IRAC Group 4A). Imidacloprid and thiamethoxam provide early season flea beetle control, although these materials are primarily used for CPB control.

Cultural Control Practices: Deep plowing after harvest may reduce overwintering populations. Flea beetles migrate from weedy areas, so remove weeds along field margins. After harvest, deeply disc plant residues in infested fields and practice good sanitation by removing any leftover debris. Row covers may be used on small plantings to exclude beetles after transplanting.

Biological Controls: There are entomopathogenic nematodes that control flea beetles (30).

Other Issues: During harvesting gamma-cyhalothrin (IRAC Group 3) may not be used due to the 7 day PHI.

Beet Armyworm, *Spodoptera exigua*

Description and Damage: Beet armyworms (BAW) are another southern pest that migrate into southern New Jersey in mid to late August. The larvae have a wide host range, including alfalfa, asparagus, beans, beets, cole crops, lettuce, spinach, onions, peppers, and tomatoes, as well as some weeds. Population levels depend on favorable

survival in the southern states in combination with favorable conditions for migration. In New Jersey, outbreaks occur sporadically in the southern counties. Early detection and management of high population levels of the small larvae is critical for effective control. High populations of larvae can quickly defoliate fields if left uncontrolled.

Like fall armyworms, BAW females deposit oval-shaped light brown fuzzy eggs in clusters on the undersides of the leaves. Eggs hatch in 3 to 4 days, and larvae mature in 2 to 3 weeks depending on environmental conditions. Larvae are green or greenish-black, and have a characteristic dark spot above the second pair of legs. Small larvae feed in groups on the plant within fine webbing on the undersides of the leaves. As the larvae mature they spread out on the plant, consuming leaves and fruit. The larvae skeletonize leaves and damage fruit by both boring into the fruit at the calyx end and leaving surface marks.

Most years some BAW occur in the southern counties at low levels, but occasionally large influxes of moths occur. High populations can quickly defoliate fields, causing significant yield loss from fruit injury and plant defoliation, if not controlled with effective materials. Resistance management is a concern since BAW migrates from areas where resistance to several materials is present.

Monitoring and Thresholds: Pheromone traps (green unitrap) can be used to determine when influxes of moths occur. As trap captures increase to 20 per night, scout fields for presence of larvae, infested plants, and/or egg masses. Infestations should be monitored closely, and control measures should be evaluated within a week after application.

Chemical Controls:

1. emamectin (Proclaim, IRAC Group 6)
 - Percent acres treated: Newer material; data not available.
 - Typical rates and frequency of application: 2.4-4.8 fl oz 5WDG/A, 1-2 applications. Do not exceed 4.8 fl oz/A per application or 28.8 oz per acre per season. Do not make subsequent applications less than 7 days apart.
 - Method of application: Foliar application with ground equipment.
 - REI: 48 hours PHI: 7 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Emamectin (IRAC Group 6) is recommended for use on small larvae when larvae first appear and before populations reach damaging levels. The lower rate is used for low to moderate populations, and the high rate for high infestations. Since the product needs to be ingested, coverage is important. Rotate with materials from other insecticide groups for resistance management.

2. indoxacarb (Avaunt, IRAC Group 22)
 - Percent acres treated: 2.6% (42)

- Typical rates and frequency of application: 3.5 oz 30WDG/A, 1-2 applications. Do not apply more than 14 oz per acre per crop. Allow at least 5 days between applications.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 3 days
 - Efficacy: Very good.
 - Use in IPM and resistance management: Use at threshold levels and rotate with materials from other insecticide groups for resistance management. This product is useful in an IPM program for conserving certain beneficial insect populations.
3. methomyl (Lannate, IRAC Group 1A)
- Percent acres treated: 6.6% (42)
 - Typical rates and frequency of application: 1.5-3.0 pts 2.4LV/A, 1-2 applications. Do not apply more than 16 applications or 2.7 gal per acre per crop.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 48 hours PHI: 1 day
 - Efficacy: Fair.
 - Use in IPM and resistance management: This broad spectrum material has high toxicity and moderate duration of activity against beneficial insects (51). Treat at threshold levels and reapply on a 5-7 day spray schedule to maintain control. Use in rotation with materials from other insecticide groups for resistance management.
4. methoxyfenozide (Intrepid, IRAC Group 18)
- Percent acres treated: Newer material, data not available.
 - Typical rates and frequency of application: 4-8 fl oz 2F/A early season, 8-16 fl oz 2F/A late season; 1-2 applications. Do not apply more 16.0 oz per acre per application, and no more than 64 oz per acre per season.
 - Method of application: Foliar application with ground equipment.
 - REI: 12 hours PHI: 1 day
 - Efficacy: Good.
 - Use in IPM and resistance management: Since larvae must ingest the material, additional applications may be needed to protect new growth until moth flights and/or infestations subside. Methoxyfenozide (IRAC Group 18) selectively controls multiple lepidopteran species but does not impact beneficial insect populations or bees. Rotate with materials from other insecticide groups for resistance management.
5. spinosad (SpinTor 2SC, Entrust; IRAC Group 5)
- Percent acres treated: 22.3% (0% Entrust) (42)
 - Typical rates and frequency of application:
 - SpinTor 2SC: 4.0-8.0 fl oz 2SC/A, 1-2 applications. Do not exceed 29 total fl oz per acre per season.
 - Entrust: 1.25-2.5 oz 80W/A, 1-2 applications. Do not apply more than 9 oz per acre per crop.

- Method of application: Foliar application with ground or aerial equipment.
- REI: 4 hours PHI: 1 day
- Efficacy: Good.
- Use in IPM and resistance management: Treat at threshold levels and/or time applications to peak egg hatch. Use a higher rate for heavy infestations or advanced growth stages. Since spinosad (IRAC Group 5) does not impact certain predators and parasites, secondary pest outbreaks are minimized. For resistance management, use in rotation with other groups of insecticides and do not apply more than 3 times in any 21 day period; rotate to another insecticide class or do not use spinosad for the next 21 days (label).

6. tebufenozide (Confirm, IRAC Group 18)

- Percent acres treated: 1.7% (42)
- Typical rates and frequency of application: 8.0-16.0 fl oz 2F/A, 1-2 applications. Do not exceed 64 total fluid ounces per acre per season.
- Method of application: Foliar application with ground or aerial equipment.
- REI: 4 hours PHI: 7 days
- Efficacy: Good.
- Use in IPM and resistance management: Tebufenozide (IRAC Group 18) selectively controls multiple lepidopteran species but does not impact beneficial insect populations or bees. Lower rates are recommended for light infestations and higher rates for moderate to heavy infestations. Application timing is important since the material must be ingested before larvae enter the fruit. Re-application is recommended when insect populations are high and/or the plants are rapidly growing. For resistance management, rotate with materials from other insecticide groups.

Alternatives: There are recommended alternatives to diazinon (IRAC Group 1B), methomyl (IRAC Group 1A) and methamidophos (IRAC Group 1B) for BAW control including spinosad (IRAC Group 5), and methoxyfenozide and tebufenozide (IRAC Group 18). Although not recommended for this pest due to poor efficacy, the pyrethroids (bifenthrin, cyfluthrin, esfenvalerate, fenproparthrin, gamma-cyhalothrin, permethrin, and zeta-cypermethrin; IRAC Group 3) are labeled for control of BAW.

Cultural Control Practices: None available.

Biological Controls: Although there are many natural enemies that attack beet armyworms (21), none provide reliable control under high population levels.

Other Issues: Bifenthrin and fenproparthrin (IRAC Group 3), emamectin (IRAC Group 6), methamidophos (IRAC Group 1B), and tebufenozide (IRAC Group 18) may not be used during harvest due to the 7-day PHI.

Tomato Hornworm, *Manduca quinquemaculata*
Tobacco Hornworm, *Manduca sexta*

- Percent acres treated: Newer material; data not available.
 - Typical rates and frequency of application: 2.4-4.8 fl oz 5WDG/A, 1-2 applications. Do not exceed 4.8 fl oz/A per application or 28.8 total fluid ounces per acre per season. Do not make subsequent applications less than 7 days apart.
 - Method of application: Foliar application with ground equipment.
 - REI: 48 hours PHI: 7 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Emamectin (IRAC Group 6) is recommended for use on small larvae when larvae first appear and before populations reach damaging levels. The lower rate is used for low to moderate populations, and the high rate for high infestations. The product needs to be ingested so coverage is important. Rotate with materials from other insecticide groups for resistance management.
4. esfenvalerate (Asana, IRAC Group 3)
- Percent acres treated: 3.6% (42)
 - Typical rates and frequency of application: 2.9-5.8 fl oz 0.66EC/A, 1-2 applications. Do not exceed 96 total fluid ounces per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 1 day
 - Efficacy: Good.
 - Use in IPM and resistance management: The broad-spectrum contact activity results in its use when multiple pests are present. Rotate with materials from other insecticide groups for resistance management. Overuse of pyrethroid (IRAC Group 3) related materials impacts predators and parasites and may cause secondary pest outbreaks.
5. fenproparthrin (Danitol, IRAC Group 3)
- Percent acres treated: 11.7% (42)
 - Typical rates and frequency of application: 10.67 fl oz 2.4EC/A, 1 application. Do not exceed 42.67 fl oz per acre per season and maintain at least 7 days between applications. Do not tank mix with any copper formulations.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 24 hours PHI: 3 days
 - Efficacy: Good.
 - Use in IPM and resistance management: This material is primarily used as a miticide for two-spotted spider mites, but it also controls other tomato pests that may be active at the same time. However, the broad spectrum activity results in high toxicity to beneficial insects (51). Use in rotation with other insecticides.
6. gamma-cyhalothrin (Proaxis, IRAC Group 3)
- Percent acres treated: Newer material, data not available.
 - Typical rates and frequency of application: 1.9-3.2 fl oz/A, 1 application. Do not apply more than 2.88 pts per acre per season.

- Method of application: Foliar application with ground or aerial equipment.
 - REI: 24 hours PHI: 5 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Use in rotation with other groups of insecticides. This material has broad-spectrum activity so that it may be used when multiple pests are present. Overuse of IRAC Group 3 insecticides impacts predators and parasites and may cause secondary pest outbreaks.
7. indoxacarb (Avaunt, IRAC Group 22)
- Percent acres treated: 2.6% (42)
 - Typical rates and frequency of application: 2.5-3.5 oz 30WDG/A, 1-2 applications. Do not apply more than 14 oz per acre per crop. Allow at least 5 days between applications.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 3 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Rotate with materials from other insecticide groups for resistance management. This product is useful in an IPM program for conserving certain beneficial insect populations.
8. lambdacyhalothrin (Warrior, IRAC Group 3)
- Percent acres treated: 36.5% (42)
 - Typical rates and frequency of application: 1.92-3.2 fl oz/A, 1-2 applications.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 24 hours PHI: 5 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Lambdacyhalothrin (IRAC Group 3) has broad-spectrum activity for multiple pest species. Rotate with materials from other insecticide groups for resistance management. Overuse of pyrethroids (IRAC Group 3) impacts predators and parasites and may cause secondary pest outbreaks.
9. methomyl (Lannate, IRAC Group 1A)
- Percent acres treated: 6.6% (42)
 - Typical rates and frequency of application: 1.5-3.0 pts LV/A, 1-2 applications. Do not apply more than 16 applications or 2.7 gal per acre per crop.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 48 hours PHI: 1 day
 - Efficacy: Good.
 - Use in IPM and resistance management: This broad spectrum material has high toxicity and moderate duration of activity against beneficial insects (51). Use in rotation with materials from other insecticide groups for resistance management.
10. methoxyfenozide (Intrepid, IRAC Group 18)
- Percent acres treated: Newer material, data not available.

- Typical rates and frequency of application: 4-8 fl oz 2F/A early season, 8-16 fl oz 2F/A late season; 1-2 applications. Do not apply more 16.0 fl oz per acre per application, and no more than 64 fl oz per acre per season.
- Method of application: Foliar application with ground equipment.
- REI: 12 hours PHI: 1 day
- Efficacy: Good.
- Use in IPM and resistance management: Since larvae must ingest the material, reapplications may be needed to protect new growth until moth flights and/or infestations subside. Methoxyfenozide (IRAC Group 18) selectively controls multiple lepidopteran species but does not impact beneficial insect populations or bees. Rotate with materials from other insecticide groups for resistance management.

11. spinosad (SpinTor 2SC, Entrust; IRAC Group 5)

- Percent acres treated: 22.3% (0% Entrust) (42)
- Typical rates and frequency of application:
 - SpinTor 2SC: 3.0-6.0 fl oz 2SC/A, 1-2 applications. Do not exceed 29 total fluid ounces per acre per season.
 - Entrust: 1.0-2.0 oz 80W/A, 1-2 applications. Do not apply more than 9 oz per acre per crop.
- Method of application: Foliar application with ground or aerial equipment.
- REI: 4 hours PHI: 1 day
- Efficacy: Good.
- Use in IPM and resistance management: Time applications to peak egg hatch. Use a higher rate for heavy infestations or advanced growth stages. Since spinosad (IRAC Group 5) does not impact certain predators and parasites, secondary pest outbreaks are minimized. For resistance management, use in rotation with other groups of insecticides and do not apply more than 3 times in any 21 day period; rotate to another insecticide class or do not use spinosad for the next 21 days (see label).

12. tebufenozide (Confirm, IRAC Group 18)

- Percent acres treated: 1.7% (42)
- Typical rates and frequency of application: 6.0-16.0 fl oz 2F/A, 1-2 applications. Do not exceed 64 total fluid ounces per acre per season.
- Method of application: Foliar application with ground or aerial equipment.
- REI: 4 hours PHI: 7 days
- Efficacy: Good.
- Use in IPM and resistance management: Tebufenozide (IRAC Group 18) selectively controls multiple lepidopteran species but does not impact beneficial insect populations or bees. Lower rates are recommended for light infestations and higher rates for moderate to heavy infestations. Application timing is important since the material must be ingested before larvae enter the fruit. Re-application is recommended when insect populations are high and/or the plants

are rapidly growing. For resistance management, rotate with materials from other insecticide groups.

13. zeta-cypermethrin (Mustang Max, IRAC Group 3)

- Percent acres treated: 2.0% (42)
- Typical rates and frequency of application: 2.24-4.0 fl oz/A, 1-2 applications.
- Method of application: Foliar application with ground or aerial equipment.
- REI: 12 hours PHI: 1 day
- Efficacy: Good.
- Use in IPM and resistance management: Zeta-cypermethrin (IRAC Group 3) has broad-spectrum activity for multiple pest species. Rotate with materials from other insecticide groups for resistance management. Overuse of pyrethroid (IRAC Group 3) related materials impacts predators and parasites and may cause secondary pest outbreaks.

Alternatives: Although methomyl (IRAC Group 1A) and methamidophos (IRAC Group 1B) are recommended in New Jersey, and carbaryl (IRAC Group 1A) and endosulfan (IRAC Group 2A) are labeled, there are other alternatives for hornworm control including the pyrethroids (IRAC Group 3), emamectin (IRAC Group 6), methoxyfenozide and tebufenozide (IRAC Group 18), and indoxacarb (IRAC Group 22).

Cultural Control Practices: Handpicking the hornworms from infested plants is a safe and effective option in smaller plantings. Discing the soil after harvest will destroy many of the burrowing larvae which are attempting to pupate. Crop rotation will also aid in control.

Biological Controls: A parasitic wasp, *Cotesia congregata*, is an important biological control agent. Conservation of natural enemies is important since parasites can infest greater than 80% of hornworm larvae in the field (13).

Other Issues: Emamectin (IRAC Group 6), and methamidophos and tebufenozide (IRAC Group 18) may not be used during harvest due to the 7-14 day PHI.

Cabbage Looper, *Trichoplusia ni*

Description and Damage: Cabbage looper larvae are pale green with thin white stripes down the back and sides, and are distinguished by their looping movement. The larvae feed on the underside of leaves, producing ragged holes of various sizes. Feeding begins in late July or early August and usually continues through harvest. Healthy plants can usually sustain feeding injury unless populations become exceedingly large. Several generations can occur during a year. This pest does not typically reach economically damaging levels in New Jersey, although identification is important so that they are not mistaken for other more serious defoliators like the armyworms.

Monitoring and Thresholds: The typical scouting method is to note the presence of holes on the leaves and determine the insect species responsible for the damage. No thresholds have been established in New Jersey.

Chemical Controls:

1. *Bacillus thuringiensis kurstaki* (Biobit, Condor, Crymax, Cutlass, Deliver, Dipel, Javelin WG, Lepinox WDG, Mattch, Prolong, etc.; IRAC Group 11B2) or *Bacillus thuringiensis aizawai* (Agree, XenTari, etc.; IRAC Group 11B1)
 - Percent acres treated: 19.7% (10% XenTari; 9.7% Dipel) (42)
 - Typical rates and frequency of application: Consult label for rates and restrictions.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 4 hours PHI: 0 days
 - Efficacy: Very good.
 - Use in IPM and resistance management: More effective on small larvae. Use higher rates for heavier infestations and re-apply on a 3-4 day schedule. *B.t.* materials are most effective when temperatures are above 75 °F at application.

2. bifenthrin (Capture, IRAC Group 3)
 - Percent acres treated: 9.7% (42)
 - Typical rates and frequency of application: 2.1-5.2 fl oz 2EC/A, 1-2 applications. Do not make applications less than 10 days apart. A maximum of 4 applications may be applied per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 1 day
 - Efficacy: Good.
 - Use in IPM and resistance management: Use in rotation with other groups of insecticides. Overuse of pyrethroid (IRAC Group 3) related materials impacts predators and parasites and may cause secondary pest outbreaks.

3. cyfluthrin (Baythroid, IRAC Group 3)
 - Percent acres treated: 11.3% (42)
 - Typical rates and frequency of application: 2.1-2.8 fl oz 2E/A, 1-2 applications. Do not exceed 16.8 total fluid ounces per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 0 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Rotate with non IRAC group 3 insecticides. The broad-spectrum activity results in its use when multiple pests are present. Overuse of IRAC Group 3 materials impacts predators and parasites and may cause secondary pest outbreaks.

4. emamectin (Proclaim, IRAC Group 6)
 - Percent acres treated: Newer material; data not available.
 - Typical rates and frequency of application: 2.4-4.8 fl oz 5WDG/A, 1-2 applications. Do not exceed 4.8 fl oz/A per application or 28.8 total fluid ounces

per acre per season. Do not make subsequent applications less than 7 days apart.

- Method of application: Foliar application with ground equipment.
- REI: 48 hours PHI: 7 days
- Efficacy: Good.
- Use in IPM and resistance management: Emamectin (IRAC Group 6) is recommended for use on small larvae when larvae first appear and before populations reach damaging levels. The lower rate is used for low to moderate populations, and the high rate for high infestations. The product needs to be ingested so coverage is important. Rotate with materials from other insecticide groups for resistance management.

5. esfenvalerate (Asana, IRAC Group 3)

- Percent acres treated: 3.6% (42)
- Typical rates and frequency of application: 5.8-9.6 fl oz 0.66EC/A, 1-2 applications. Do not exceed 96 total fluid ounces per acre per season.
- Method of application: Foliar application with ground or aerial equipment.
- REI: 12 hours PHI: 1 day
- Efficacy: Good.
- Use in IPM and resistance management: The broad-spectrum contact activity results in its use when multiple pests are present. Rotate with materials from other insecticide groups for resistance management. Repeated use of IRAC Group 3 materials may impact predators and parasites and cause secondary pest outbreaks.

6. fenproparthrin (Danitol, IRAC Group 3)

- Percent acres treated: 11.7% (42)
- Typical rates and frequency of application: 10.67 fl oz 2.4EC/A in a tank mix with Monitor, 1-2 applications. Do not exceed 42.67 fl oz per acre per season and maintain at least 7 days between applications. Do not tank mix with any copper formulations.
- Method of application: Foliar application with ground or aerial equipment.
- REI: 24 hours PHI: 3 days (7 days w/Monitor)
- Efficacy: Good.
- Use in IPM and resistance management: This material is primarily used as a miticide for two-spotted spider mites, but it also controls other tomato pests that may be active at the same time. However, this broad spectrum material has high toxicity to beneficial insects (51). Use in rotation with other insecticides.

7. gamma-cyhalothrin (Proaxis, IRAC Group 3)

- Percent acres treated: Newer material, data not available.
- Typical rates and frequency of application: 2.56-3.84 fl oz/A, 1 application. Do not apply more than 2.88 pts per acre per season.
- Method of application: Foliar application with ground or aerial equipment.
- REI: 24 hours PHI: 5 days

- Efficacy: Good.
 - Use in IPM and resistance management: Use in rotation with other groups of insecticides. This material has broad-spectrum activity so that it may be used when multiple pests are present. Overuse of IRAC Group 3 insecticides impacts predators and parasites and may cause secondary pest outbreaks.
8. indoxacarb (Avaunt, IRAC Group 22)
- Percent acres treated: 2.6% (42)
 - Typical rates and frequency of application: 2.5-3.5 oz 30WDG/A, 1-2 applications. Do not apply more than 14 oz per acre per crop. Allow at least 5 days between applications.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 3 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Rotate with materials from other insecticide groups for resistance management. This product is useful in an IPM program for conserving certain beneficial insect populations.
9. lambdacyhalothrin (Warrior, IRAC Group 3)
- Percent acres treated: 36.5% (42)
 - Typical rates and frequency of application: 1.92-3.2 fl oz/A, 1-2 applications.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 24 hours PHI: 5 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Lambdacyhalothrin (IRAC Group 3) has broad-spectrum activity for multiple pest species. Rotate with materials from other insecticide groups for resistance management. Overuse of pyrethroids (IRAC Group 3) impacts predators and parasites and may cause secondary pest outbreaks.
10. methomyl (Lannate, IRAC Group 1A)
- Percent acres treated: 6.6% (42)
 - Typical rates and frequency of application: 1.5-3.0 pts LV/A, 1-2 applications. Do not apply more than 16 applications or 2.7 gal per acre per crop.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 48 hours PHI: 1 day
 - Efficacy: Good.
 - Use in IPM and resistance management: This broad spectrum material has high toxicity and moderate duration of activity against beneficial insects (51). Use in rotation with materials from other insecticide groups for resistance management.
11. methoxyfenozide (Intrepid, IRAC Group 18)
- Percent acres treated: Newer material, data not available.

- Typical rates and frequency of application: 4-8 fl oz 2F/A early season, 8-16 fl oz 2F/A late season; 1-2 applications. Do not apply more 16.0 fl oz per acre per application, and no more than 64 fl oz per acre per season.
- Method of application: Foliar application with ground equipment.
- REI: 12 hours PHI: 1 day
- Efficacy: Good.
- Use in IPM and resistance management: Since larvae must ingest the material, reapplications may be needed to protect new growth. This material selectively controls multiple lepidopteran species but does not impact beneficial insect populations and bees. Rotate with materials from other insecticide groups for resistance management.

12. spinosad (SpinTor 2SC, Entrust; IRAC Group 5)

- Percent acres treated: 22.3% (0% Entrust) (42)
- Typical rates and frequency of application:
 - SpinTor 2SC: 3.0-6.0 fl oz 2SC/A, 1-2 applications. Do not exceed 29 total fluid ounces per acre per season.
 - Entrust: 1.0-2.0 oz 80W/A, 1-2 applications. Do not apply more than 9 oz per acre per crop.
- Method of application: Foliar application with ground or aerial equipment.
- REI: 4 hours PHI: 1 day
- Efficacy: Good.
- Use in IPM and resistance management: Time applications to peak egg hatch. Use a higher rate for heavy infestations or advanced growth stages. Since spinosad (IRAC Group 5) does not impact certain predators and parasites, secondary pest outbreaks are minimized. For resistance management, use in rotation with other groups of insecticides and do not apply more than 3 times in any 21 day period; rotate to another insecticide class or do not use spinosad for the next 21 days (see label).

13. tebufenozide (Confirm, IRAC Group 18)

- Percent acres treated: 1.7% (42)
- Typical rates and frequency of application: 6.0-16.0 fl oz 2F/A, 1-2 applications. Do not exceed 64 total fluid ounces per acre per season.
- Method of application: Foliar application with ground or aerial equipment.
- REI: 4 hours PHI: 7 days
- Efficacy: Good.
- Use in IPM and resistance management: Tebufenozide (IRAC Group 18) selectively controls multiple lepidopteran species but does not impact beneficial insect populations and bees. Lower rates are recommended for light infestations and higher rates for moderate to heavy infestations. Application timing is important since the material must be ingested before larvae enter the fruit. Re-application is recommended when insect populations are high and/or the plants are rapidly growing. Rotate with materials from other insecticide groups.

insecticides used for other fruit invading larvae (TFW, FAW, and BAW) usually controls ECB in tomatoes.

Monitoring and Thresholds: Blacklight traps are used to track the local adult ECB population levels on individual farms throughout New Jersey. The Rutgers Cooperative Extension (RCE) Integrated Pest Management (IPM) Program uses a statewide blacklight trap network to produce geo-referenced maps of adult activity. The maps are published weekly throughout the growing season in the RCE Plant & Pest Advisory Newsletter, allowing growers statewide to determine approximate activity in their area. There are no established thresholds for ECB for tomatoes. During peak adult activity in late summer and early fall monitor fields for the presence of egg masses and/or larvae.

Chemical Controls:

1. bifenthrin (Capture, IRAC Group 3)
 - Percent acres treated: 9.7% (42)
 - Typical rates and frequency of application: 2.1-5.2 fl oz 2EC/A, 1-2 applications. Do not make applications less than 10 days apart. A maximum of 4 applications may be applied per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 1 day
 - Efficacy: Good.
 - Use in IPM and resistance management: Rotate with materials in other IRAC groups. Overuse of IRAC Group 3 related impacts predators and parasites and may cause secondary pest outbreaks.

2. cyfluthrin (Baythroid, IRAC Group 3)
 - Percent acres treated: 11.3% (42)
 - Typical rates and frequency of application: 1.6-2.8 fl oz 2E/A, 1-2 applications. Do not exceed 16.8 total fluid ounces per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 0 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Rotate with non IRAC group 3 insecticides. The broad-spectrum activity results in its use when multiple pests are present. Overuse of IRAC Group 3 materials impacts predators and parasites and may cause secondary pest outbreaks.

3. gamma-cyhalothrin (Proaxis, IRAC Group 3)
 - Percent acres treated: Newer material, data not available.
 - Typical rates and frequency of application: 2.56-3.84 fl oz/A, 1 application. Do not apply more than 2.88 pts per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 24 hours PHI: 5 days
 - Efficacy: Good.

- Use in IPM and resistance management: Treat before larvae enter stems or fruit and rotate with materials in other IRAC groups. This material has broad-spectrum activity so that it may be used when multiple pests are present. Overuse of IRAC Group 3 insecticides impacts predators and parasites and may cause secondary pest outbreaks.
4. lambda-cyhalothrin (Warrior, IRAC Group 3)
- Percent acres treated: 36.5% (42)
 - Typical rates and frequency of application: 2.56-3.84 fl oz/A, 1-2 applications.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 24 hours PHI: 5 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Lambda-cyhalothrin (IRAC Group 3) has broad-spectrum activity for multiple pest species. Rotate with materials from other insecticide groups for resistance management. Overuse of IRAC Group 3 materials impacts predators and parasites and may cause secondary pest outbreaks.
5. methoxyfenozide (Intrepid, IRAC Group 18)
- Percent acres treated: Newer material, data not available.
 - Typical rates and frequency of application: 4-8 fl oz 2F/A early season, 8-16 fl oz 2F/A late season; 1-2 applications. Do not apply more 16.0 fl oz per acre per application, and no more than 64 fl oz per acre per season.
 - Method of application: Foliar application with ground equipment.
 - REI: 12 hours PHI: 1 day
 - Efficacy: Good.
 - Use in IPM and resistance management: Since larvae must ingest the material, reapplications may be needed to protect new growth until moth flights and/or infestations subside. This material selectively controls multiple lepidopteran species but does not impact beneficial insect populations and bees. Rotate with materials from other insecticide groups for resistance management.
6. spinosad (SpinTor 2SC, Entrust; IRAC Group 5)
- Percent acres treated: 22.3% (0% Entrust) (42)
 - Typical rates and frequency of application:
 - SpinTor 2SC: 3.0-6.0 fl oz 2SC/A, 1-2 applications. Do not exceed 29 total fluid ounces per acre per season.
 - Entrust: 1.0-2.0 oz 80W/A, 1-2 applications. Do not apply more than 9 oz per acre per crop.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 4 hours PHI: 1 day
 - Efficacy: Good.
 - Use in IPM and resistance management: Use a higher rate for heavy infestations or advanced growth stages. Since spinosad (IRAC Group 5) does not impact certain predators and parasites, secondary pest outbreaks are minimized. For

Other Issues: Tebufenozide (IRAC Group 18) may not be used during harvest due to the 7-day PHI.

Tomato Pinworm, *Keiferia lycopersicella*

Description and Damage: Pinworm moths deposit eggs on the undersides of the leaves. Larvae feed on the leaves, stems, and fruit of plants in the nightshade (Solanaceae) family, and particularly tomatoes. The initial leaf damage appears as a small blotchy mine. As populations increase leaf folding and tying occurs. Mature larvae may bore into the fruit under the calyx, leaving a small pin-sized hole that can be difficult to detect. Undetected infestations may result in fruit that enter the market and rot in the shipping boxes due to the invasion of secondary pathogens at the feeding sites. Damage to the leaves and vines is not usually as important as the fruit damage, although larvae can cause 100% defoliation.

Tomato pinworm is a sporadic pest in New Jersey. Pinworms do not typically overwinter in New Jersey, although they may overwinter in sheltered areas like greenhouses. However, pinworm infested tomatoes grown in greenhouses in the neighboring states of Delaware, Pennsylvania, Virginia, and North Carolina have also been reported (49). Pest occurrence has been also associated with transplants imported from southern production regions, although New Jersey growers do not typically use southern transplants.

Monitoring and Thresholds: In areas where pinworms are a yearly problem, pheromone traps are used for detection. In New Jersey, plant inspection is more practical since populations occur only sporadically. Yellow sticky cards placed above the canopy in the greenhouse may provide early detection of greenhouse infestations. Although field sampling and threshold levels have not been tested in New Jersey due to the infrequency of the pest, the techniques used in Florida could be used. If pinworms are suspected, sample the lower leaves and treat when the larval population exceeds 0.7 larvae per plant (47). Once threshold populations are present the planting will need to be treated weekly. Time sprays for younger larvae while there are still blotch mines in the leaves and before the leaf rolls or they infest the fruit.

Chemical Controls:

1. abamectin (Agri-Mek, IRAC Group 6)
 - Percent acres treated: 15.8% (42)
 - Typical rates and frequency of application: 8.0-16.0 fl oz 0.15 EC/A, 1-2 applications. Do not exceed 48 fl oz per acre per season. Do not make more than 2 sequential applications.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 7 days
 - Efficacy: Good.

- Use in IPM and resistance management: Treat at threshold levels or when leaf damage is observed. This material has high toxicity to some natural enemies, especially predatory mites (51).
2. emamectin (Proclaim, IRAC Group 6)
- Percent acres treated: Newer material; data not available.
 - Typical rates and frequency of application: 2.4-4.8 fl oz 5WDG/A, 1-2 applications. Do not exceed 4.8 fl oz/A per application or 28.8 total fluid ounces per acre per season. Do not make subsequent applications less than 7 days apart.
 - Method of application: Foliar application with ground equipment.
 - REI: 48 hours PHI: 7 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Emamectin (IRAC Group 6) is recommended for use on small larvae when larvae first appear and before populations reach damaging levels. The lower rate is used for low to moderate populations, and the high rate for high infestations. Since the product needs to be ingested, coverage is important. Rotate with materials from other insecticide groups for resistance management.
3. indoxacarb (Avaunt, IRAC Group 22)
- Percent acres treated: 2.6% (42)
 - Typical rates and frequency of application: 3.5 oz 30WDG/A, 1-2 applications. Do not apply more than 14 oz per acre per crop. Allow at least 5 days between applications.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 3 days
 - Efficacy: Good. Not listed in the 2007 New Jersey Commercial Vegetable Production Recommendations manual for this pest.
 - Use in IPM and resistance management: Use at threshold levels and rotate with materials from other insecticide groups for resistance management. This product is useful in an IPM program for conserving certain beneficial insect populations.
4. spinosad (SpinTor 2SC, Entrust; IRAC Group 5)
- Percent acres treated: 22.3% (0% Entrust) (42)
 - Typical rates and frequency of application:
 - SpinTor 2SC: 4.0-8.0 fl oz 2SC/A, 1-2 applications. Do not exceed 29 total fluid ounces per acre per season.
 - Entrust: 1.25-2.5 oz 80W/A, 1-2 applications. Do not apply more than 9 oz per acre per crop.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 4 hours PHI: 1 day
 - Efficacy: Good.
 - Use in IPM and resistance management: Treat at threshold levels and rotate with materials in other IRAC groups. Since spinosad (IRAC Group 5) does not impact

certain predators and parasites, secondary pest outbreaks are minimized. Use a higher rate for heavy infestations or advanced growth stages. For resistance management do not apply more than 3 times in any 21 day period; rotate to another insecticide class or do not use spinosad for the next 21 days (see label).

5. zeta-cypermethrin (Mustang Max, IRAC Group 3)
 - Percent acres treated: 2.0% (42)
 - Typical rates and frequency of application: 2.24-4.0 fl oz/A, 1-2 applications.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 1 day
 - Efficacy: Good.
 - Use in IPM and resistance management: This material has broad-spectrum activity for multiple pest species. Rotate with materials from other insecticide groups for resistance management. Overuse of IRAC Group 3 materials impacts predators and parasites and may cause secondary pest outbreaks.

Alternatives: The two EPA targeted materials labeled for pinworms (carbaryl and methomyl, IRAC Group 1A) would not be recommended in New Jersey for control of pinworm.

Cultural Control Practices: Avoid southern transplants. Shut down greenhouses in the winter to allow for freezing to prevent overwintering. Destroy solanaceous weeds in and around greenhouses.

Biological Controls: Pheromone mating disruption is registered and useful in areas where pinworms are a common pest. Apply NoMate TPW at the rate of 200 spiral/A at the first sign of pinworm damage.

Other Issues: Abamectin (IRAC Group 6) and emamectin (IRAC Group 6) may not be used during harvest due to the PHI.

Leafminers, *Liriomyza* sp.

Description and Damage: Leafminers are very occasional minor insect pests of tomatoes. The adult fly is black with yellow strips and very small, about 1/10 inch long, and deposits a single egg just under the leaf surface. Larvae feed between the leaf surfaces, causing serpentine white tunnels or mines that coalesce to appear as blotches. The larvae mature within the leaf, and emerge from the leaf to drop off and pupate in the soil. The entire life cycle can be completed in 23 days and several generations can occur within a season. Heavy infestations reduce plant vigor and in some extreme cases can cause premature leaf drop and complete crop loss.

Monitoring and Thresholds: The typical scouting method is to consider control if mines are easily found and numbers of infested leaves are increasing throughout the field. Southern-grown transplants should be inspected for evidence of leafminers.

Chemical Controls:

1. abamectin (Agri-Mek, IRAC Group 6)
 - Percent acres treated: 15.8% (42)
 - Typical rates and frequency of application: 8.0-16.0 fl oz 0.15 EC/A, 1-2 applications. Do not exceed 48 fl oz per acre per growing season. Do not make more than 2 sequential applications.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 7 days
 - Efficacy: Good.
 - Use in IPM and resistance management: This material has high toxicity to some natural enemies, especially predatory mites (51).

2. azadirachtin (Azatin, Ecozin, Neemix, etc.; IRAC Group 26)
 - Percent acres treated: 9.6% (42)
 - Typical rates and frequency of application: 8.0-16.0 fl oz EC/A or OLF, 1-2 applications.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 0 days
 - Efficacy: Good. Not listed in the 2007 New Jersey Commercial Vegetable Production Recommendations manual for this pest.
 - Use in IPM and resistance management: Compatible with the use of most beneficial insects. For high pest populations use the higher rate and treat more frequently.

3. dimethoate (Dimethoate, IRAC Group 1B)
 - Percent acres treated: 4.1% (42)
 - Typical rates and frequency of application: 0.5-1.0 pt 4EC/A or OLF, 1-2 applications.
 - Method of application: Foliar application with ground equipment.
 - REI: 48 hours PHI: 7 days
 - Efficacy: Fair. Not listed in the 2007 New Jersey Commercial Vegetable Production Recommendations manual for this pest.
 - Use in IPM and resistance management: Use in rotation with other groups of insecticides. This material will not control organophosphate resistant leafminers (see label). It has high toxicity and long duration of activity against beneficial insects (51).

4. dinotefuran (Venom, IRAC Group 4A)
 - Percent acres treated: New material; data not available.
 - Typical rates and frequency of application: 5.0-6.0 oz (soil); 1.0-4.0 oz (foliar) 70SG/A, 1-3 applications. Do not apply to varieties less than 2 inches in size (cherry or grape varieties). Do not apply more than 6.0 oz (foliar) or 12 oz (soil) per acre per season.

- Method of application: Do not combine applications; use either a foliar application with ground or aerial equipment or a soil application applied as a transplant drench, in-furrow, side-dressed, or drip-irrigated.
 - REI: 12 hours PHI: 1 day foliar; 21 days for soil application
 - Efficacy: Good.
 - Use in IPM and resistance management: Time applications before damaging populations become established, and use higher rates when pest pressure is severe. The rate applied affects the length of control (see label). Rotate with non-IRAC Group 4A insecticides.
5. spinosad (SpinTor 2SC, Entrust; IRAC Group 5)
- Percent acres treated: 22.3% (0% Entrust) (42)
 - Typical rates and frequency of application:
 - SpinTor 2SC: 6.0-8.0 fl oz 2SC/A, 1-2 applications. Do not exceed 29 total fluid ounces per acre per season.
 - Entrust: 2.0-2.5 oz 80W/A, 1-2 applications. Do not apply more than 9 oz per acre per crop.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 4 hours PHI: 1 day
 - Efficacy: Good.
 - Use in IPM and resistance management: Treat at threshold levels and rotate with materials in other IRAC groups. Since spinosad (IRAC Group 5) does not impact certain predators and parasites, secondary pest outbreaks are minimized. Use a higher rate for heavy infestations. For resistance management do not apply more than 3 times in any 21 day period; rotate to another insecticide class or do not use spinosad for the next 21 days (label).
6. zeta-cypermethrin (Mustang Max, IRAC Group 3)
- Percent acres treated: 2.0% (42)
 - Typical rates and frequency of application: 2.24-4.0 fl oz/A, 1-2 applications.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 1 day
 - Efficacy: Good. Not listed in the 2007 New Jersey Commercial Vegetable Production Recommendations manual for this pest.
 - Use in IPM and resistance management: Zeta-cypermethrin (IRAC Group 3) has broad-spectrum activity for multiple pest species. Rotate with materials from other insecticide groups for resistance management.

Alternatives: Avoid repeated use of a single class of insecticides for resistance management. There are alternatives to oxamyl (IRAC Group 1A), and diazinon, methamidophos, and dimethoate (IRAC Group 1B) for leafminer control including spinosad (IRAC Group 5), abamectin (IRAC Group 6), and cyromazine (IRAC Group 17). The IRAC Group 3 pyrethroids cyfluthrin, esfenvalerate, and permethrin are labeled but are not recommended in New Jersey (16).

Cultural Control Practices: Destroy alternate hosts, particularly broad-leaf weeds. Avoid the use of southern-grown transplants.

Biological Controls: A complex of natural enemies controls leafminers. Population outbreaks have been associated with continuous use of broad-spectrum insecticides that destroy the natural enemies.

Other Issues: Abamectin (IRAC Group 6), and dimethoate and methamidophos (IRAC Group 1B) may not be used during harvest due to the PHI.

Whiteflies, *T. vaporariorum*, *B. tabaci*

Description and Damage: There are several species of whitefly that infest tomatoes, including the greenhouse whitefly (*T. vaporariorum*) and the sweetpotato whitefly (*B. tabaci*). Whiteflies infest greenhouse and field-grown tomatoes. Infestations in general are sporadic in New Jersey, and more commonly found in the greenhouse and high tunnels than in the field, although field infestations have occurred later in the season some years. Adults are tiny (1.5 mm long) winged insects with yellow body and white wings. They are found on the undersides of the leaves and will fly when disturbed. Adults and nymphs extract plant sap, reducing plant vigor and causing stunting under high populations. Leaves become discolored and may fall off the plant. Like aphids, whiteflies exude honeydew which accumulates on the fruit and leaves. Sooty mold grows on the honeydew, resulting in unmarketable fruit.

Monitoring and Thresholds: Yellow sticky cards are used in the greenhouse to detect whitefly populations. In the field, scouts check for the presence of whiteflies on the undersides of the leaves, and note if populations are increasing.

Chemical Controls:

1. acetamiprid (Assail, IRAC Group 4A)
 - Percent acres treated: 0.1% (42)
 - Typical rates and frequency of application: 2.5-4.0 30SG/A, 1 application.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 7 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Rotate with non IRAC Group 4A insecticides. Lower rates preserve beneficial insect populations and allow for faster rebound of the beneficial populations.
2. dinotefuran (Venom, IRAC Group 4A)
 - Percent acres treated: New material; data not available.
 - Typical rates and frequency of application: 5.0-6.0 oz (soil); 1.0-4.0 oz (foliar) 70SG/A, 1-3 applications. Do not apply to varieties less than 2 inches in size (cherry or grape varieties). Do not apply more than 6.0 oz (foliar) or 12 oz (soil) per acre per season.

- Method of application: Use either a foliar application with ground or aerial equipment or a soil application applied as a transplant drench, in-furrow, side-dressed, or drip-irrigated. Do not combine applications.
 - REI: 12 hours PHI: 1 day foliar; 21 days for soil application
 - Efficacy: Good.
 - Use in IPM and resistance management: Time applications before damaging populations become established, and use higher rates when pest pressure is severe. The rate applied affects the length of control (label). Rotate with non-IRAC Group 4A insecticides.
3. endosulfan (Thionex, Thiodan, Phaser, etc.; IRAC Group 2A)
- Percent acres treated: 3.7% (42)
 - Typical rates and frequency of application: 0.67 qts 3EC/A, 1-2 applications. Do not make more than 6 applications per year; do not exceed 4.0 qts/A per year.
 - Method of application: Foliar application with ground equipment.
 - REI: 24 hours PHI: 2 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Use in rotation with other groups of insecticides. The broad-spectrum activity of this material results in its use when multiple pests are present.
4. imidacloprid (Admire, Admire Pro, Provado; IRAC Group 4A)
- Percent acres treated: 43.7% (25.7% Admire; 18.0% Provado) (42)
 - Typical rates and frequency of application:
 - Admire: 16-24 fl oz 2F/A, 1 application. Lower rates provide a shorter residual control. Do not exceed 24 oz per acre per season.
 - Provado: 3.75 fl oz 1.6F/A, 1-2 applications. Do not exceed 19.2 fl oz per acre per season.
 - Method of application:
 - Admire: Soil application applied as a transplant drench, in-furrow, side-dressed, or drip-irrigated.
 - Provado: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 21 days (Admire)
 - REI: 12 hours PHI: 0 days (Provado)
 - Efficacy: Good.
 - Use in IPM and resistance management: Growers apply this material primarily as a drench application to transplants 3-4 days before transplanting as a preventative treatment for early season control of CPB. Early season whitefly populations would be controlled as a result of the CPB treatment.
5. pymetrozine (Fulfill, IRAC Group 9B)
- Percent acres treated: Newer material; data not available.
 - Typical rates and frequency of application: 2.75 oz 50W/A, 1-2 applications. Do not exceed a total of 5.5 oz/A per crop per season. Allow a minimum of 7 days between applications.

- Method of application: Foliar application with ground equipment.
 - REI: 12 hours PHI: 0 days
 - Efficacy: Fair.
 - Use in IPM and resistance management: Provides suppression of whiteflies. Apply when adults first appear and before populations build to damaging levels. Low toxicity to beneficial insect populations. Rotate with products with different modes of action for resistance management.
6. pyriproxyfen (Knack, IRAC Group 7C)
- Percent acres treated: Newer material, data not available.
 - Typical rates and frequency of application: 8.0-10.0 fl oz/A, 1-2 applications. Do not exceed 20 fl oz per acre per season or 2 treatments, and do not apply within 14 days of the first treatment.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 14 days
 - Efficacy: Good.
 - Use in IPM and resistance management: This material is an insect growth regulator which has no activity against adults, but which causes suppression of egg hatch by treated adults. Translaminar movement is important to controlling whiteflies since they are located on the undersides of leaves.
7. spiromesifen (Oberon, IRAC Group 23)
- Percent acres treated: New material; data not available.
 - Typical rates and frequency of application: 7.0-8.5 2SC/A. Do not apply more than 3 applications or 25.5 fl oz per acre per season, and do not apply more than 8.5 fl oz per acre per 7-day interval.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 7 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Begin applications before populations build and/or a damaging population becomes established. Use in rotation with other groups of insecticides for resistance management.
8. thiamethoxam (Platinum, IRAC Group 4A)
- Percent acres treated: 0.4% (42)
 - Typical rates and frequency of application: 5.0-8.0 oz 2SC/A, 1 application. Lower rates provide a shorter residual control.
 - Method of application: Soil application may be applied as a transplant drench, in-furrow, side-dressed, or drip-irrigated.
 - REI: 12 hours PHI: 30 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Thiamethoxam, like imidacloprid, is an IRAC Group 4A insecticide. For resistance management, if the soil treatment is applied, subsequent foliar applications should be made with materials in different insecticide groups.

Alternatives: There are several alternatives to endosulfan (IRAC Group 2A) for whitefly control, including spiromesifen (IRAC Group 23), acetamiprid, imidacloprid, and thiamethoxam (IRAC Group 4A), pyriproxyfen (IRAC Group 7C), and pymetrozin (IRAC Group 9B). Some of the pyrethroids (bifenthrin, cyfluthrin, esfenvalerate, and zeta-cypermethrin; IRAC Group 3) are also labeled for control.

Cultural Control Practices: Maintain good sanitation by destroying and removing all crop residues as soon as possible. Control weeds.

Biological Controls: Whiteflies are controlled by a number of naturally occurring parasites and predators. Conservation of natural enemies is important for management of whiteflies in the field.

Other Issues: Acetamiprid (IRAC Group 4A), pyriproxyfen (IRAC Group 7C), and spiromesifen (IRAC Group 23) may not be used during harvest due to the PHI.

Black Cutworm, *Agrotis ipsilon* (Hufnagel)
Variegated Cutworm, *Peridroma saucia* (Hubner)

Description and Damage: Several species of cutworms attack tomatoes, but black cutworm is the primary species in New Jersey. Cutworms have a wide host range, including many field crops, grasses, and vegetable crops such as asparagus, bean, crucifers, cucurbits, corn, cowpea, lettuce, onion, pea, pepper, potato, spinach, sweet potato, and tomato. Adult moths lay eggs on the undersides of tomato leaves. Young larvae may feed on leaves, but larger larvae are most commonly found in the soil around the base of the tomato plant. Black cutworm larvae are dark greasy gray to black with a light colored line down the center of the back and are 38 to 45 mm long when mature. Larvae hide under clods and in cracks in the soil by day and appear at night cutting off young plants near the ground and feeding on the foliage. After feeding for 3 to 4 weeks and developing through 5 to 8 instars, larvae pupate in the soil. A new generation of moths soon emerges. Most cutworms complete 3 or 4 generations per year.

Young tomato transplants are at risk of cutworm damage early in the season. The black cutworm is one of the most destructive. One larva often severs numerous plants in a row during a single night. Small populations can cause considerable injury resulting in the need to replant.

Monitoring and Thresholds: Fields should be scouted regularly after planting for the presence of cutworm damage. A general guideline for treating vegetable transplants is 5% plants infested (5). Treatment with insecticides is only effective if the larvae are very small (under 2.5 cm) and soil conditions are favorable. If damage is isolated to a small patch or field border area, spot treatments are recommended. Apply insecticide treatments late in the day or at night. In many cases the level of damage is not high enough to warrant insecticide treatments.

Chemical Controls:

1. bifenthrin (Capture, IRAC Group 3)
 - Percent acres treated: 9.7% (42)
 - Typical rates and frequency of application: 2.1-5.2 fl oz 2EC/A, 1-2 applications. Do not make applications less than 10 days apart. A maximum of 4 applications may be applied per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 1 day
 - Efficacy: Good. Not listed in the 2007 New Jersey Commercial Vegetable Production Recommendations manual for this pest.
 - Use in IPM and resistance management: Treat at threshold levels and rotate with materials in other IRAC groups. Overuse of pyrethroid (IRAC Group 3) related materials impacts predators and parasites and may cause secondary pest outbreaks.

2. cyfluthrin (Baythroid, IRAC Group 3)
 - Percent acres treated: 11.3% (42)
 - Typical rates and frequency of application: 2.1-2.8 fl oz 2E/A, 1-2 applications for variegated cutworm only. Do not exceed 16.8 total fluid ounces per acre per season. Allow 7 days between applications.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 0 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Treat at threshold levels and rotate with non IRAC group 3 insecticides. The broad-spectrum activity results in its use when multiple pests are present. Overuse of IRAC Group 3 materials impacts predators and parasites and may cause secondary pest outbreaks.

3. carbaryl (Sevin Bait, IRAC Group 1A)
 - Percent acres treated: 2.0% (42)
 - Typical rates and frequency of application: 40 lbs 5% bait/A or OLF, 1 application.
 - Method of application: Broadcast application with ground or aerial equipment.
 - REI: 12 hours PHI: 3 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Use at threshold levels.

4. diazinon (Diazinon, IRAC Group 1B)
 - Percent acres treated: 1.1% (42)
 - Typical rates and frequency of application: 4.0-8.0 lbs 50WP/A or OLF, 1 application.
 - Method of application: Broadcast on the soil surface before seeding or transplanting. Diazinon granules can be used in place of spray; work into the top 4 inches of the soil.

- REI: 24 hours PHI: 1 day
 - Efficacy: Fair.
 - Use in IPM and resistance management: This material is used as a preventative treatment if cutworms are typically a problem or expected to be a problem.
5. esfenvalerate (Asana, IRAC Group 3)
- Percent acres treated: 3.6% (42)
 - Typical rates and frequency of application: 5.8-9.6 fl oz 0.66EC/A, 1-2 applications. Do not exceed 96 total fluid ounces per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 1 day
 - Efficacy: Good.
 - Use in IPM and resistance management: Rotate with materials from other insecticide groups for resistance management. Overuse of IRAC Group 3 insecticides impacts predators and parasites and may cause secondary pest outbreaks.
6. gamma-cyhalothrin (Proaxis, IRAC Group 3)
- Percent acres treated: Newer material, data not available.
 - Typical rates and frequency of application: 1.92-3.2 fl oz/A, 1-2 applications. Do not apply more than 2.88 pts per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 24 hours PHI: 5 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Treat at threshold levels and rotate with materials in other IRAC groups. This material has broad-spectrum activity so that it may be used when multiple pests are present. Overuse of IRAC Group 3 insecticides impacts predators and parasites and may cause secondary pest outbreaks.
7. lambdacyhalothrin (Warrior, IRAC Group 3)
- Percent acres treated: 36.5% (42)
 - Typical rates and frequency of application: 1.92-3.2 fl oz/A, 1-2 applications.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 24 hours PHI: 5 days
 - Efficacy: Good.
 - Use in IPM and resistance management: This material has broad-spectrum activity for multiple pest species. Rotate with materials from other insecticide groups for resistance management. Overuse of IRAC Group 3 materials impacts predators and parasites and may cause secondary pest outbreaks.
8. methomyl (Lannate, IRAC Group 1A)
- Percent acres treated: 6.6% (42)
 - Typical rates and frequency of application: 1.5 pts LV/A, 1-2 applications. Do not apply more than 16 applications or 2.7 gal per acre per crop.

- Method of application: Foliar application with ground or aerial equipment.
- REI: 48 hours PHI: 1 day
- Efficacy: Good.
- Use in IPM and resistance management: This broad spectrum material has high toxicity and moderate duration of activity against beneficial insects (51). Treat at threshold levels and use in rotation with materials from other insecticide groups for resistance management.

9. zeta-cypermethrin (Mustang Max, IRAC Group 3)

- Percent acres treated: 2.0% (42)
- Typical rates and frequency of application: 2.24-4.0 fl oz/A, 1-2 applications.
- Method of application: Foliar application with ground or aerial equipment.
- REI: 12 hours PHI: 1 day
- Efficacy: Good. Not listed in the 2007 New Jersey Commercial Vegetable Production Recommendations manual for this pest.
- Use in IPM and resistance management: This material has broad-spectrum activity for multiple pest species. Rotate with materials from other insecticide groups for resistance management.

Alternatives: There are alternatives to the EPA targeted materials for this pest, but they are all in the same chemical class, the pyrethroids (esfenvalerate, gamma-cyhalothrin, lambdacyhalothrin, zeta-cypermethrin; IRAC Group 3). Although labeled, tebufenozide (IRAC Group 18) is not recommended for control of cutworms in New Jersey.

Cultural Control Practices: Field selection, field history and weed management are important methods to reduce damage from cutworms. Fields with large weed populations, especially grasses and chickweed, may experience more cutworm problems the following season. Crop rotation is also a helpful management tool. Minimum tilled or weedy fields are attractive egg-laying sites for adult moths.

Biological Controls: Many natural predators, parasites and birds prey upon cutworms and reduce the population. Reducing unnecessary spraying for other pests and providing refuges may help to encourage beneficial organisms.

Other Issues: None.

Weed Control

The major weeds that infest tomatoes are summer annual broadleaves including common cocklebur, common lambsquarters, common purslane, common ragweed, hairy galinsoga, ivyleaf morning glory, jimsonweed, smooth pigweed, nightshade and velvetleaf. Summer annual grasses include barnyardgrass, giant foxtail, green foxtail, yellow foxtail, fall panicum, large crabgrass, and goosegrass. The main perennial weed affecting tomatoes is yellow nutsedge.

Herbicide Resistance Management: Herbicides have been grouped by the Herbicide Resistance Action Committee (HRAC) by the mode of action (i.e. inhibition of acetyl CoA carboxylase (ACCase)) of each chemical so mixtures or rotations of active ingredients can be planned. This system is not based on resistance risk assessment, but to aid in selection of chemicals to avoid using the same product in a class all season. The system was developed in cooperation with the Weed Science Society of America (WSSA). Each herbicide listed in this section will have the HRAC group listed first followed by the WSSA group (i.e. halosulfuron-methyl (Sanda, Group B/2)).

General Monitoring Scheme: All weeds listed below are monitored and treated at the same threshold levels. Using a county soil map, growers identify the different soils in the field and take a sample from each area where soil types differ to obtain an analysis of texture and organic matter. This information is used to develop a cultural and/or chemical control program for each soil type.

Fields are scouted in a zigzag pattern sampling 10 random locations. The sample is either 1 square yard or 10 feet of row at each location depending on which scheme works best with the field. Note the weed species and whether they are scattered throughout the field or predominate in one area. This is done in late summer prior to planting tomatoes the following year to develop a control strategy for the following season. Threshold:

<u>Number of weeds:</u>	<u>Threshold:</u>
< 1	Very light
1-4	Light
4-10	Medium
10-100	Heavy
>100	Very Heavy

After transplanting the following year, repeat the same pattern except sample 5 locations with the 1 square yard method and 5 locations with the 10 ft of row method. Note which weeds could be controlled by cultivation between the rows and which would not. This monitoring takes place once 15 – 20 days after transplanting. Threshold:

<u>Average Number of Weeds:</u>	<u>Threshold:</u>
<0.25	No control required
0.25 – 1	Some control may be required
>1	Control required

Annual Broadleaf Weeds

Common Cocklebur, *Xanthium strumarium*

Description and Damage: This summer annual reproduces by seed from early spring through summer. Seed can germinate from as deep as 6 inches in the soil. The cotyledons and first leaves are opposite. Later leaves are alternate with a triangular

shape, green in color with purple to brown spots and at maturity may be 6 inches long. The stem is hairy with dark spots. The flowers are found in the upper part of the plant and the male and female flowers are separate. The male flower falls off leaving the female flower enclosed within a bur. The burs are elliptical to egg-shaped, woody, covered with hooked trichomes and contain many seeds (52, 53, 55).

On tomatoes grown without plastic mulch, cocklebur can compete shortly after planting if not controlled. For fresh market tomatoes, the weed can interfere with the laborers as the burs stick to clothing and slow down harvest or with processing tomatoes it can go through the machine and mix with the bulk tomatoes.

Chemical Controls:

1. glyphosate (Roundup Ultra Max II, Glyphomax Plus, Touchdown, etc.; Group G/9)
 - Percent acres treated: 0.5% (42)
 - Typical rates and frequency of application: 12 to 36 fl oz/A, 1 application. Do not apply more than 8.0 qts/A per year.
 - Method of application: Broadcast at least 3 days prior to transplanting when weeds are at most 16-32 inches tall.
 - REI: 4 or 12 hours PHI: Not available
 - Efficacy: Good.
 - Use in IPM and resistance management: This material controls most weeds and can be used as a pre-plant control measure. It is not used between plastic after transplanting.

2. halosulfuron-methyl (Sandea, Group B/2)
 - Percent acres treated: 1.0% (42)
 - Typical rates and frequency of application: 0.5-1.0 oz/A, 1-4 applications depending on rate. Do not exceed 2 oz/A per year. Up to a 36 month plant-back interval applies depending on the rotational crop.
 - Method of application: For plastic culture only, apply prior to plastic laying or as a banded directed shielded spray between rows. Has both pre-emergent and post emergent activity.
 - REI: 12 hours PHI: 30 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Do not apply more than 1 oz under plastic. More than one additional application may be necessary to control multiple flushes of weeds. Weeds can become resistant to this herbicide if used with herbicides with the same mode of action (Group B/2). Use mechanical control and/or chemical control with materials from other herbicide classes.

3. rimsulfuron (Matrix, Group B/2)
 - Percent acres treated: 13.3% (42)
 - Typical rates and frequency of application: 1-2 oz/A early post emergence. Do not exceed 4 oz per acre per year. Up to a 12 month plant-back interval applies depending on the rotational crop.

- Method of application: Broadcast over the field when weeds are less than one inch but have two fully expanded true leaves.
- REI: 4 hours PHI: Not available
- Efficacy: Provides suppression.
- Use in IPM and resistance management: More than one additional application may be necessary to control multiple flushes of weeds. Weeds can become resistant to this herbicide if used with herbicides with the same mode of action (Group B/2). Use mechanical control and/or chemical control with materials from other herbicide classes.

Alternatives: The possibility of resistance to halosulfuron-methyl and rimsulfuron (Group B/2) restricts flexibility to control this weed. Monitoring weeds the summer before planting tomatoes will help identify cocklebur and allow spot treatment to reduce the weed population. However, with only two other chemical groups available, paraquat (Group D/22) and glyphosate (Group G/9), the chance of resistance developing is increased.

Cultural Control Practices: Monitoring the weeds in the previous crop followed by cultivation will help reduce cocklebur, but seeds can survive for one to several years in the soil (52). Cultivation is only practical for approximately one month after transplanting since the plants are too large to allow equipment to pass between the rows.

Biological Controls: None available.

Post Harvest Control Practices: Incorporate plant residue immediately after harvesting. If practical, leave weeds to regrow, then map the field and develop weed management strategies for the following year.

Common Lambsquarters, *Chenopodium album*

Description and Damage: This erect summer annual reproduces by seed and emerges from spring to early summer from near the soil surface (down to approximately 1 inch). The first set of leaves is opposite then alternate for all others. Young leaves have either smoothed or toothed margins that are light green on top and maroon on the underside. As the plant grows, the leaves become more toothed in appearance. Young leaves and older leaves on mature plants have a gray to white mealy coating that feels oily to the touch. Stems are gray in color and are fragile when the plants are young, but are erect, vertically ridged, and have maroon stripes at maturity. Flowers develop from June to September in spiked groupings. The seeds are small and persist in the soil for many years (11, 52, 53, and 55).

Lambsquarters emerge in groups of plants shortly after the soil is tilled and continue to emerge each time the soil is disturbed. If not controlled, this weed competes directly with tomatoes early in the season for light, nutrients, and moisture.

Chemical Controls:

1. DCPA (Dacthal 6F, Dacthal W-75; Group K1/3)
 - Percent acres treated: 0.1% (42)
 - Typical rates and frequency of application:
 - Dacthal 6F: 8.0-14.0 pts/A, 4-6 weeks after transplanting; 1 application.
 - Dacthal W-75: 8.0-14.0 lbs/A, 4-6 weeks after transplanting; 1 application.
 - Method of application: Broadcast over plants that are grown without plastic mulch, or directed spray between rows with plastic mulch as a pre-emergent control.
 - REI: 12 hours PHI: Not available
 - Efficacy: Good.
 - Use in IPM and resistance management: Good for rotation with the other herbicides to reduce chance of resistance.

2. glyphosate (Roundup Ultra Max II, Glyphomax Plus, Touchdown, etc.; Group G/9)
 - Percent acres treated: 0.5% (42)
 - Typical rates and frequency of application: 16 to 48 fl oz/A, 1 application. Do not apply more than 8.0 qts per acre per year.
 - Method of application: Broadcast at least 3 days prior to transplanting when weeds are at most 6–20 inches tall.
 - REI: 4 or 12 hours PHI: Not available
 - Efficacy: Good.
 - Use in IPM and resistance management: Controls most weeds and can be used as a pre-plant control measure. Not for use between plastic after transplanting.

3. halosulfuron-methyl (Sandea, Group B/2)
 - Percent acres treated: 1.0% (42)
 - Typical rates and frequency of application: 0.5-1.0 oz/A, 1-4 applications depending on rate. Do not exceed 2 oz per acre per year. Up to a 36 month plant-back interval applies depending on the rotational crop.
 - Method of application: For plastic culture only, apply prior to plastic laying or as a banded directed shielded spray between rows as a pre-emergent to the weed.
 - REI: 12 hours PHI: 30 days
 - Efficacy: Fair to good pre-emergence; poor post-emergence.
 - Use in IPM and resistance management: Do not apply more than 1 oz under plastic. More than one additional application may be necessary to control multiple flushes of weeds. Weeds can become resistant to this herbicide if used with herbicides with the same mode of action (Group B/2). Use mechanical control and/or chemical control with materials from other herbicide classes.

4. metribuzin (Sencor 4, Sencor DF; Group C1/5)
 - Percent acres treated: 46.1% (42)
 - Typical rates and frequency of application:
 - Sencor 4: 0.5-2 pt/A, 2-3 applications pre-plant incorporated and post emergence. Do not apply more than 2 pts per acre per season.

- Sencor DF: 1/3-2/3 lbs/A, 2-3 applications pre-plant incorporated and post emergence. Do not apply more than 1 1/3 lbs per acre per season.
 - Method of application: For plastic culture, band immediately prior to laying plastic. Use as a directed shielded spray between beds after transplanting. For bare ground culture, incorporate before transplanting. After transplanting, delay additional applications until plants recover from transplant shock (at least two weeks). Do not apply within 24 hours of other pesticides or when there are three days of cool, wet, or cloudy weather.
 - REI: 12 hours PHI: 7 days
 - Efficacy: Good except for triazine (Group C1/5) resistant lambsquarters.
 - Use in IPM and resistance management: Used in combination with other herbicides for broad spectrum control.
5. napropamide (Devrinol 50-DF, Devrinol 2-EC; Group K3/15)
- Percent acres treated: 9.0% (42)
 - Typical rates and frequency of application:
 - Devrinol 50-DF: 2.0-4.0 lbs/A, 1-2 applications. Do not apply more than 4.0 lbs/A 50-DF per crop cycle.
 - Devrinol 2-EC: 2.0-4.0 qts/A, 1-2 applications. Do not apply more than 4.0 qts/A 2-EC per crop cycle.
 - Up to a 12-month plant back restriction applies depending on the rotational crop.
 - Method of application: For plastic culture, apply banded under the plastic or banded directed shielded spray between the plastic and incorporated with irrigation. For bare ground culture broadcast and incorporate 1-2 inches before transplanting.
 - REI: 12 hours PHI: Not available
 - Efficacy: Fair.
 - Use in IPM and resistance management: This material is the best to use during periods of wet weather. Good for rotation with the other herbicides to reduce chance of resistance. Generally used in combination with metribuzin (Group C1/5) to improve broadleaf weed control.
6. rimsulfuron (Matrix, Group B/2)
- Percent acres treated: 13.3% (42)
 - Typical rates and frequency of application: 1-2 oz/A early post emergence. Do not exceed 4 oz per acre per year. Up to a 12 month plant-back interval applies depending on the rotational crop.
 - Method of application: Broadcast over the field when weeds are less than one inch but have two fully expanded true leaves.
 - REI: 4 hours PHI: Not available
 - Efficacy: Provides suppression pre-emergence but poor post-emergence.
 - Use in IPM and resistance management: More than one additional application may be necessary to control multiple flushes of weeds. Weeds can become resistant to this herbicide if used with herbicides with the same mode of action (Group B/2). Use mechanical control and/or chemical control with materials from other herbicide classes.

7. trifluralin (Treflan 4 EC, Treflan HFP, Treflan 4L, Trifluralin HF Trifluralin 4EC, Trilin, etc.; Group K1/3)
 - Percent acres treated: 7.0% (42)
 - Typical rates and frequency of application: 1.0-2.0 pts/A, 1 application.
 - Method of application: Broadcast and incorporate 2 to 3 inches within 8 hours prior to transplanting. Do not use under plastic mulch.
 - REI: 12 hours PHI: Not available
 - Efficacy: Fair to good.
 - Use in IPM and resistance management: Avoid planting during periods of cold wet weather to reduce the risk of temporary stunting. Good for rotation with the other herbicides to reduce chance of resistance. Used in combination with metribuzin (Group C1/5) to improve broadleaf weed control.

Alternatives: There are several chemical options to control lambsquarters.

Cultural Control Practices: Cultivation for up to approximately one month after transplanting will help reduce weed populations.

Biological Control: None available.

Post Harvest Control Practices: Incorporate plant residue immediately after harvesting to reduce weed seed production. Planting a cover crop will help keep weeds under control.

Common Purslane, *Portulaca oleracea*

Description and Damage: This summer annual reproduces by seed and stem segments that root at individual nodes. Seeds germinate from May through August. The plant has a prostrate mat-forming habit with thick succulent leaves and stems. Leaves are green on the upper side with a maroon color on the underside. Stems are green when young, turning maroon as the plant matures. Flowers appear from July through September, have yellow petals, and are only open when it is sunny. The leaves decay after a frost, but the maroon stems remain (11, 52, 53, 55).

Purslane is common in all of New Jersey and can spread easily from field to field on equipment. Each time a field is cultivated plants are broken up and each stem piece has the potential to produce a new plant at the node. This weed is more of a potential problem early in the season since it prefers high light intensity. As tomato plants grow, the purslane is shaded.

Chemical Controls:

1. DCPA (Dacthal 6F, Dacthal W-75; Group K1/3)
 - Percent acres treated: 0.1% (42)
 - Typical rates and frequency of application: 6.0-14.0 lbs/A, 4-6 weeks after transplanting; 1 application.

- Method of application: Broadcast over plants that are grown without plastic mulch, or directed spray between rows with plastic mulch as a pre-emergent control.
 - REI: 12 hours PHI: Not available
 - Efficacy: Good to excellent.
 - Use in IPM and resistance management: Good for rotation with the other herbicides to reduce chance of resistance.
2. glyphosate (Roundup Ultra Max II, Glyphomax Plus, Touchdown, etc.; Group G/9)
- Percent acres treated: 0.5% (42)
 - Typical rates and frequency of application: 22 to 48 fl oz/A, 1 application. Do not apply more than 8.0 qts per acre per year.
 - Method of application: Broadcast at least 3 days prior to transplanting when weeds are at most 3-6 inches tall.
 - REI: 4 or 12 hours PHI: Not available
 - Efficacy: Fair.
 - Use in IPM and resistance management: Controls most weeds and can be used as a pre-plant control measure. This chemical would not be effective for early-planted tomatoes since the weed would not have germinated before transplanting. Not for use between plastic after transplanting.
3. halosulfuron-methyl (Sanda, Group B/2)
- Percent acres treated: 1.0% (42)
 - Typical rates and frequency of application: 0.5-1.0 oz/A, 1-4 applications depending on rate. Do not exceed 2 oz per acre per year. Up to a 36 month plant-back interval applies depending on the rotational crop.
 - Method of application: For plastic culture only, apply prior to plastic laying or as a banded directed shielded spray between rows. Has both pre-emergent and post emergent activity.
 - REI: 12 hours PHI: 30 days
 - Efficacy: Provides weed suppression.
 - Use in IPM and resistance management: Do not apply more than 1 oz under plastic. More than one additional application may be necessary to control multiple flushes of weeds. Weeds can become resistant to this herbicide if used with herbicides with the same mode of action (Group B/2). Use mechanical control and/or chemical control with materials from other herbicide classes.
4. metribuzin (Sencor 4, Sencor DF; Group C1/5)
- Percent acres treated: 46.1% (42)
 - Typical rates and frequency of application:
 - Sencor 4: 0.5-2 pt/A, 2-3 applications pre-plant incorporated and post emergence. Do not apply more than 2 pts per acre per season.
 - Sencor DF: 1/3-2/3 lbs/A, 2-3 applications pre-plant incorporated and post emergence. Do not apply more than 1 1/3 lbs per acre per season.

- Method of application: For plastic culture, band immediately prior to laying plastic. Use as a directed shielded spray between beds after transplanting. For bare ground culture, incorporate before transplanting. After transplanting, delay additional applications until plants recover from transplant shock (at least two weeks). Do not apply within 24 hours of other pesticides or when there are three days of cool, wet, or cloudy weather.
 - REI: 12 hours PHI: 7 days
 - Efficacy: Fair to good.
 - Use in IPM and resistance management: Used in combination with other herbicides for broad spectrum control.
5. napropamide (Devrinol 50-DF, Devrinol 2-EC; Group K3/15)
- Percent acres treated: 9.0% (42)
 - Typical rates and frequency of application:
 - Devrinol 50-DF: 2.0-4.0 lbs/A, 1-2 applications. Do not apply more than 4.0 lbs per acre per crop cycle.
 - Devrinol 2-EC: 2.0-4.0 qts/A, 1-2 applications. Do not apply more than 4.0 qts per acre per crop cycle.
 Up to a 12-month plant-back restriction applies depending on the rotational crop.
 - Method of application: For plastic culture, apply banded under the plastic or banded directed shielded spray between the plastic and incorporated with irrigation. For bare ground culture broadcast and incorporate 1-2 inches before transplanting.
 - REI: 12 hours PHI: Not available
 - Efficacy: Fair to good.
 - Use in IPM and resistance management: This material is the best to use during periods of wet weather. Good for rotation with the other herbicides to reduce chance of resistance. Generally used in combination with metribuzin (Group C1/5) to improve broadleaf weed control
6. rimsulfuron (Matrix, Group B/2)
- Percent acres treated: 13.3% (42)
 - Typical rates and frequency of application: 1-2 oz/A early post emergence. Do not exceed 4 oz per acre per year. Up to a 12 month plant-back interval applies depending on the rotational crop.
 - Method of application: Broadcast over the field when weeds are less than one inch but have two fully expanded true leaves.
 - REI: 4 hours PHI: Not available
 - Efficacy: Fair to good.
 - Use in IPM and resistance management: More than one additional application may be necessary to control multiple flushes of weeds. Weeds can become resistant to this herbicide if used with herbicides with the same mode of action (Group B/2). Use mechanical control and/or chemical control with materials from other herbicide classes.
7. S-metolachlor (Dual Magnum 7.62E, Group K3/15)

- Percent acres treated: 16.2% (42)
 - Typical rates and frequency of application: 1.0-2.0 pts/A. Do not make more than one application per season.
 - Method of application: For bare ground culture only broadcast pre-emergence to the weeds prior to transplanting. For plastic culture apply as a directed shielded spray between beds after plant establishment.
 - REI: 24 hours PHI: 90 days
 - Efficacy: Fair.
 - Use in IPM and resistance management: Good for rotation with the other herbicides for resistance management.
8. trifluralin (Treflan 4 EC, Treflan HFP, Treflan 4L, Trifluralin HF Trifluralin 4EC, Trilin, etc.; Group K1/3)
- Percent acres treated: 7.0% (42)
 - Typical rates and frequency of application: 1.0-2.0 pts/A, 1 application.
 - Method of application: Broadcast and incorporate 2 to 3 inches within 8 hours prior to transplanting. Do not use under plastic mulch.
 - REI: 12 hours PHI: Not available
 - Efficacy: Fair.
 - Use in IPM and resistance management: Avoid planting during periods of cold wet weather to reduce the risk of temporary stunting. Good for rotation with the other herbicides to reduce chance of resistance. Used in combination with metribuzin (Group C1/5) to improve broadleaf weed control.

Alternatives: There are several effective options to control purslane. Paraquat (Group D/22) is labeled by is not typically used by New Jersey growers.

Cultural Control Practices: Cultivation up to approximately one month after transplanting will help reduce weed populations. Cultivation should be done during sunny dry periods to reduce the chance of the plant re-rooting.

Biological Control: The purslane sawfly can provide effective control but is susceptible to every insecticide and some of the fungicides commonly used in commercial tomato production.

Post Harvest Control Practices: Incorporate plant residue immediately after harvesting to reduce weed seed production. Planting a cover crop will help keep weeds under control.

Common Ragweed, *Ambrosia artemisiifolia*

Description and Damage: Ragweed is a summer annual with an erect plant habit from 1 to 7 feet tall. This weed reproduces from seed that germinates from May to late June. Germination is inhibited with high temperatures (86°F or above). The leaves have rounded margins and are hairy and deeply cut when small. As the plant matures, the tips become less rounded. Leaves are opposite up to the fourth node then alternate.

Stems are branched with long rough hairs. Stems with some desiccated leaves will persist through the winter. Flowers are present from August to October with the male flowers in the top of the plant and female flowers on the lower portions. The seed can survive up to 80 years (52, 53, 55). This weed can compete with tomatoes throughout the production season if not controlled. Ragweed will germinate and overtake the tomatoes (especially processing tomatoes) during the season. It also affects the labor force since it produces large amount of pollen, of which many people are allergic.

Chemical Controls:

1. glyphosate (Roundup Ultra Max II, Glyphomax Plus, Touchdown, etc.; Group G/9)
 - Percent acres treated: 0.5% (42)
 - Typical rates and frequency of application: 24 to 48 fl oz/A, 1 application. Do not apply more than 8.0 qts per acre per year.
 - Method of application: Broadcast at least 3 days prior to transplanting when weeds are at most 6-18 inches tall.
 - REI: 4 or 12 hours PHI: Not available
 - Efficacy: Fair.
 - Use in IPM and resistance management: Controls most weeds and can be used as a pre-plant control measure. Not for use between plastic after transplanting.

2. halosulfuron-methyl (Sandea, Group B/2)
 - Percent acres treated: 1.0% (42)
 - Typical rates and frequency of application: 0.5-1.0 oz/A, 1-4 applications depending on rate. Do not exceed 2 oz per acre per year. Up to a 36 month plant-back interval applies depending on the rotational crop.
 - Method of application: For plastic culture only, apply prior to plastic laying or as a banded directed shielded spray between rows. Has both pre-emergent and post emergent activity.
 - REI: 12 hours PHI: 30 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Do not apply more than 1 oz under plastic. More than one additional application may be necessary to control multiple flushes of weeds. Weeds can become resistant to this herbicide if used with herbicides with the same mode of action (Group B/2). Use mechanical control and/or chemical control with materials from other herbicide classes.

3. metribuzin (Sencor 4, Sencor DF; Group C1/5)
 - Percent acres treated: 46.1% (42)
 - Typical rates and frequency of application:
 - Sencor 4: 0.5-2 pt/A, 2-3 applications pre-plant incorporated and post emergence. Do not apply more than 2 pts per acre per season.
 - Sencor DF: 1/3-2/3 lbs/A, 2-3 applications pre-plant incorporated and post emergence. Do not apply more than 1 1/3 lbs per acre per season.
 - Method of application: For plastic culture, band immediately prior to laying plastic. Use as a directed shielded spray between beds after transplanting. For bare ground culture, incorporate before transplanting. After transplanting, delay

additional applications until plants recover from transplant shock (at least two weeks). Do not apply within 24 hours of other pesticides or when there are three days of cool, wet, or cloudy weather.

- REI: 12 hours PHI: 7 days
- Efficacy: Good except for triazine (Group C1/5) resistant biotypes.
- Use in IPM and resistance management: Used in combination with other herbicides for broad spectrum control.

4. napropamide (Devrinol 50-DF, Devrinol 2-EC; Group K3/15)

- Percent acres treated: 9.0% (42)
- Typical rates and frequency of application:
 - Devrinol 50-DF: 2.0-4.0 lbs/A, 1-2 applications. Do not apply more than 4.0 lbs per acre per crop cycle.
 - Devrinol 2-EC: 2.0-4.0 qts/A, 1-2 applications. Do not apply more than 4.0 qts per acre per crop cycle.

Up to a 12-month plant-back restriction applies depending on the rotational crop.

- Method of application: For plastic culture, apply banded under the plastic or banded directed shielded spray between the plastic and incorporated with irrigation. For bare ground culture, broadcast and incorporate 1-2 inches before transplanting.
- REI: 12 hours PHI: Not available
- Efficacy: Poor.
- Use in IPM and resistance management: This material is the best to use during periods of wet weather. Suppresses weeds only, which may lead to resistance. Generally used in combination with metribuzin (Group C1/5) to improve broadleaf weed control

5. rimsulfuron (Matrix, Group B/2)

- Percent acres treated: 13.3% (42)
- Typical rates and frequency of application: 1-2 oz/A early post emergence. Do not exceed 4 oz per acre per year. Up to a 12 month plant-back interval applies depending on the rotational crop.
- Method of application: Broadcast over the field when weeds are less than one inch but have two fully expanded true leaves.
- REI: 4 hours PHI: Not available
- Efficacy: Provides suppression.
- Use in IPM and resistance management: More than one additional application may be necessary to control multiple flushes of weeds. Weeds can become resistant to this herbicide if used with herbicides with the same mode of action (Group B/2). Use mechanical control and/or chemical control with materials from other herbicide classes.

Alternatives: There are few effective chemical alternatives for common ragweed. If any of the above materials are lost, or no new herbicides developed, ragweed control will be difficult. Paraquat (Group D/22) is labeled by is not typically used by New Jersey growers.

Cultural Control Practices: Cultivation up to approximately one month after transplanting will help reduce weed populations.

Biological Control: None available.

Post Harvest Control Practices: Incorporate plant residue immediately after harvesting to reduce weed seed production. Planting a cover crop will help keep weeds under control.

Hairy Galinsoga, *Galinsoga ciliata*

Description and Damage: Hairy galinsoga is an erect plant with a branching stem approximately 4 to 30 inches tall. The leaves are opposite, triangular with a pointed tip, and slightly toothed on the margins. The seed is produced from early spring through September and has no dormancy thus there can be several generations in a season. The leaves and stem are green and covered with hair. Flowers are present from June to October. They have 4 to 5 white three-toothed petals around several yellow center flowers. One plant can produce thousands of seed, but they survive only for a few years (52, 53). Galinsoga is more of a problem for bare ground culture tomatoes than for tomatoes grown with plastic mulch.

Chemical Controls:

1. halosulfuron-methyl (Sandea, Group B/2)
 - Percent acres treated: 1.0% (42)
 - Typical rates and frequency of application: 0.5-1.0 oz/A, 1-4 applications depending on rate. Do not exceed 2 oz per acre per year. Up to a 36 month plant-back interval applies depending on the rotational crop.
 - Method of application: For plastic culture only, apply prior to plastic laying or as a banded directed shielded spray between rows. Has both pre-emergent and post emergent activity.
 - REI: 12 hours PHI: 30 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Do not apply more than 1 oz under plastic. More than one additional application may be necessary to control multiple flushes of weeds. Weeds can become resistant to this herbicide if used with herbicides with the same mode of action (Group B/2). Use mechanical control and/or chemical control with materials from other herbicide classes.

2. metribuzin (Sencor 4, Sencor DF; Group C1/5)
 - Percent acres treated: 46.1% (42)
 - Typical rates and frequency of application:
 - Sencor 4: 0.5-2 pts/A, 2-3 applications pre-plant incorporated and post emergence. Do not apply more than 2 pts per acre per season.
 - Sencor DF: 1/3-2/3 lbs/A, 2-3 applications pre-plant incorporated and post emergence. Do not apply more than 1 1/3 lbs per acre per season.

- Method of application: For plastic culture, band immediately prior to laying plastic. Use as a directed shielded spray between beds after transplanting. For bare ground culture, incorporate before transplanting. After transplanting, delay additional applications until plants recover from transplant shock (at least two weeks). Do not apply within 24 hours of other pesticides or when there are three days of cool, wet, or cloudy weather.
 - REI: 12 hours PHI: 7 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Used in combination with other herbicides for broad spectrum control.
3. S-metolachlor (Dual Magnum 7.62E, Group K3/15)
- Percent acres treated: 16.2% (42)
 - Typical rates and frequency of application: 1.0-2.0 pts/A. Do not make more than one application per season.
 - Method of application: For bare ground culture only broadcast pre-emergence to the weeds prior to transplanting. For plastic culture apply as a directed shielded spray between beds after plant establishment.
 - REI: 24 hours PHI: 90 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Good for rotation with other herbicides to reduce chance of resistance.

Alternatives: There are few chemical controls for galinsoga. This is one weed that needs additional control options. Paraquat (Group D/22) is labeled by is not typically used by New Jersey growers.

Cultural Control Practices: Cultivation between the rows up to approximately one month after transplanting will help reduce weed populations.

Biological Control: None available.

Post Harvest Control Practices: Incorporate plant residue immediately after harvesting to reduce weed seed production. Planting a cover crop will help keep weeds under control.

Ivyleaf Morning glory, *Ipomoea hederacea*

Description and Damage: This plant is a long vining summer annual with deeply three-lobed leaves and erect hairs on the stems, petioles, and leaves. The cotyledons are “butterfly shaped” and similar to other morning glories before taking on the typical ivy-shape. The vining stems twine around other plants or grow along the ground. Flower petals are white or pale blue to purple and form a trumpet or funnel shape. Plants die with the first frost, but the dry vines can be found in undisturbed fields through the winter (52, 53, and 55). Morning glory can grow over the top of tomatoes any time during the

Alternatives: There are few effective chemical controls for morning glory. Other chemical options should be explored. Paraquat (Group D/22) is labeled but is not typically used by New Jersey growers.

Cultural Control Practices: Cultivation around field edges will help reduce movement of morning glory into the field.

Biological Control: None available.

Post Harvest Control Practices: Spot treating at the end of the season will reduce the weed population.

Jimsonweed, *Datura stramonium*

Description and Damage: This large summer annual is erect with a branching stem. The plant grows 12 to 60 inches tall with egg-shaped fruit covered with green spines that turn light brown at maturity. Plants emerge from May until late summer. The cotyledons are opposite, narrow, and pointed, with the first true leaves being complete with no toothed margins. Later leaves are large toothed and pointed at the tip, resembling oak leaves. The plant has a thick, large taproot, which makes it difficult to pull. Flowers are produced from June until frost and open in the late afternoon and evening. The flowers are white to purple and funnel shaped. The seeds are enclosed in a capsule that is divided into four segments with many seeds in each. Jimsonweed competes with tomatoes for nutrients, water, and light, and can interfere with harvesting since the seed capsules have sharp spines (11, 52, 53, 55). This weed is found in groups and can reduce yields, but generally is not found over a whole field. It is more serious in processing tomatoes than fresh market tomatoes.

Chemical Controls:

1. DCPA (Dacthal 6F, Dacthal W-75; Group K1/3)
 - Percent acres treated: 0.1% (42)
 - Typical rates and frequency of application: 6.0-14.0 lbs/A, 4-6 weeks after transplanting; 1 application.
 - Method of application: Broadcast over plants that are grown without plastic mulch, or directed spray between rows with plastic mulch as a pre-emergent control.
 - REI: 12 hours PHI: Not available
 - Efficacy: Good.
 - Use in IPM and resistance management: Good for rotation with the other herbicides to reduce chance of resistance.

2. glyphosate (Roundup Ultra Max II, Glyphomax Plus, Touchdown, etc.; Group G/9)
 - Percent acres treated: 0.5% (42)
 - Typical rates and frequency of application: 32 to 48 fl oz/A, 1 application. Do not apply more than 8.0 qts per acre per year.

- Method of application: Broadcast at least 3 days prior to transplanting when weeds are at most 6-18 inches tall.
 - REI: 4 or 12 hours PHI: 14 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Controls most weeds and can be used as a pre-plant control measure. Not for use between plastic after transplanting.
3. halosulfuron-methyl (Sandea, Group B/2)
- Percent acres treated: 1.0% (42)
 - Typical rates and frequency of application: 0.5-1.0 oz/A, 1-4 applications depending on rate. Do not exceed 2 oz per acre per year. Up to a 36 month plant-back interval applies depending on the rotational crop.
 - Method of application: For plastic culture only apply prior to plastic laying or as a banded directed shielded spray between rows. This material has both pre-emergent and post emergent activity.
 - REI: 12 hours PHI: 30 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Do not apply more than 1 oz under plastic. More than one additional application may be necessary to control multiple flushes of weeds. Weeds can become resistant to this herbicide if used with herbicides with the same mode of action (Group B/2). Use mechanical control and/or chemical control with materials from other herbicide classes.
4. metribuzin (Sencor 4, Sencor DF; Group C1/5)
- Percent acres treated: 46.1% (42)
 - Typical rates and frequency of application:
 - Sencor 4: 0.5-2 pt/A, 2-3 applications pre-plant incorporated and post emergence. Do not apply more than 2 pts per acre per season.
 - Sencor DF: 1/3-2/3 lbs/A, 2-3 applications pre-plant incorporated and post emergence. Do not apply more than 1 1/3 lbs per acre per season.
 - Method of application: For plastic culture, band immediately prior to laying plastic. Use as a directed shielded spray between beds after transplanting. For bare ground culture, incorporate before transplanting. After transplanting, delay additional applications until plants recover from transplant shock (at least two weeks). Do not apply within 24 hours of other pesticides or when there are three days of cool, wet, or cloudy weather.
 - REI: 12 hours PHI: 7 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Used in combination with other herbicides for broad spectrum control.
5. rimsulfuron (Matrix, Group B/2)
- Percent acres treated: 13.3% (42)

- Typical rates and frequency of application: 8.0-14.0 pts/A or 8.0-14.0 lbs/A, 4-6 weeks after transplanting; 1 application.
 - Method of application: Broadcast over plants that are grown without plastic mulch, or directed spray between rows with plastic mulch as a pre-emergent weed treatment.
 - REI: 12 hours PHI: Not available
 - Efficacy: Poor.
 - Use in IPM and resistance management: Good for rotation with the other herbicides to reduce chance of resistance.
2. glyphosate (Roundup Ultra Max II, Glyphomax Plus, Touchdown, etc.; Group G/9)
- Percent acres treated: 0.5% (42)
 - Typical rates and frequency of application:
 - Roundup Max II: 16 - 32 fl oz/A, 1 application.
 - Glyphomax Plus: 24 - 48 fl oz/A, 1 application.
 - Touchdown: 24 - 32 fl oz/ A, 1 application.
 Do not apply more than 8.0 qts/A per year.
 - Method of application: Broadcast at least 3 days prior to transplanting when weeds are at most 4-12 inches (Glyphomax and Roundup) and 6-12 inches (Touchdown) tall.
 - REI: 4 or 12 hours PHI: 14 days
 - Efficacy: Fair.
 - Use in IPM and resistance management: Glyphosate provides good weed control before transplanting. Not for use between plastic after transplanting.
3. metribuzin (Sencor 4, Sencor DF; Group C1/5)
- Percent acres treated: 46.1% (42)
 - Typical rates and frequency of application:
 - Sencor 4: 1/2-2 pts/A, 2-3 applications. Do not apply more than 2 pts per acre per season.
 - Sencor DF: 1/3-2/3 lbs/A, 2-3 applications pre-plant incorporated and post emergence. Do not apply more than 1 1/3 lbs per acre per season.
 - Method of application: For plastic culture, band immediately prior to laying plastic. Use as a directed shielded spray between beds after transplanting. For bare ground culture, incorporate before transplanting. After transplanting, delay additional applications until plants recover from transplant shock (at least two weeks). Do not apply within 24 hours of other pesticides or when there are three days of cool, wet, or cloudy weather.
 - REI: 12 hours PHI: 7 days
 - Efficacy: Poor.
 - Use in IPM and resistance management: Used in combination with other herbicides for broad spectrum control.
4. S-metolachlor (Dual Magnum 7.62E, Group K3/15)
- Percent acres treated: 16.2% (42)

- Typical rates and frequency of application: 1.0-2.0 pts/A. Do not make more than one application per season.
- Method of application: For bare ground culture only, broadcast pre-emergence to the weeds prior to transplanting. For plastic culture, apply as a directed shielded spray between beds after plant establishment.
- REI: 24 hours PHI: 90 days
- Efficacy: Good.
- Use in IPM and resistance management: Good for rotation with the other herbicides to reduce chance of resistance.

Alternatives: There is only one effective material (S-metolachlor, Group K3/15) available for nightshade control. Paraquat (Group D/22) is labeled but is not typically used by New Jersey growers.

Cultural Control Practices: Cultivation between the rows up to approximately one month after transplanting will help reduce weed populations.

Biological Control: The Colorado potato beetle feeds on nightshade, but is also a pest of tomatoes.

Post Harvest Control Practices: Incorporate plant residue immediately after harvesting to reduce weed seed production. Planting a cover crop will help keep weeds under control.

Smooth Pigweed, *Amaranthus hybridus*

Description and Damage: The plant is erect and 1 to 7 feet tall with many branches. The stems are slender with dense short hairs on the upper part. The leaves are simple, alternate, oval, and egg-shaped with a green color above and light green to magenta on the underside. The cotyledons are narrow and pointed dark green on the top surface, and bright red below. Seedling stems are green, very hairy, and may be red at the base. The plants have a shallow taproot and may be pink or red in color. Flowers and seed heads are mainly located at the top of the plant. The plants persist in the field after frost (11, 52, 53). Several other species that are found in New Jersey have similar descriptive characteristics. Among these are redroot pigweed (*Amaranthus retroflexus*) and Powell amaranth (*Amaranthus powellii*). All three species may be found in the same field (11). Pigweed can compete with tomatoes throughout the growing season, especially in bare ground plantings. Harvesting can be slowed if weeds are not controlled between the rows. In processing fields, fruit can be stained with sap if the weeds are not dry. Pigweed has the potential to completely infest a field.

Chemical Controls:

1. DCPA (Dacthal 6F, Dacthal W-75; Group K1/3)
 - Percent acres treated: 0.1% (42)
 - Typical rates and frequency of application: 6.0-14.0 lbs/A, 4-6 weeks after transplanting; 1 application.

- Method of application: Broadcast over plants that are grown without plastic mulch, or directed spray between rows with plastic mulch as a pre-emergent control.
 - REI: 12 hours PHI: Not available
 - Efficacy: Fair to good depending on the species.
 - Use in IPM and resistance management: Good for rotation with the other herbicides to reduce chance of resistance.
2. glyphosate (Roundup Ultra Max II, Glyphomax Plus, Touchdown, etc.; Group G/9)
- Percent acres treated: 0.5% (42)
 - Typical rates and frequency of application: 16 to 40 fl oz/A, 1 application. Do not apply more than 8.0 qts/A per year.
 - Method of application: Broadcast at least 3 days prior to transplanting when weeds are at most 12-24 inches tall.
 - REI: 4 or 12 hours PHI: 14 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Good for control of smooth pigweed, but only if applied as a pre-transplant treatment. Not for use between plastic after transplanting.
3. halosulfuron-methyl (Sanda, Group B/2)
- Percent acres treated: 1.0% (42)
 - Typical rates and frequency of application: 0.5-1.0 oz/A, 1-4 applications depending on rate. Do not exceed 2 oz per acre per year. Up to a 36 month plant-back interval applies depending on the rotational crop.
 - Method of application: For plastic culture only, apply prior to plastic laying or as a banded directed shielded spray between rows. Has both pre-emergent and post emergent activity.
 - REI: 12 hours PHI: 30 days
 - Efficacy: Poor to good depending on the species.
 - Use in IPM and resistance management: Do not apply more than 1 oz under plastic. More than one additional application may be necessary to control multiple flushes of weeds. Weeds can become resistant to this herbicide if used with herbicides with the same mode of action (Group B/2). Use mechanical control and/or chemical control with materials from other herbicide classes.
4. metribuzin (Sencor 4, Sencor DF; Group C1/5)
- Percent acres treated: 46.1% (42)
 - Typical rates and frequency of application:
 - Sencor 4: 0.5-2 pt/A, 2-3 applications post emergence. Do not apply more than 2 pts per acre per season.
 - Sencor DF: 1/3-2/3 lbs/A, 2-3 applications post emergence. Do not apply more than 1 1/3 lbs per acre per season.
 - Method of application: For plastic culture, band immediately prior to laying plastic. Use as a directed shielded spray between beds after transplanting. For

bare ground culture, incorporate before transplanting. After transplanting, delay additional applications until plants recover from transplant shock (at least two weeks). Do not apply within 24 hours of other pesticides or when there are three days of cool, wet, or cloudy weather.

- REI: 12 hours PHI: 7 days
- Efficacy: Good except on triazine (Group C1/5) resistant biotypes.
- Use in IPM and resistance management: Used in combination with other herbicides for broad spectrum control.

5. napropamide (Devrinol 50-DF, Devrinol 2-EC; Group K3/15)

- Percent acres treated: 9.0% (42)
- Typical rates and frequency of application:
 - Devrinol 50-DF: 2.0-4.0 lbs/A, 1-2 applications. Do not apply more than 4.0 lbs/A per crop cycle.
 - Devrinol 2-EC: 2.0-4.0 qts/A, 1-2 applications. Do not apply more than 4.0 qts/A per crop cycle.
- Up to a 12-month plant-back restriction applies depending on the rotational crop.
- Method of application: For plastic culture, apply banded under the plastic or banded directed shielded spray between the plastic and incorporated with irrigation. For bare ground culture, broadcast and incorporate 1-2 inches before transplanting.
- REI: 12 hours PHI: Not available
- Efficacy: Fair to good.
- Use in IPM and resistance management: Best chemical to use during periods of wet weather. Good for rotation with the other herbicides to reduce chance of resistance. Generally used in combination with metribuzin (Group C1/5) to improve broadleaf weed control.

6. rimsulfuron (Matrix, Group B/2)

- Percent acres treated: 13.3% (42)
- Typical rates and frequency of application: 1-2 oz/A early post emergence. Do not exceed 4 oz/A/yr. Up to a 12 month plant-back interval applies depending on the rotational crop.
- Method of application: Broadcast over the field when weeds are less than one inch but have two fully expanded true leaves.
- REI: 4 hours PHI: Not available
- Efficacy: Good.
- Use in IPM and resistance management: More than one additional application may be necessary to control multiple flushes of weeds. Weeds can become resistant to this herbicide if used with herbicides with the same mode of action (Group B/2). Use mechanical control and/or chemical control with materials from other herbicide classes.

7. S-metolachlor (Dual Magnum 7.62E, Group K3/15)

- Percent acres treated: 16.2% (42)

- Typical rates and frequency of application: 1.0-2.0 pts/A. Do not make more than one application per season.
 - Method of application: For bare ground culture only, broadcast pre-emergence to the weeds prior to transplanting. For plastic culture, apply as a directed shielded spray between beds after plant establishment.
 - REI: 24 hours PHI: 90 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Good for rotation with the other herbicides to reduce chance of resistance.
8. trifluralin (Treflan 4 EC, Treflan HFP, Treflan 4L, Trifluralin HF Trifluralin 4EC, Trilin, etc.; Group K1/3)
- Percent acres treated: 7.0% (42)
 - Typical rates and frequency of application: 1.0-2.0 pts/A, 1 application.
 - Method of application: Broadcast and incorporate 2 to 3 inches within 8 hours prior to transplanting. Do not use under plastic mulch.
 - REI: 12 hours PHI: Not available
 - Efficacy: Fair to good.
 - Use in IPM and resistance management: Avoid planting during periods of cold wet weather to reduce the risk of temporary stunting. Good for rotation with the other herbicides to reduce chance of resistance. Used in combination with metribuzin (Group C1/5) to improve broadleaf weed control.

Alternatives: S-metolachlor (Group K3/15) and halosulfuron-methyl (Group B/2) are the only two effective materials for control of pigweed, and halosulfuron-methyl is not recommended for bare ground culture. Paraquat (Group D/22) is labeled but is not typically used by New Jersey growers.

Cultural Control Practices: Cultivation between the rows up to approximately one month after transplanting will help reduce weed populations.

Biological Control: None available.

Post Harvest Control Practices: Incorporate plant residue immediately after harvesting to reduce weed seed production. Planting a cover crop will help keep weeds under control.

Velvetleaf, *Abutilon theophrasti*

Description and Damage: This summer annual is erect (3 to 5 feet) with an unbranched hairy stem. The large leaves are heart shaped and covered with soft hairs which gives it a velvety texture. Seeds emerge from mid to late May. The cotyledons are heart shaped, alternate, and hairy, as are the young leaves, which point downward. The plant flowers from July into the fall. Flowers are produced on small stalks in the upper leaf axils and have five yellow petals. The fruits have a distinct appearance of a circular cup-shaped disk that is ribbed and pointed at the end of each rib. Seeds remain viable

weeks). Do not apply within 24 hours of other pesticides or when there are three days of cool, wet, or cloudy weather.

- REI: 12 hours PHI: 7 days
- Efficacy: Good.
- Use in IPM and resistance management: Used in combination with other herbicides for broad spectrum control.

4. rimsulfuron (Matrix, Group B/2)

- Percent acres treated: 13.3% (42)
- Typical rates and frequency of application: 1-2 oz/A early post emergence. Do not exceed 4 oz/A/yr. Up to a 12 month plant-back interval applies depending on the rotational crop.
- Method of application: Broadcast over the field when weeds are less than one inch but have two fully expanded true leaves.
- REI: 4 hours PHI: Not available
- Efficacy: Provides suppression.
- Use in IPM and resistance management: More than one additional application may be necessary to control multiple flushes of weeds. Weeds can become resistant to this herbicide if used with herbicides with the same mode of action (Group B/2). Use mechanical control and/or chemical control with materials from other herbicide classes.

Alternatives: There are no effective pre-emergence materials for velvetleaf control. This is an area where additional herbicides are needed. Paraquat (Group D/22) is labeled but is not typically used by New Jersey growers.

Cultural Control Practices: Cultivation between the rows up to approximately one month after transplanting will help reduce weed populations.

Biological Control: None available.

Post Harvest Control Practices: Incorporate plant residue immediately after harvesting to reduce weed seed production. Planting a cover crop will help keep weeds under control.

Other Issues: If manure is applied it should be well composted. Velvetleaf seeds pass through animal digestive systems and the seeds are spread in the manure.

Annual Grass Weeds

Barnyardgrass, *Echinochloa crus-galli*

Description and Damage: This summer annual is erect (up 5 feet) and grows in clumps. The seed germinates from early spring to midsummer. When the weed emerges, the leaf opens parallel to the ground. The sheaths are tinted maroon near the base. The leaves have no auricles or ligules and have a smooth green collar. After the

first leaves, the remaining leaves are upright. Mature plants are similar to the seedlings with blades that are 4 to 8 inches in length. The sheaths are open and smooth with a collar that is whitish and smooth. Flowers occur from July through September. The seed heads come out of the top sheath and are branched with green to purple panicles. Barnyardgrass is killed by the first frost, but the thick stem remains standing through the winter (11, 52, 53, 55). Barnyardgrass can compete with tomatoes early in the season especially if not grown on plastic mulch. Within row, competition is more of a concern if soil is not thrown around the plants during cultivation.

Chemical Controls:

1. clethodim (Select 2EC, Arrow 2EC, Select Max 0.97EC, Prism 0.94EC; Group A/1)
 - Percent acres treated: 6.8% (42)
 - Typical rates and frequency of application:
 - Select and Arrow: 6.0-8.0 oz/A, 1-2 applications.
 - Select Max and Prism: 12.0-17.0 oz/A, 1-2 applications.Applications should be timed to when the weed is at most 2-8 inches tall.
 - Method of application: Broadcast post emergence to the weeds and tomatoes.
 - REI: 24 hours PHI: 20 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Must use an oil concentrate or nonionic surfactant for good control, however during periods of hot or humid weather crop injury may occur and control may be reduced. Should not be tank-mixed or applied within 2 to 3 days of any other pesticide unless labeled. The herbicide should be applied when the weed is actively growing and before tillers are present.

2. DCPA (Dacthal 6F, Dacthal W-75; Group K1/3)
 - Percent acres treated: 0.1% (42)
 - Typical rates and frequency of application: 6.0-14.0 lbs/A, 4-6 weeks after transplanting; 1 application.
 - Method of application: Broadcast over plants that are grown without plastic mulch, or directed spray between rows with plastic mulch as a pre-emergent control.
 - REI: 12 hours PHI: Not available
 - Efficacy: Good.
 - Use in IPM and resistance management: Good for rotation with the other herbicides to reduce chance of resistance.

3. glyphosate (Roundup Ultra Max II, Glyphomax Plus, Touchdown, etc.; Group G/9)
 - Percent acres treated: 0.5% (42)
 - Typical rates and frequency of application:
 - Roundup Max II: 16 - 32 fl oz/A, 1 application.
 - Glyphomax Plus, Touchdown: 24 - 48 fl oz/A, 1 application.Do not apply more than 8.0 qts/A per year.
 - Method of application: Broadcast at least 3 days prior to transplanting when weeds are at most 3-12 inches tall.

- REI: 4 or 12 hours PHI: 14 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Glyphosate provides good weed control before transplanting. Not for use between plastic after transplanting.
4. metribuzin (Sencor 4, Sencor DF; Group C1/5)
- Percent acres treated: 46.1% (42)
 - Typical rates and frequency of application:
 - Sencor 4: 0.5-2 pt/A, 2-3 applications pre-plant incorporated and post emergence. Do not apply more than 2 pts per acre per season.
 - Sencor DF: 1/3-2/3 lbs/A, 2-3 applications pre-plant incorporated and post emergence. Do not apply more than 1 1/3 lbs per acre per season.
 - Method of application: For plastic culture, band immediately prior to laying plastic. Use as a directed shielded spray between beds after transplanting. For bare ground culture, incorporate before transplanting. After transplanting, delay additional applications until plants recover from transplant shock (at least two weeks). Do not apply within 24 hours of other pesticides or when there are three days of cool, wet, or cloudy weather.
 - REI: 12 hours PHI: 7 days
 - Efficacy: Suppression.
 - Use in IPM and resistance management: Used in combination with other herbicides for broad spectrum control.
5. napropamide (Devrinol 50-DF, Devrinol 2-EC; Group K3/15)
- Percent acres treated: 9.0% (42)
 - Typical rates and frequency of application:
 - Devrinol 50-DF: 2.0-4.0 lbs/A, 1-2 applications. Do not apply more than 4.0 lbs/A per crop cycle.
 - Devrinol 2-EC: 2.0-4.0 qts/A, 1-2 applications. Do not apply more than 4.0 qts/A per crop cycle.
 - Up to a 12-month plant-back restriction applies depending on the rotational crop.
 - Method of application: For plastic culture, apply banded under the plastic or banded directed shielded spray between the plastic and incorporated with irrigation. For bare ground culture, broadcast and incorporate 1-2 inches before transplanting.
 - REI: 12 hours PHI: Not available
 - Efficacy: Good.
 - Use in IPM and resistance management: Best chemical to use during periods of wet weather. Good for rotation with the other herbicides to reduce chance of resistance. Generally used in combination with metribuzin (Group C1/5) to improve broadleaf weed control.
6. rimsulfuron (Matrix, Group B/2)
- Percent acres treated: 13.3% (42)

- Typical rates and frequency of application: 1-2 oz/A early post emergence. Do not exceed 4 oz/A/yr. Up to a 12 month plant-back interval applies depending on the rotational crop.
 - Method of application: Broadcast over the field when weeds are less than one inch but have two fully expanded true leaves.
 - REI: 4 hours PHI: Not available
 - Efficacy: Good.
 - Use in IPM and resistance management: More than one additional application may be necessary to control multiple flushes of weeds. Weeds can become resistant to this herbicide if used with herbicides with the same mode of action (Group B/2). Use mechanical control and/or chemical control with materials from other herbicide classes.
7. sethoxydim (Poast 1.5EC, Poast Plus 1.0EC; Group A/1)
- Percent acres treated: 10.6% (42)
 - Typical rates and frequency of application:
 - Poast: 1.0 fl oz/A, 1-2 applications.
 - Poast Plus: 1.5 fl oz/A, 1-2 applications.
 Do not apply more than 4.5 pts per acre per season.
 - Method of application: Broadcast for weeds up to 8 inches tall.
 - REI: 12 hours PHI: 20 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Must use an oil concentrate or nonionic surfactant for good control, however during periods of hot or humid weather crop injury may occur and control may be reduced. The herbicide should be applied when the weed is actively growing and before tillers are present.
8. S-metolachlor (Dual Magnum 7.62E, Group K3/15)
- Percent acres treated: 16.2% (42)
 - Typical rates and frequency of application: 1.0-2.0 pts/A. Do not make more than one application per season.
 - Method of application: For bare ground culture only, broadcast pre-emergence to the weeds prior to transplanting. For plastic culture, apply as a directed shielded spray between beds after plant establishment.
 - REI: 24 hours PHI: 90 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Good for rotation with the other herbicides to reduce chance of resistance.
9. trifluralin (Treflan 4 EC, Treflan HFP, Treflan 4L, Trifluralin HF Trifluralin 4EC, Trilin, etc.; Group K1/3)
- Percent acres treated: 7.0% (42)
 - Typical rates and frequency of application: 1.0-2.0 pts/A, 1 application.
 - Method of application: Broadcast and incorporate 2 to 3 inches within 8 hours prior to transplanting. Do not use under plastic mulch.

- REI: 12 hours PHI: Not available
- Efficacy: Good.
- Use in IPM and resistance management: Avoid planting during periods of cold wet weather to reduce the risk of temporary stunting. Good for rotation with the other herbicides to reduce chance of resistance. Used in combination with metribuzin (Group C1/5) to improve broadleaf weed control.

Alternatives: There are effective chemical controls for barnyardgrass. Paraquat (Group D/22) is labeled but is not typically used by New Jersey growers.

Cultural Control Practices: Cultivation between the rows up to approximately one month after transplanting will help reduce weed populations.

Biological Control: None available.

Post Harvest Control Practices: Incorporate plant residue immediately after harvesting to reduce weed seed production. Planting a cover crop will help keep weeds under control.

**Giant Foxtail, *Setaria faveri*, Green Foxtail, *Setaria viridis*,
Yellow Foxtail, *Setaria glauca***

Description and Damage: These three species are similar in general characteristics. They have a clump forming erect habit. These summer annuals reproduce by seed that germinates from late spring through summer. The first leaf opens parallel to the ground and is much longer than its width. The leaves emerge rolled, auricles are absent, and the ligule is fringed with hairs. The leaves are smooth on the lower surface. Giant foxtail has short numerous hairs on the upper surface of the blade and the margin of the sheath, whereas green foxtail has rough blades and no hairs, and the sheaths have hairy margins. Yellow foxtail is covered with long hairs at the base of the upper surface. The collar is green and smooth on all species. At maturity the plants appear very similar as the seedlings except that the sheathes are often reddish at the base and have a prominent mid-vein. Roots are fibrous and tillers will root at the base of the plant. Foxtails flower from mid to late summer with seed heads present from late summer through fall. The seed heads are coarse, bristly in appearance, and approximately 0.8 to 6.0 inches in length. The giant foxtail seed head is the largest of the three with a green to purple color. Green foxtail has a seed head larger and greener than yellow foxtail. The yellow foxtail seed head has a yellowish color. The seed head remains yellow through early winter, which helps distinguish it from the other foxtails that turn brown (52, 53, 55). All three foxtails can compete with tomatoes early in the season if not controlled, especially within the row when plastic mulch is not used.

Chemical Controls:

1. clethodim (Select 2EC, Arrow 2EC, Select Max 0.97EC, Prism 0.94EC; Group A/1)
 - Percent acres treated: 6.8% (42)
 - Typical rates and frequency of application:

- Select and Arrow: 6.0–8.0 oz/A, 1–2 applications.
- Select Max: 9.0-17.0 oz/A, 1-2 applications.
- Prism: 13.0-17.0 oz/A, 1–2 applications.

Applications should be timed to when the weed is 2–8 inches tall (green and yellow foxtail), or 2-12 inches tall (giant foxtail).

- Method of application: Broadcast post emergence to the weeds and tomatoes.
- REI: 24 hours PHI: 20 days
- Efficacy: Good.
- Use in IPM and resistance management: Must use an oil concentrate or nonionic surfactant for good control, however during periods of hot or humid weather crop injury may occur and control may be reduced. Should not be tank-mixed or applied within 2 to 3 days of any other pesticide unless labeled. The herbicide should be applied when the weed is actively growing and before tillers are present.

2. DCPA (Dacthal 6F, Dacthal W-75; Group K1/3)

- Percent acres treated: 0.1% (42)
- Typical rates and frequency of application: 6.0-14.0 lbs/A, 4-6 weeks after transplanting; 1 application.
- Method of application: Broadcast over plants that are grown without plastic mulch, or directed spray between rows with plastic mulch as a pre-emergent control.
- REI: 12 hours PHI: Not available
- Efficacy: Good.
- Use in IPM and resistance management: Good for rotation with the other herbicides to reduce chance of resistance.

3. glyphosate (Roundup Ultra Max II, Glyphomax Plus, Touchdown, etc.; Group G/9)

- Percent acres treated: 0.5% (42)
- Typical rates and frequency of application:
 - Roundup Max II: 11 - 22 fl oz/A, 1 application.
 - Glyphomax Plus: 16 - 32 fl oz/A, 1 application.
 - Touchdown: 12 - 16 fl oz/ A, 1 application.
 Do not apply more than 8.0 qts/A per year.
- Method of application: Broadcast at least 3 days prior to transplanting when green foxtail is 12 inches and others are 6-20 inches tall.
- REI: 4 or 12 hours PHI: 14 days
- Efficacy: Good.
- Use in IPM and resistance management: Glyphosate provides good weed control before transplanting. Not for use between plastic after transplanting.

4. metribuzin (Sencor 4, Sencor DF; Group C1/5)

- Percent acres treated: 46.1% (42)
- Typical rates and frequency of application:

- Sencor 4: 0.5-2 pt/A, 2-3 applications pre-plant incorporated. Do not apply more than 2 pts per acre per season.
 - Sencor DF: 1/3-2/3 lbs/A, 2-3 applications pre-plant incorporated. Do not apply more than 1 1/3 lbs per acre per season.
 - Method of application: For plastic culture, band immediately prior to laying plastic. Use as a directed shielded spray between beds after transplanting. For bare ground culture, incorporate before transplanting. After transplanting, delay additional applications until plants recover from transplant shock (at least two weeks). Do not apply within 24 hours of other pesticides or when there are three days of cool, wet, or cloudy weather.
 - REI: 12 hours PHI: 7 days
 - Efficacy: Suppression.
 - Use in IPM and resistance management: Used in combination with other herbicides for broad spectrum control.
5. napropamide (Devrinol 50-DF, Devrinol 2-EC; Group K3/15)
- Percent acres treated: 9.0% (42)
 - Typical rates and frequency of application:
 - Devrinol 50-DF: 2.0-4.0 lbs/A, 1-2 applications. Do not apply more than 4.0 lbs/A per crop cycle.
 - Devrinol 2-EC: 2.0-4.0 qts/A, 1-2 applications. Do not apply more than 4.0 qts/A per crop cycle.
 - Up to a 12-month plant-back restriction applies depending on the rotational crop.
 - Method of application: For plastic culture, apply banded under the plastic or banded directed shielded spray between the plastic and incorporated with irrigation. For bare ground culture, broadcast and incorporate 1-2 inches before transplanting.
 - REI: 12 hours PHI: Not available
 - Efficacy: Good.
 - Use in IPM and resistance management: Best chemical to use during periods of wet weather. Good for rotation with the other herbicides to reduce chance of resistance. Generally used in combination with metribuzin (Group C1/5) to improve broadleaf weed control.
6. rimsulfuron (Matrix, Group B/2)
- Percent acres treated: 13.3% (42)
 - Typical rates and frequency of application: 1-2 oz/A early post emergence. Do not exceed 4 oz per acre per year. Up to a 12 month plant-back interval applies depending on the rotational crop.
 - Method of application: Broadcast over the field when weeds are less than one inch but have two fully expanded true leaves.
 - REI: 4 hours PHI: Not available
 - Efficacy: Good.
 - Use in IPM and resistance management: More than one additional application may be necessary to control multiple flushes of weeds. Weeds can become resistant to this herbicide if used with herbicides with the same mode of action

(Group B/2). Use mechanical control and/or chemical control with materials from other herbicide classes.

7. sethoxydim (Poast 1.5EC, Poast Plus 1.0EC; Group A/1)
 - Percent acres treated: 10.6% (42)
 - Typical rates and frequency of application:
 - Poast: 1.0 fl oz/A, 1-2 applications.
 - Poast Plus: 1.5 fl oz/A, 1-2 applications.
 - Do not apply more than 4.5 pts per acre per season.
 - Method of application: Broadcast for weeds up to 8 inches tall.
 - REI: 12 hours PHI: 20 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Must use an oil concentrate or nonionic surfactant for good control, however during periods of hot or humid weather crop injury may occur and control may be reduced. The herbicide should be applied when the weed is actively growing and before tillers are present.

8. S-metolachlor (Dual Magnum 7.62E, Group K3/15)
 - Percent acres treated: 16.2% (42)
 - Typical rates and frequency of application: 1.0-2.0 pts/A. Do not make more than one application per season.
 - Method of application: For bare ground culture only, broadcast pre-emergence to the weeds prior to transplanting. For plastic culture, apply as a directed shielded spray between beds after plant establishment.
 - REI: 24 hours PHI: 90 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Good for rotation with the other herbicides to reduce chance of resistance.

9. trifluralin (Treflan 4 EC, Treflan HFP, Treflan 4L, Trifluralin HF Trifluralin 4EC, Trilin, etc.; Group K1/3)
 - Percent acres treated: 7.0% (42)
 - Typical rates and frequency of application: 1.0-2.0 pts/A, 1 application.
 - Method of application: Broadcast and incorporate 2 to 3 inches within 8 hours prior to transplanting. Do not use under plastic mulch.
 - REI: 12 hours PHI: Not available
 - Efficacy: Good.
 - Use in IPM and resistance management: Avoid planting during periods of cold wet weather to reduce the risk of temporary stunting. Good for rotation with the other herbicides to reduce chance of resistance. Used in combination with metribuzin (Group C1/5) to improve broadleaf weed control.

Alternatives: There are several chemicals labeled with good efficacy for foxtail control. Paraquat (Group D/22) is labeled but is not typically used by New Jersey growers.

Cultural Control Practices: Cultivation between the rows up to approximately one month after transplanting will help reduce weed populations.

Biological Control: None available.

Post Harvest Control Practices: Incorporate plant residue immediately after harvesting to reduce weed seed production. Planting a cover crop will help keep weeds under control.

Fall Panicum, *Panicum dichotomiflorum*

Description and Damage: The plant growth habit varies from erect to sprawling. Seeds germinate from late spring to midsummer. The first leaves are parallel to the ground, rolled in a bud, and lack auricles. The ligule has a fringe of hair and the first few leaves and sheaths are hairy on the underside, but become hairless with age. The collar is very hairy. The mature plants appear waxy with enlarged nodes and red to purplish sheaths. Plants grow 20 to 40 inches tall. The roots are fibrous and can root from the lower nodes. Fall panicum flowers from July to October. The large seed heads are red to purple with an open branching appearance (52, 53, 55). As with the foxtails, fall panicum can compete with tomatoes early in the season, especially for small transplants and fields without plastic mulch. It can interfere with harvesting of processing tomatoes.

Chemical Controls:

1. clethodim (Select 2EC, Arrow 2EC, Select Max 0.97EC, Prism 0.94EC; Group A/1)
 - Percent acres treated: 6.8% (42)
 - Typical rates and frequency of application:
 - Select and Arrow: 6.0–8.0 oz/A, 1–2 applications.
 - Select Max: 9.0 – 16.0 oz/A, 1-2 applications.
 - Prism: 13.0-17.0 oz/A, 1–2 applications.
 - Applications should be timed to when the weed is at most 2–8 inches tall.
 - Method of application: Broadcast post emergence to the weeds and tomatoes.
 - REI: 24 hours PHI: 20 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Must use an oil concentrate or nonionic surfactant for good control, however during periods of hot or humid weather crop injury may occur and control may be reduced. Should not be tank -mixed or applied within 2 to 3 days of any other pesticide unless labeled. The herbicide should be applied when the weed is actively growing and before tillers are present.

2. DCPA (Dacthal 6F, Dacthal W-75; Group K1/3)
 - Percent acres treated: 0.1% (42)
 - Typical rates and frequency of application: 6.0-14.0 lbs/A, 4-6 weeks after transplanting; 1 application.

- Method of application: Broadcast over plants that are grown without plastic mulch, or directed spray between rows with plastic mulch as a pre-emergent control.
 - REI: 12 hours PHI: Not available
 - Efficacy: Fair to good.
 - Use in IPM and resistance management: Good for rotation with the other herbicides to reduce chance of resistance.
3. glyphosate (Roundup Ultra Max II, Glyphomax Plus, Touchdown, etc.; Group G/9)
- Percent acres treated: 0.5% (42)
 - Typical rates and frequency of application:
 - Roundup Max II: 11 - 32 fl oz/A, 1 application.
 - Glyphomax Plus, Touchdown: 24 - 48 fl oz/A, 1 application.
 Do not apply more than 8.0 qts/A per year.
 - Method of application: Broadcast at least 3 days prior to transplanting when weeds are 4 to 12 (Glyphomax and Roundup) and 3 to 24 (Touchdown) inches tall.
 - REI: 4 or 12 hours PHI: 14 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Glyphosate provides good weed control before transplanting. Not for use between plastic after transplanting.
4. metribuzin (Sencor 4, Sencor DF; Group C1/5)
- Percent acres treated: 46.1% (42)
 - Typical rates and frequency of application:
 - Sencor 4: 0.5-2 pt/A, 2-3 applications pre-plant incorporated. Do not apply more than 2 pts per acre per season.
 - Sencor DF: 1/3-2/3 lbs/A, 2-3 applications pre-plant incorporated. Do not apply more than 1 1/3 lbs per acre per season.
 - Method of application: For plastic culture, band immediately prior to laying plastic. Use as a directed shielded spray between beds after transplanting. For bare ground culture, incorporate before transplanting. After transplanting, delay additional applications until plants recover from transplant shock (at least two weeks). Do not apply within 24 hours of other pesticides or when there are three days of cool, wet, or cloudy weather.
 - REI: 12 hours PHI: 7 days
 - Efficacy: Poor to fair.
 - Use in IPM and resistance management: Used in combination with other herbicides for broad spectrum control.
5. napropamide (Devrinol 50-DF, Devrinol 2-EC; Group K3/15)
- Percent acres treated: 9.0% (42)
 - Typical rates and frequency of application:

- Devrinol 50-DF: 2.0-4.0 lbs/A, 1-2 applications. Do not apply more than 4.0 lbs/A per crop cycle.
- Devrinol 2-EC: 2.0-4.0 qts/A, 1-2 applications. Do not apply more than 4.0 qts/A per crop cycle.

Up to a 12-month plant-back restriction applies depending on the rotational crop.

- Method of application: For plastic culture, apply banded under the plastic or banded directed shielded spray between the plastic and incorporated with irrigation. For bare ground culture, broadcast and incorporate 1-2 inches before transplanting.
- REI: 12 hours PHI: Not available
- Efficacy: Fair to good.
- Use in IPM and resistance management: Best chemical to use during periods of wet weather. Good for rotation with the other herbicides to reduce chance of resistance. Generally used in combination with metribuzin (Group C1/5) to improve broadleaf weed control.

6. rimsulfuron (Matrix, Group B/2)

- Percent acres treated: 13.3% (42)
- Typical rates and frequency of application: 1-2 oz/A early post emergence. Do not exceed 4 oz/A/yr. Up to a 12 month plant-back interval applies depending on the rotational crop.
- Method of application: Broadcast over the field when weeds are less than one inch but have two fully expanded true leaves.
- REI: 4 hours PHI: Not available
- Efficacy: Good.
- Use in IPM and resistance management: More than one additional application may be necessary to control multiple flushes of weeds. Weeds can become resistant to this herbicide if used with herbicides with the same mode of action (Group B/2). Use mechanical control and/or chemical control with materials from other herbicide classes.

7. sethoxydim (Poast 1.5EC, Poast Plus 1.0EC; Group A/1)

- Percent acres treated: 10.6% (42)
- Typical rates and frequency of application:
 - Poast: 1.0 fl oz/A, 1-2 applications.
 - Poast Plus: 1.5 fl oz/A, 1-2 applications.
 Do not apply more than 4.5 pts/A per season.
- Method of application: Broadcast for weeds up to 8 inches tall.
- REI: 12 hours PHI: 20 days
- Efficacy: Good.
- Use in IPM and resistance management: Must use an oil concentrate or nonionic surfactant for good control, however during periods of hot or humid weather crop injury may occur and control may be reduced. The herbicide should be applied when the weed is actively growing and before tillers are present.

8. S-metolachlor (Dual Magnum 7.62E, Group K3/15)

- Percent acres treated: 16.2% (42)
 - Typical rates and frequency of application: 1.0-2.0 pts/A. Do not make more than one application per season.
 - Method of application: For bare ground culture only, broadcast pre-emergence to the weeds prior to transplanting. For plastic culture, apply as a directed shielded spray between beds after plant establishment.
 - REI: 24 hours PHI: 90 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Good for rotation with the other herbicides to reduce chance of resistance.
9. trifluralin (Treflan 4 EC, Treflan HFP, Treflan 4L, Trifluralin HF Trifluralin 4EC, Trilin, etc.; Group K1/3)
- Percent acres treated: 7.0% (42)
 - Typical rates and frequency of application: 1.0-2.0 pts/A, 1 application.
 - Method of application: Broadcast and incorporate 2 to 3 inches within 8 hours prior to transplanting. Do not use under plastic mulch.
 - REI: 12 hours PHI: Not available
 - Efficacy: Good.
 - Use in IPM and resistance management: Avoid planting during periods of cold wet weather to reduce the risk of temporary stunting. Good for rotation with the other herbicides to reduce chance of resistance. Used in combination with metribuzin (Group C1/5) to improve broadleaf weed control.

Alternatives: There are several good chemical alternatives for fall panicum control. Paraquat (Group D/22) is labeled but is not typically used by New Jersey growers.

Cultural Control Practices: Cultivation between the rows up to approximately one month after transplanting will help reduce weed populations.

Biological Control: None available.

Post Harvest Control Practices: Incorporate plant residue immediately after harvesting to reduce weed seed production. Planting a cover crop will help keep weeds under control.

Large Crabgrass, *Digitaria sanguinalis*

Description and Damage: This summer annual grows mainly prostrate, but as the plant matures the stem may turn upward to 40 inches. Seeds germinate from mid spring through late summer. Seedlings are upright and the leaves taper to the tip. The leaves are rolled in the bud, lack auricles, but have a jagged membranous ligule. Stiff hairs are found on the blade and sheath at a 90° angle to the plant surface. The collar has long hairs at the margin. On mature plants, hairs are found on both blade surfaces and on the sheath. Plants tiller at the four or five leaf stage and elongate later in the summer. Older sheaths and leaves may turn dark red to maroon. The plant has fibrous roots and

may root from nodes after tiller elongation. The seed heads are at the top of the plant and consist of 3-5 spikes. The individual spikes have two rows of seedpods. Large crabgrass is killed by the first frost, but brown patches of plants can remain in uncultivated areas (11, 52, 53, 55). Large crabgrass is only a problem early in the season when tomatoes are planted on bare ground.

Chemical Controls:

1. clethodim (Select 2EC, Arrow 2EC, Select Max 0.97EC, Prism 0.94EC; Group A/1)
 - Percent acres treated: 6.8% (42)
 - Typical rates and frequency of application:
 - Select and Arrow: 6.0–8.0 oz/A, 1-2 applications.
 - Select Max: 9.0-16.0 oz/A, 1-2 applications.
 - Prism: 13.0-17.0 oz/A, 1-2 applications.Applications should be timed to when the weed is 2-6 inches tall.
 - Method of application: Broadcast post emergence to the weeds and tomatoes.
 - REI: 24 hours PHI: 20 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Must use an oil concentrate or nonionic surfactant for good control, however during periods of hot or humid weather crop injury may occur and control may be reduced. Should not be tank -mixed or applied within 2 to 3 days of any other pesticide unless labeled. The herbicide should be applied when the weed is actively growing and before tillers are present.

2. DCPA (Dacthal 6F, Dacthal W-75; Group K1/3)
 - Percent acres treated: 0.1% (42)
 - Typical rates and frequency of application: 6.0-14.0 lbs/A, 4-6 weeks after transplanting; 1 application.
 - Method of application: Broadcast over plants that are grown without plastic mulch, or directed spray between rows with plastic mulch as a pre-emergent control.
 - REI: 12 hours PHI: Not available
 - Efficacy: Good.
 - Use in IPM and resistance management: Good for rotation with the other herbicides to reduce chance of resistance.

3. glyphosate (Roundup Ultra Max II, Glyphomax Plus, Touchdown, etc.; Group G/9)
 - Percent acres treated: 0.5% (42)
 - Typical rates and frequency of application:
 - Roundup Max II: 11 - 22 fl oz/A, 1 application.
 - Glyphomax Plus, Touchdown: 16 - 32 fl oz/A, 1 application.Do not apply more than 8.0 qts/A per year.
 - Method of application: Broadcast at least 3 days prior to transplanting when weeds are 3 - 12 (Glyphomax and Roundup) and 6 - 18 (Touchdown) inches tall.
 - REI: 4 or 12 hours PHI: 14 days

- Typical rates and frequency of application: 1-2 oz/A early post emergence. Do not exceed 4 oz per acre per year. Up to a 12 month plant-back interval applies depending on the rotational crop.
 - Method of application: Broadcast over the field when weeds are less than one inch but have two fully expanded true leaves.
 - REI: 4 hours PHI: Not available
 - Efficacy: Fair to good.
 - Use in IPM and resistance management: More than one additional application may be necessary to control multiple flushes of weeds. Weeds can become resistant to this herbicide if used with herbicides with the same mode of action (Group B/2). Use mechanical control and/or chemical control with materials from other herbicide classes.
7. sethoxydim (Poast 1.5EC, Poast Plus 1.0EC; Group A/1)
- Percent acres treated: 10.6% (42)
 - Typical rates and frequency of application:
 - Poast: 1.0 fl oz/A, 1-2 applications.
 - Poast Plus: 1.5 fl oz/A, 1-2 applications.
 Do not apply more than 4.5 pts/A per season.
 - Method of application: Broadcast for weeds up to 6 inches tall.
 - REI: 12 hours PHI: 20 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Must use an oil concentrate or nonionic surfactant for good control, however during periods of hot or humid weather crop injury may occur and control may be reduced. The herbicide should be applied when the weed is actively growing and before tillers are present.
8. S-metolachlor (Dual Magnum 7.62E, Group K3/15)
- Percent acres treated: 16.2% (42)
 - Typical rates and frequency of application: 1.0-2.0 pts/A. Do not make more than one application per season.
 - Method of application: For bare ground culture only, broadcast pre-emergence to the weeds prior to transplanting. For plastic culture, apply as a directed shielded spray between beds after plant establishment.
 - REI: 24 hours PHI: 90 days
 - Efficacy: Fair to good.
 - Use in IPM and resistance management: Good for rotation with the other herbicides to reduce chance of resistance.
9. trifluralin (Treflan 4 EC, Treflan HFP, Treflan 4L, Trifluralin HF Trifluralin 4EC, Trilin, etc.; Group K1/3)
- Percent acres treated: 7.0% (42)
 - Typical rates and frequency of application: 1.0-2.0 pts/A, 1 application.
 - Method of application: Broadcast and incorporate 2 to 3 inches within 8 hours prior to transplanting. Do not use under plastic mulch.

- REI: 12 hours PHI: Not available
- Efficacy: Good.
- Use in IPM and resistance management: Avoid planting during periods of cold wet weather to reduce the risk of temporary stunting. Good for rotation with the other herbicides to reduce chance of resistance. Used in combination with metribuzin (Group C1/5) to improve broadleaf weed control.

Alternatives: There are good pre and post emergent weed control options for large crabgrass. Paraquat (Group D/22) is labeled but is not typically used by New Jersey growers.

Cultural Control Practices: Cultivation between the rows up to approximately one month after transplanting will help reduce weed populations.

Biological Control: None available.

Post Harvest Control Practices: Incorporate plant residue immediately after harvesting to reduce weed seed production. Planting a cover crop will help keep weeds under control.

Goosegrass, *Eleusine indica*

Description and Damage: The plant grows prostrate forming a rosette, but as it matures the stems may turn upward to approximately 24 inches. The leaf sheaths are flattened and have a whitish to silver color in the center. Seeds germinate from early to midsummer when soil temperatures are above 65 °F. Leaves grow parallel to the ground, lack auricles, and have a short, membranous, unevenly toothed ligule that is gapped in the center. The blades are smooth and distinctly formed at the midrib. The collar is broad and hairless. Mature plants are similar to the seedlings except there may be some hairs on the blades toward the ligule on the sheath and on the collar edge. The roots are fibrous and do not root at the nodes. Goosegrass flowers in June through September and seed heads mature from late summer through early autumn. The seed heads are at the top of the plant and consist of 2 to 6 spikes. The individual spikes have two rows of seedpods. The plants die with the first hard freeze (11, 52, 53, 55). Goosegrass can compete with tomatoes early in the season, especially in fields without plastic mulch. Within row, competition is more of a concern if soil is not thrown around the plants during cultivation.

Chemical Controls:

1. clethodim (Select 2EC, Arrow 2EC, Select Max 0.97EC, Prism 0.94EC; Group A/1)
 - Percent acres treated: 6.8% (42)
 - Typical rates and frequency of application:
 - Select and Arrow: 6.0-8.0 oz/A, 1-2 applications.
 - Select Max: 9.0-16.0 oz/A, 1-2 applications.
 - Prism: 13.0-17.0 oz/A, 1-2 applications.
- Applications should be timed to when the weed is 2-6 inches tall.

- Method of application: Broadcast post emergence to the weeds and tomatoes.
 - REI: 24 hours PHI: 20 days
 - Efficacy: Poor.
 - Use in IPM and resistance management: Must use an oil concentrate or nonionic surfactant for good control, however during periods of hot or humid weather crop injury may occur and control may be reduced. Should not be tank- mixed or applied within 2 to 3 days of any other pesticide unless labeled. The herbicide should be applied when the weed is actively growing and before tillers are present.
2. DCPA (Dacthal 6F, Dacthal W-75; Group K1/3)
- Percent acres treated: 0.1% (42)
 - Typical rates and frequency of application: 6.0-14.0 lbs/A, 4-6 weeks after transplanting; 1 application.
 - Method of application: Broadcast over plants that are grown without plastic mulch, or directed spray between rows with plastic mulch as a pre-emergent control.
 - REI: 12 hours PHI: Not available
 - Efficacy: Fair to good.
 - Use in IPM and resistance management: Good for rotation with the other herbicides to reduce chance of resistance.
3. glyphosate (Roundup Ultra Max II, Glyphomax Plus, Touchdown, etc.; Group G/9)
- Percent acres treated: 0.5% (42)
 - Typical rates and frequency of application:
 - Roundup Max II: 16 - 32 fl oz/A, 1 application.
 - Glyphomax Plus: 24 - 48 fl oz/A, 1 application.
 - Touchdown: 16 - 48 fl oz/A, 1 application.
 Do not apply more than 8.0 qts/A per year.
 - Method of application: Broadcast at least 3 days prior to transplanting when weeds are 3 - 12 (Glyphomax and Roundup) and 3 - 18 (Touchdown) inches tall.
 - REI: 4 or 12 hours PHI: 14 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Glyphosate provides good weed control before transplanting. Not for use between plastic after transplanting.
4. metribuzin (Sencor 4, Sencor DF; Group C1/5)
- Percent acres treated: 46.1% (42)
 - Typical rates and frequency of application:
 - Sencor 4: 0.5-2 pt/A, 2-3 applications pre-plant incorporated and post emergence. Do not apply more than 2 pts per acre per season.
 - Sencor DF: 1/3-2/3 lbs/A, 2-3 applications pre-plant incorporated and post emergence. Do not apply more than 1 1/3 lbs per acre per season.
 - Method of application: For plastic culture, band immediately prior to laying plastic. Use as a directed shielded spray between beds after transplanting. For

bare ground culture, incorporate before transplanting. After transplanting, delay additional applications until plants recover from transplant shock (at least two weeks). Do not apply within 24 hours of other pesticides or when there are three days of cool, wet, or cloudy weather.

- REI: 12 hours PHI: 7 days
- Efficacy: Poor to fair.
- Use in IPM and resistance management: Used in combination with other herbicides for broad spectrum control.

5. napropamide (Devrinol 50-DF, Devrinol 2-EC; Group K3/15)

- Percent acres treated: 9.0% (42)
- Typical rates and frequency of application:
 - Devrinol 50-DF: 2.0-4.0 lbs/A, 1-2 applications. Do not apply more than 4.0 lbs/A per crop cycle.
 - Devrinol 2-EC: 2.0-4.0 qts/A, 1-2 applications. Do not apply more than 4.0 qts/A per crop cycle.
- Up to a 12-month plant-back restriction applies depending on the rotational crop.
- Method of application: For plastic culture, apply banded under the plastic or banded directed shielded spray between the plastic and incorporated with irrigation. For bare ground culture, broadcast and incorporate 1-2 inches before transplanting.
- REI: 12 hours PHI: Not available
- Efficacy: Fair to good.
- Use in IPM and resistance management: Best chemical to use during periods of wet weather. Good for rotation with the other herbicides to reduce chance of resistance. Generally used in combination with metribuzin (Group C1/5) to improve broadleaf weed control.

6. sethoxydim (Poast 1.5EC, Poast Plus 1.0EC; Group A/1)

- Percent acres treated: 10.6% (42)
- Typical rates and frequency of application:
 - Poast: 1.0 fl oz/A, 1-2 applications.
 - Poast Plus: 1.5 fl oz/A, 1-2 applications.
- Do not apply more than 4.5 pts/A per season.
- Method of application: Broadcast for weeds up to 6 inches tall.
- REI: 12 hours PHI: 20 days
- Efficacy: Poor.
- Use in IPM and resistance management: Must use an oil concentrate or nonionic surfactant for good control, however during periods of hot or humid weather crop injury may occur and control may be reduced. The herbicide should be applied when the weed is actively growing and before tillers are present.

7. S-metolachlor (Dual Magnum 7.62E, Group K3/15)

- Percent acres treated: 16.2% (42)

- Typical rates and frequency of application: 1.0-2.0 pts/A. Do not make more than one application per season.
 - Method of application: For bare ground culture only, broadcast pre-emergence to the weeds prior to transplanting. For plastic culture, apply as a directed shielded spray between beds after plant establishment.
 - REI: 24 hours PHI: 90 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Good for rotation with the other herbicides.
8. trifluralin (Treflan 4 EC, Treflan HFP, Treflan 4L, Trifluralin HF Trifluralin 4EC, Trilin, etc.; Group K1/3)
- Percent acres treated: 7.0% (42)
 - Typical rates and frequency of application: 1.0-2.0 pts/A, 1 application.
 - Method of application: Broadcast and incorporate 2 to 3 inches within 8 hours prior to transplanting. Do not use under plastic mulch.
 - REI: 12 hours PHI: Not available
 - Efficacy: Good.
 - Use in IPM and resistance management: Avoid planting during periods of cold wet weather to reduce the risk of temporary stunting. Good for rotation with the other herbicides to reduce chance of resistance. Used in combination with metribuzin (Group C1/5) to improve broadleaf weed control.

Alternatives: There are good pre and post emergence weed control options for goosegrass. Paraquat (Group D/22) is labeled but is not typically used by New Jersey growers.

Cultural Control Practices: Cultivation between the rows up to approximately one month after transplanting will help reduce weed populations.

Biological Control: None available.

Post Harvest Control Practices: Incorporate plant residue immediately after harvesting to reduce weed seed production. Planting a cover crop will help keep weeds under control.

Perennial Weeds

Yellow Nutsedge, *Cyperus esculentus*

Description and Damage: Yellow nutsedge has triangular stems, yellowish green foliage, and has a grass appearance before maturity. Tubers, the main form of reproduction, sprout from May until mid-July. Rhizomes spread from the plants that emerge producing new plants until the day length reaches a critical length (late June). The plants produce 0.4 to 0.8 inch tubers and most are located in the top 6 inches of soil. They require a cold period to break dormancy, but remain viable for at least 10

years. Nutsedge leaves are shiny, flat or ridged and formed in groups of three, which give it the triangular shape. Flowers are inconspicuous and are organized on yellow to brown spikelets. These are located on stems and visible from July to September. After the first killing frost foliage and rhizomes die, but the tubers survive in the soil (11, 52, 53, 55). Yellow nutsedge has the potential to reduce yields in tomatoes under any management system. The stems will even push through plastic mulch as the plants emerge from the soil. Nutsedge does not tolerate shading once the plant is established. It is mainly a problem shortly after transplanting through mid season.

Chemical Controls:

1. glyphosate (Roundup Ultra Max II, Glyphomax Plus, Touchdown, etc.; Group G/9)
 - Percent acres treated: 0.5% (42)
 - Typical rates and frequency of application:
 - Roundup Max II: 64 fl oz/A, first application; 22-44 fl oz/A subsequent applications.
 - Glyphomax Plus, Touchdown: 96 fl oz/A first application; 32-64 fl oz subsequent applications.
 - Do not apply more than 8.0 qts/A per year.
 - Method of application: Treat when plants are in flower or when new nutlets can be found at rhizome tips. Make additional applications when the plants have 3-5 leaves and less than 6 inches tall.
 - REI: 4 or 12 hours PHI: 14 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Use of glyphosate prior to planting generally is not practical since the soil is tilled and the nutsedge does not emerge until after bedding. Not for use between plastic beds after transplanting.

2. halosulfuron-methyl (Sanda, Group B/2)
 - Percent acres treated: 1.0% (42)
 - Typical rates and frequency of application: 0.5-1.0 oz/A, 1-4 applications depending on rate. Do not exceed 2 oz/A per year. Do not apply more than 1 oz under plastic. Up to a 36 month plant-back interval applies depending on the rotational crop.
 - Method of application: For plastic culture only, apply prior to plastic laying or as a banded directed shielded spray between rows. Has both pre-emergent and post emergent activity.
 - REI: 12 hours PHI: 30 days
 - Efficacy: Suppresses nutsedge as a pre-emergent treatment; good as a post emergent application.
 - Use in IPM and resistance management: More than one additional application may be necessary to control multiple flushes of weeds. Weeds can become resistant to this herbicide if used with herbicides with the same mode of action (Group B/2). Use mechanical control and/or chemical control with materials from other herbicide classes.

3. metribuzin (Sencor 4, Sencor DF; Group C1/5)

- Percent acres treated: 46.1% (42)
 - Typical rates and frequency of application:
 - Sencor 4: 0.5-2 pt/A, 2-3 applications pre-plant incorporated and post emergence. Do not apply more than 2 pts per acre per season.
 - Sencor DF: 1/3-2/3 lbs/A, 2-3 applications pre-plant incorporated and post emergence. Do not apply more than 1 1/3 lbs per acre per season.
 - Method of application: For plastic culture, band immediately prior to laying plastic. Use as a directed shielded spray between beds after transplanting. For bare ground culture, incorporate before transplanting. After transplanting, delay additional applications until plants recover from transplant shock (at least two weeks). Do not apply within 24 hours of other pesticides or when there are three days of cool, wet, or cloudy weather.
 - REI: 12 hours PHI: 7 days
 - Efficacy: Poor to fair to good as rate increases from 1 to 2 to 3 or 4 post-emergence applications.
 - Use in IPM and resistance management: Used in combination with other herbicides for broad spectrum control.
4. rimsulfuron (Matrix, Group B/2)
- Percent acres treated: 13.3% (42)
 - Typical rates and frequency of application: 1-2 oz/A early post emergence. Do not exceed 4 oz per acre per year. Up to a 12 month plant-back interval applies depending on the rotational crop.
 - Method of application: Broadcast over the field when weeds are less than one inch but have two fully expanded true leaves.
 - REI: 4 hours PHI: Not available
 - Efficacy: Suppression.
 - Use in IPM and resistance management: More than one additional application may be necessary to control multiple flushes of weeds. Weeds can become resistant to this herbicide if used with herbicides with the same mode of action (Group B/2). Use mechanical control and/or chemical control with materials from other herbicide classes.
5. S-metolachlor (Dual Magnum 7.62E, Group K3/15)
- Percent acres treated: 16.2% (42)
 - Typical rates and frequency of application: 1.0-2.0 pts/A. Do not make more than one application per season.
 - Method of application: For bare ground culture only, broadcast pre-emergence to the weeds prior to transplanting. For plastic culture, apply as a directed shielded spray between beds after plant establishment.
 - REI: 24 hours PHI: 90 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Good for rotation with the other herbicides

Alternatives: There are few effective materials for controlling nutsedge. This is an area where additional options are needed. Paraquat (Group D/22) is labeled but is not typically used by New Jersey growers.

Cultural Control Practices: The use of green plastic mulch will help control the emerging plants. The mulch allows some light through which permits the plants to emerge, but not develop completely.

Biological Control: None available.

Post Harvest Control Practices: Post harvest applications of glyphosate in August will reduce tuber survival.

Disease Control

Cultural controls such as field and greenhouse sanitation, the use of disease-free seed and transplants, and proper crop rotation are critical for the prevention and control of important tomato diseases. For some of the more common tomato diseases in New Jersey, such as bacterial spot and speck, early blight, late blight, septoria leaf spot, buckeye fruit and root rot (*Phytophthora*), and anthracnose fruit rot control, fungicides are applied preventatively. For other important tomato diseases, which include damping-off, gray mold (*Botrytis*), leaf mold, powdery mildew, and timber rot, fungicides are applied preventatively or as needed based on weather forecasts and conditions. There are no good chemical control options available for diseases such as bacterial soft rot, bacterial wilt, fusarium and verticillium wilt, pythium fruit rot, southern blight and tomato spotted wilt virus. Genetic resistance is available in some cultivars for diseases such as fusarium wilt. These diseases occur occasionally and are typically managed with cultural control methods. Weather-based forecasting systems for early blight, septoria leaf spot and anthracnose fruit rot (Tom-Cast) and late blight (Blitecast) control are utilized more by processing tomato growers than fresh market growers to improve the timing of fungicide applications.

Fungicide Resistance Management Guidelines Fungicides are organized into groups (i.e. Fungicide Resistance Action Committee, FRAC codes) based on their modes-of-action (14). Fungicides within a given FRAC code are often analogs built from the same basic chemical structure, and generally have similar mode-of-action, control similar type of fungi, and share the same risk for fungicide resistance development. The overuse of some fungicides such as the QoI's (FRAC code 11), DMI's (FRAC code 3), phenylamides (FRAC code 4), and benzimidazoles (FRAC code 1) may result in the development of resistant populations of fungi and bacteria. Fungicides in FRAC codes such as these are referred to as high-risk fungicides and should not be used exclusively in any disease control program. Fungicides with a high risk for resistance development should be tank-mixed or rotated with fungicides from other FRAC codes. Protectant fungicides (FRAC group M1, M3, M5) should be tank-mixed with high-risk fungicides whenever possible to delay the development of resistant strains of fungi. Do not use high-risk fungicides as rescue treatments for disease control.

In the following section fungicides listed for the control of specific diseases are listed according to active ingredient followed by trade name and FRAC code in parenthesis. Where appropriate, guidelines for specific use according to resistance management guidelines are included. Always follow and apply fungicides according to label rates and recommendations.

Anthracnose fruit rot, *Colletotrichum coccodes*, other spp.

Description and Damage: Anthracnose fruit rot is a common disease of ripe tomato fruit caused by a species of the fungus (*C. coccodes*) which overwinters on old debris and residue from diseased plants, and in or on infested-seed. Fungal spores are splashed onto the lower leaves of plants and on green fruit. Symptoms do not develop until fruit reach maturity. In some cases, infections are more prevalent on lower fruit clusters touching the soil surface. Infected fruit develop small, water-soaked, sunken circular lesions that enlarge and develop a darkened area in the center of the lesion. Masses of black microsclerotia may develop in the center of lesions and serve as overwintering structures. As infected fruit rot, secondary organisms such as bacterial soft rot may infect fruit.

Infection and spread of the disease is moisture dependent. Long periods of leaf wetness, high relative humidity, and/or rain favor anthracnose development. Germination of spores can occur over a wide range of temperatures, but the optimal temperature range is 68-75°F. During the production season diseased fruit, foliage, and stems are sources of secondary inoculum that are spread via splashing rain and overhead irrigation.

In New Jersey, 100% of the acreage is at risk, with about 10% being affected each year. Severe losses to fruit yield and quality may occur when environmental conditions are favorable and the disease is left untreated. Yield losses can exceed 50% in severely infested fields, although typical losses run from 1-10% when fungicides are used appropriately. The disease is particularly a concern for processing tomato growers as processors impose a strict limit to the amount of anthracnose in raw product.

Monitoring and Thresholds: The Tom-Cast disease forecasting system and thresholds for timing preventative fungicide applications for early blight control are effective for anthracnose fruit rot control.

Chemical Controls: Fungicides should be applied preventatively when fruit begin to size. For resistance management rotate chlorothalonil (FRAC code M5) or mancozeb (FRAC code M3) with azoxystrobin, trifloxystrobin, pyraclostrobin (FRAC code 11), or famoxadone + cymoxanil (FRAC code 11 + 27).

1. azoxystrobin (Quadris; FRAC code 11)
 - Percent acres treated: 45.4% (42)
 - Typical rates and frequency of application: 5.0-6.2 fl oz 2.08F/A, 4-5 applications
Do not apply near apples. Do not apply more than 36 oz per acre per season of azoxystrobin containing products.

- Method of application: Foliar application with ground or aerial equipment.
 - REI: 4 hours PHI: 0 days
 - Efficacy: Very good.
 - Use in IPM and resistance management: Rotate azoxystrobin with chlorothalonil or mancozeb every 7-10 days or according to Tom-Cast for resistance management. Do not make more than one application of azoxystrobin before rotating to a fungicide with a different mode of action. Do not tank mix with other FRAC code 11 fungicides.
2. chlorothalonil (Bravo, Bravo Ultrex, Bravo 720, Ultrex, Echo, Equus, etc.; FRAC code M5)
- Percent acres treated: 95% (42)
 - Typical rates and frequency of application: 2-3 pt 6F/A or OLF, 4-5 applications. Do not apply more than 20 pts per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 0 days
 - Efficacy: Very good.
 - Use in IPM and resistance management: Rotate with a FRAC code 11 fungicide on a 7-10 day spray schedule or as scheduled by Tom-Cast.
3. famoxadone + cymoxanil (Tanos, FRAC code 11 + 27)
- Percent acres treated: Newer material; data not available.
 - Typical rates and frequency of application: 8 oz 50W/A, 2-3 applications. Do not apply more than 72 oz per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 3 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Rotate with chlorothalonil or mancozeb every 7-10 days or according to Tom-Cast for resistance management. Do not make more than one application before rotating to a fungicide with a different mode of action. Do not tank mix with other FRAC code 11 fungicides.
4. mancozeb (Dithane, Manex II, Manzate, Penncozeb; FRAC code M3)
- Percent acres treated: 42% (42)
 - Typical rates and frequency of application: 3.0 lb 75DF/A or OLF, approx. 4-5 applications. Do not apply more than 25.6 lbs per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12, 24 hours PHI: 5 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Rotate with a FRAC code 11 fungicide on a 7-10 day spray schedule or as scheduled by Tom-Cast.
5. pyraclostrobin (Cabrio, FRAC code 11)
- Percent acres treated: Newer material; data not available.
 - Typical rates and frequency of application: 8.0-12.0 oz 20EG/A, 4-5 applications.

- Method of application: Foliar application with ground or aerial equipment.
- REI: 12 hours PHI: 0 days
- Efficacy: Very good.
- Use in IPM and resistance management: Rotate with chlorothalonil or mancozeb every 7-10 days or according to Tom-Cast for resistance management. Do not make more than one application before rotating to a fungicide with a different mode of action. Do not tank mix with other FRAC code 11 fungicides.

Alternatives: Other materials labeled for anthracnose include fixed copper (FRAC code M1), mancozeb + copper (Cuprofix MZ, ManKocide; FRAC codes M1 + M3), mefenoxam + chlorothalonil (Ridomil Gold/Bravo, FRAC codes 4 + M5), maneb and ziram (FRAC code M3), oxidate (not classified), azoxystrobin + chlorothalonil (Quadris Opti, FRAC code 11 + M5), and potassium bicarbonate (not classified).

Cultural Control Practices: Plant disease-free transplants or use seed that has been hot water treated. A minimum of 3-4 year rotation from solanaceous crops is recommended. Practices to improve air movement and reduce the time of leaf wetness (staking plants and using mulch and drip irrigation) will help reduce disease severity. Control weeds throughout the production season. Thoroughly incorporate plant refuse after harvest to promote decomposition.

Biological Controls: None.

Post Harvest Control Practices: None.

Bacterial Canker, *Clavibacter michiganensis* subsp. *michiganensis* (Smith)

Description and Damage: Bacterial canker is a serious disease of tomatoes worldwide and in recent years has become a major problem of tomato production in New Jersey. There is wide variability in symptom expression, which makes bacterial canker difficult to detect. The bacteria colonize the surface of plant and fruit tissue (causing foliar and fruit damage) as well as invade the vascular tissue of the plant (causing systemic injury). Foliar symptoms appear as dark, necrotic lesions at the margins of older leaves, and also as small slightly raised white spots on the leaves, stems, and petioles. White spots with raised centers (also called 'birds-eye' spots) may become visible on infected fruit, making them unmarketable. Systemic infections cause stunting, wilting, vascular discoloration, open stem cankers, and fruit lesions. Infections may occur anytime during plant development, but are more serious in transplant production. Infected transplants rarely survive the season in the field.

Sources of bacterial canker include infested seed, volunteer plants, solanaceous weeds like horsenettle and nightshade, infested tomato stakes, and dead plant material from infected fields. During transplant production infested seed can result in widespread infections due to greenhouse growing conditions and the close proximity of transplants. Seedlings may also be at risk from infested weeds and unsanitized greenhouses and greenhouse equipment (trays, benches, etc.). In the field, infections can originate from

old plant debris, volunteer plants, weeds, and infested tomato stakes. Spread of the bacterial canker occurs through splashing water from wind driven rains or irrigation, contaminated equipment, worker hands, and through pruning and tying of staked plants during wet conditions.

Although occurrence is sporadic each year, the severity of the disease is such that proper management is required. Losses range from minimal foliar injury to total crop loss from fruit infections. Epidemics are usually localized and the extent of damage depends on the source of the infection, weather conditions, and cultural practices. In New Jersey all fresh-market tomato acreage is at risk of infection, although the disease is more commonly found in the northern counties due to more favorable environmental conditions. Yield losses from this disease can be 100% in severely infected fields, although typical yields losses range from 5-40% each year.

Monitoring and Thresholds: Scout fields full season for the presence of disease and treat when disease occurs.

Chemical Controls: The fungicide program for bacterial spot and speck may also help slow canker disease progression. Although not listed in the New Jersey Commercial Vegetable Production Recommendations, famoxadone + cymoxanil (Tanos, FRAC cod 11 + 27) in a tank mix with copper is listed on the label as providing disease suppression.

1. famoxadone + cymoxanil (Tanos, FRAC code 11 + 27)
 - Percent acres treated: Newer material; data not available.
 - Typical rates and frequency of application: 8 to 10 oz 50WG/A in a tank mix with a contact fungicide (mancozeb or copper), 1-2 applications.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 3 days
 - Efficacy: Provides suppression of bacterial diseases; tank mix with fixed copper. Not listed in the New Jersey Commercial Vegetable Recommendations manual for this disease.
 - Use in IPM and resistance management: Do not make more than one application before rotating with a fungicide of a different mode of action. Do not tank mix with other FRAC code 11 fungicides.

Alternatives: There are no effective materials for controlling this disease. Addition of acibenzolar-S-methyl (FRAC code P1) and fixed copper (FRAC code M1) to sprays for bacterial diseases has been shown to reduce bacterial canker symptoms on fruit (16).

Cultural Control Practices: Cultural practices are critical for the prevention and proper management of bacterial canker. Do not save seed from previous crops, especially if canker has been a problem in the past. Use seed that is certified and/or heat treated, or plant only certified disease-free transplants. Treat all benches and greenhouse surface areas with a commercial sanitizer. Eliminate all weeds from within and around the greenhouse structure, as well as eliminate all solanaceous weeds in and around production areas. Maintain a 3-year minimum crop rotation. At the end of the season

incorporate all plant material completely into the soil to promote plant decomposition. Use new stakes or completely wash and sterilize old stakes before reusing them. Regularly sterilize all tying and pruning implements. Avoid working in the field when the foliage is wet. If the disease is suspected or confirmed in the greenhouse or high tunnel, do not use high pressure volume spray equipment.

Biological Controls: None.

Post Harvest Control Practices: None.

Bacterial Spot, *Xanthomonas campestris* pv. *vesicatoria* (Doidge) Dye

Description and Damage: Bacterial leaf spot is a seed-borne disease that infects all above ground parts of the plant and occurs where peppers and tomatoes are grown. The bacterium enters the plant through natural leaf openings and wounds. Leaf spots begin as small (less than 3 mm in diameter) greasy, water-soaked lesions that turn brown and become necrotic in the center. Spots will appear water-soaked during rainy periods or when dew is present. As infections progress, leaves turn yellow and drop off. Blossoms may also become infected, resulting in blossom or fruit abortion. Fruit lesions are distinct small (3-6 mm), dark raised spots with water-soaked margins on the green fruit that turn brown and become slightly raised scab-like spots. Yield loss occurs from defoliation and severe spotting or sunscald injury to the fruit.

Although infested seed is the most common source of the bacterium, the pathogen may also be introduced into a field through infected solanaceous weeds, crop debris, and stakes. High night temperatures (75-85°F) in combination with high moisture favor disease development. Wind-driven rain and overhead irrigation help spread the disease through the field, as well as individuals and machinery working in infected fields when leaf surfaces are wet.

Crop losses from bacterial leaf spot occur every year in New Jersey from defoliation, blossom abortion, and unmarketable fruit. All acres are at risk, although epidemics are usually localized and depend on weather conditions. In severely affected fields 80% yield loss can occur, although typically 5-10% yield loss occurs in fields managed for the disease. This disease is managed from transplant through harvest with cultural controls combined with a preventative fungicide program.

Monitoring and Thresholds: Begin a preventative spray schedule shortly after transplanting. Scout fields weekly for the presence of leaf spot symptoms and to determine effectiveness of control methods. Spray schedules may be extended when conditions are not favorable for disease development (long periods of dry weather).

Chemical Controls: Protection is needed during early flowering and fruit setting periods. Apply streptomycin before transplanting. After transplanting, apply a mixture of mancozeb plus copper before the occurrence of disease.

1. acibenzolar-S-methyl (Actigard, FRAC code P1)
 - Percent acres treated: 9.3% (42)
 - Typical rates and frequency of application: 0.33 oz 50WG/A, begin one week after transplanting and make 8 applications. Do not apply more than 6 oz per acre per season. In some areas, application rate is gradually increased from 0.22 to 0.75 oz/A during the production season (see label).
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 14 days
 - Efficacy: Good.
 - Use in IPM and resistance management: This product is a plant activator and should be used preventatively prior to disease development. Yield reductions can occur under certain conditions. Use this material either alone or with copper-containing materials if copper-resistant bacteria are suspected.

2. famoxadone + cymoxanil (Tanos, FRAC codes 11 + 27)
 - Percent acres treated: Newer material; data not available.
 - Typical rates and frequency of application: 8 oz 50WG/A in a tank mix with a contact fungicide (mancozeb or copper), 1-2 applications.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 3 days
 - Efficacy: Provides suppression of bacterial diseases; tank mix with fixed copper.
 - Use in IPM and resistance management: Do not make more than one application before rotating with a fungicide of a different mode of action. Do not tank mix with other FRAC code 11 fungicides.

3. fixed copper (i.e. Champ, Champion, Cuprofix Disperss, Kocide, Tenn-Cop; FRAC code M1)
 - Percent acres treated: 89% (42)
 - Typical rates and frequency of application: 2-4 lbs or OLF in a tank mix with mancozeb (see below), weekly from transplanting, 8-10 applications.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 24 hours PHI: 0 days
 - Efficacy: Good; tank mix with mancozeb.
 - Use in IPM and resistance management: Resistance to copper is known to exist in region. Use newer formulations of copper fungicides, tank mix with mancozeb to reduce chances for copper resistance development. Spray schedules may be extended when conditions are not favorable for disease development (long periods of dry weather).

4. hydrogen dioxide (OxiDate, not classified)
 - Percent acres treated: 26.3% (42)

- Typical rates and frequency of application: 0.33-1.0 gal per 100 gal water, 4-5 applications.
 - Method of application: Foliar application with ground equipment.
 - REI: 0 hours PHI: 4 hours or until plants are dry
 - Efficacy: Hydrogen dioxide acts as a surface disinfectant and has no residual activity. This material is not listed in the 2007 New Jersey Commercial Vegetable Production Recommendations manual for this pathogen.
 - Use in IPM and resistance management: This material is used as a contact disinfectant at the first appearance of leaf spot or on a 7-day spray schedule when conditions are favorable for disease development. Because of the lack of residual, this material should be rotated with a protectant fungicide. Under severe disease conditions and during periods of rainy weather, apply immediately after each rain event, shorten spray intervals, and use the high rate.
5. mancozeb (Dithane, Manex II, Manzate, Penncozeb; FRAC code M3)
- Percent acres treated: 42% (42)
 - Typical rates and frequency of application: 1.5 lb 75DF/A, weekly from transplanting, 8-10 applications. Do not apply more than 25.6 lbs per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12, 24 hours PHI: 5 days
 - Efficacy: Good; tank mix with fixed copper.
 - Use in IPM and resistance management: Use in combination with fixed copper fungicides. Treat preventatively starting shortly after transplanting and maintain a 7-10 day schedule. Spray schedules may be extended when conditions are not favorable for disease development (long periods of dry weather).
6. mancozeb + copper hydroxide (ManKocide, FRAC codes M3 + M1)
- Percent acres treated: 0.7% (42)
 - Typical rates and frequency of application: 2.5-5.0 lb 61WP/A, weekly from transplanting, 8-10 applications. Do not apply more than 112 lbs. per acre per crop.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 24 hours PHI: 5 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Treat preventatively starting shortly after transplanting or when disease first appears and maintain a 7-10 day schedule. Spray schedules may be extended when conditions are not favorable for disease development (long periods of dry weather). This product is formulated for control of copper-tolerant bacteria.
7. mancozeb + copper sulfate (Cuprofix MZ Disperss, FRAC codes M3 + M1)
- Percent acres treated: Newer material; data not available.
 - Typical rates and frequency of application: 1.75-7.25 lb 52.2DF/A, weekly from transplanting, 8-10 applications. Do not apply more than 55.2 lbs/A.

- Method of application: Foliar application with ground or aerial equipment.
- REI: 12, 24 hours PHI: 5 days
- Efficacy: Good.
- Use in IPM and resistance management: Treat preventatively starting shortly after transplanting and maintain a 7-10 day schedule. Spray schedules may be extended when conditions are not favorable for disease development (long periods of dry weather).

8. streptomycin (Agri-Mycin 17, Agri-Strep; FRAC code 25)

- Percent acres treated: 1.7% (42)
- Typical rates and frequency of application: 1 lb per 100 gallons, 6-8 applications; do not combine or mix with any other pesticide or fertilizer. Apply when the first true leaves appear and continue every 4 to 5 days until transplanting.
- Method of application: Greenhouse foliar application with ground equipment.
- REI: 12 hours PHI: Not applicable
- Efficacy: Good.
- Use in IPM and resistance management: Use only in greenhouse transplant production.

Alternatives: The materials zoxamide + mancozeb (FRAC codes 22 + M3) and *Bacillus subtilis* (not classified) are labeled for this disease.

Cultural Control Practices: Use disease-free seed or seed that has been hot water or bleach treated. Avoid southern transplants and purchase only certified disease-free transplants. Rotate fields with non-solanaceous crops for 2-3 years. Practice good weed control and greenhouse sanitation. Avoid placing cull piles near production fields. Use drip irrigation to prevent splashing water and to keep leaf surfaces dry.

Biological Controls: None.

Post Harvest Control Practices: None.

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

Description and Damage: Bacterial speck, caused by *Pseudomonas syringae*, is a seed-borne disease that overwinters on seed and infected plant residue in the soil. The bacterium enters the plant through natural leaf openings and wounds. Infection causes very small, round, dark-brown to black specks to appear on leaves, stems, and fruit. As the disease progresses, spots may coalesce, killing large areas of tissue. Blossoms may also become infected, resulting in blossom or fruit abortion. The lesions that occur on the fruit are dark specks that may appear slightly raised, flat, or sunken and are rarely more than 1 mm in size. Fruit lesions are often used to identify the disease.

Although infected seed is the most common source of bacterial speck, the disease may also be introduced into a field through infected solanaceous weeds or crop debris. High humidity and low temperatures (64-75°F) favor disease development. Wind-driven rain

and overhead irrigation helps spread the disease through the field, as well as individuals and machinery working in infected fields when leaf surfaces are wet.

Bacterial speck occurs every year in New Jersey, and crop losses can occur from defoliation, blossom abortion, and unmarketable fruit. All acres are at risk, although epidemics are usually localized and depend on weather conditions. In severely infected fields 80% yield loss can occur, although typically 5-10% yield loss occurs in fields managed for the disease. This disease must be managed from transplant through harvest with cultural controls combined with a preventative fungicide program.

Monitoring and Thresholds: Begin a preventative spray schedule shortly after transplanting. Scout fields weekly for the presence of symptoms and to determine effectiveness of control methods. Spray schedules may be extended when conditions are not favorable for disease development (long periods of dry weather).

Chemical Controls: Protection is most needed during early flowering and fruit setting periods. After transplanting, apply a mixture of mancozeb plus copper before the occurrence of disease.

1. acibenzolar-S-methyl (Actigard, FRAC code P1)
 - Percent acres treated: 9.3% (42)
 - Typical rates and frequency of application: 0.33 oz 50WG/A, begin one week after transplanting. May make up to 8 applications. Do not apply more than 6 oz per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 14 days
 - Efficacy: Good.
 - Use in IPM and resistance management: This product is a plant activator and should be used preventatively prior to disease development. May cause yield reductions under certain conditions. Use this material either alone or in conjunction with copper-containing materials if copper-resistant bacteria are suspected.

2. famoxadone + cymoxanil (Tanos, FRAC code 11 + 27)
 - Percent acres treated: Newer material; data not available.
 - Typical rates and frequency of application: 8 oz 50WG/A in a tank mix with a contact fungicide (mancozeb or copper), 72 oz/acre maximum, 1-2 applications.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 3 days
 - Efficacy: Provides suppression of bacterial diseases; tank mix with fixed copper.
 - Use in IPM and resistance management: Do not make more than one application before rotating with a fungicide of a different mode of action. Do not tank mix with other FRAC code 11 fungicides.

3. fixed copper (i.e. Champ, Champion, Cuprofix Disperss, Kocide, Tenn-Cop; FRAC code M1)
 - Percent acres treated: 89% (42)

- Typical rates and frequency of application: 2-4 lbs or OLF in a tank mix with mancozeb (see below), weekly from transplanting, 8-10 applications.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 24 hours PHI: 0 days
 - Efficacy: Good; tank-mix with mancozeb.
 - Use in IPM and resistance management: Resistance to copper is known in the region. Use newer formulations of copper fungicides and tank mix with mancozeb to reduce chances for copper resistance development. Spray schedules may be extended when conditions are not favorable for disease development (long periods of dry weather).
4. hydrogen dioxide (OxiDate, not classified)
- Percent acres treated: 26.3% (42)
 - Typical rates and frequency of application: 0.33-1.0 gal per 100 gal water, 4-5 applications.
 - Method of application: Foliar application with ground equipment.
 - REI: 0 hours PHI: 4 hours or until plants are dry
 - Efficacy: Hydrogen dioxide acts as a surface disinfectant and has no residual activity. This material is not listed in the 2007 New Jersey Commercial Vegetable Production Recommendations manual for this pathogen.
 - Use in IPM and resistance management: This material is used as a contact disinfectant at the first appearance of disease or on a 7-day spray schedule when conditions are favorable for disease development. Because of the lack of residual, this material should be rotated with a copper plus mancozeb treatment. Under severe disease conditions and during periods of rainy weather, apply immediately after each rain event, shorten spray intervals, and use the high rate.
5. mancozeb (Dithane, Manex II, Manzate, Penncozeb; FRAC code M3)
- Percent acres treated: 42% (42)
 - Typical rates and frequency of application: 1.5 lb 75DF/A, weekly from transplanting, 8-10 applications. Do not apply more than 25.6 lbs per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12, 24 hours PHI: 5 days
 - Efficacy: Good; tank mix with fixed copper.
 - Use in IPM and resistance management: Use in combination with fixed copper fungicides. Treat preventatively starting shortly after transplanting and maintain a 7-10 day schedule. Spray schedules may be extended when conditions are not favorable for disease development (long periods of dry weather).
6. mancozeb + copper sulfate (Cuprofix MZ Disperss, FRAC code M3 + M1)
- Percent acres treated: Newer material; data not available.
 - Typical rates and frequency of application: 1.75 – 7.25 lb 52.2DF/A, weekly from transplanting, 8-10 applications. Do not apply more than 55.2 lbs/A per year.
 - Method of application: Foliar application with ground or aerial equipment

- REI: 12, 24 hours PHI: 5 days
- Efficacy: Good.
- Use in IPM and resistance management: Treat preventatively starting shortly after transplanting and maintain a 7-10 day schedule. Spray schedules may be extended when conditions are not favorable for disease development (long periods of dry weather).

7. mancozeb + copper hydroxide (ManKocide, FRAC code M3 + M1)

- Percent acres treated: 0.7% (42)
- Typical rates and frequency of application: 2.5-5.0 lb 61WP/A, weekly from transplanting, 8-10 applications. Do not apply more than 112 lbs/A per crop.
- Method of application: Foliar application with ground or aerial equipment.
- REI: 24 hours PHI: 5 days
- Efficacy: Good.
- Use in IPM and resistance management: Treat preventatively starting shortly after transplanting or when disease first appears and maintain a 7-10 day schedule. Spray schedules may be extended when conditions are not favorable for disease development (long periods of dry weather). This product is formulated for control of copper tolerant bacteria.

Alternatives: The materials zoxamide + mancozeb (FRAC codes 22 + M3) and *Bacillus subtilis* (not classified) are labeled for this disease.

Cultural Control Practices: Use disease-free seed or seed that has been hot water or bleach treated. Avoid southern transplants and purchase only certified disease-free transplants. Rotate fields with non-solanaceous crops for 2-3 years. Practice good weed control and greenhouse sanitation. Avoid placing cull piles near production fields. Use drip irrigation to prevent splashing water and to keep leaf surfaces dry.

Biological Controls: None.

Post Harvest Control Practices: None.

Early Blight, *Alternaria solani*

Description and Damage: Early blight is a fungal disease that occurs wherever tomatoes are grown. The fungus overwinters on infected plant residue, and can also be introduced on seed and transplants. Although the disease can occur under a wide range of weather conditions, mild temperatures (75-85°F) and heavy dews and rainfall promote infections, especially on stressed plants with poor vigor and in soils with low fertility. The fungus infects all above ground plant parts (stems, leaves, fruit) and can cause severe damage if left untreated. On seedlings, dark spots develop on leaves and stems, killing the leaves and girdling the stems (also called collar rot). On older plants dark brown spotting with characteristic concentric rings begins on the oldest leaves. Infected leaves may prematurely drop off the plant, and the subsequent defoliation results in fruit being exposed to sunscald injury. On infected fruit, brown spots appear

on the stem end and develop into a black leathery sunken area with the concentric rings. Infected fruit typically drop off the plant.

In New Jersey early blight occurs every year, and all tomatoes are at risk for infection. In most years, 50% of the tomato acreage may become infected or at-risk, although yield losses are less than 5% in fields managed for this disease. If left uncontrolled, 50% yield loss can occur. This disease is managed from transplant through harvest with cultural controls combined with a preventative fungicide program.

Monitoring and Thresholds: Scout fields at least once a week and record severity of the disease. Rutgers Cooperative Extension provides Tom-Cast disease forecasting program to processing tomato growers in the southern counties for determining preventative spray schedule.

Chemical Controls: Follow a regular 7-day spray schedule starting when crown fruit are one-third their final size, or time sprays based on a locally verified forecaster such as Tom-Cast. For resistance management, rotate chlorothalonil (FRAC code M5), mancozeb (FRAC code M3), or mancozeb +zoxamide (FRAC code M3 + 22) with azoxystrobin, trifloxystrobin, or pyraclostrobin (FRAC code 11), boscalid (FRAC code 7), or famoxadone + cymoxanil (Tanos, FRAC code 11 + 27).

1. azoxystrobin (Quadris; FRAC code 11)

- Percent acres treated: 45.4% (42)
- Typical rates and frequency of application: 5.0-6.2 fl oz 2.08F/A, 4-5 applications. Do not apply near apples. Do not apply more than 36 oz per acre per season of azoxystrobin containing products.
- Method of application: Foliar application with ground or aerial equipment.
- REI: 4 hours PHI: 0 days
- Efficacy: Excellent.
- Use in IPM and resistance management: Rotate azoxystrobin with chlorothalonil, mancozeb, or zoxamide every 7-10 days or according to Tom-Cast for resistance management. Do not make more than one application before rotating with a fungicide of a different mode of action. Do not tank mix with other FRAC code 11 fungicides.

2. boscalid (Endura, FRAC code 7)

- Percent acres treated: Newer material; data not available.
- Typical rates and frequency of application: 2.5-3.5 oz 70W/A, 1-2 applications. Do not make more than 6 applications or apply 21 oz total per acre per season.
- Method of application: Foliar application with ground or aerial equipment.
- REI: 12 hours PHI: 0 days
- Efficacy: Very good.
- Use in IPM and resistance management: Do not make more than one application before rotating with a fungicide of a different mode of action (i.e. different FRAC code).

3. chlorothalonil (Bravo, Bravo Ultrex, Bravo 720, Ultrex, Echo, Equus, etc.; FRAC code M5)
 - Percent acres treated: 95% (42)
 - Typical rates and frequency of application: 2-3 pt 6F/A or OLF, 4-5 applications. Do not apply more than 20 pts per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 0 days
 - Efficacy: Fair.
 - Use in IPM and resistance management: Rotate with FRAC code 11 fungicides on a 7-10 day spray schedule or as scheduled by Tom-Cast.

4. famoxadone + cymoxanil (Tanos, FRAC code 11 + 27)
 - Percent acres treated: Newer material; data not available.
 - Typical rates and frequency of application: 8 oz 50WG/A, 2-3 applications.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 3 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Do not make more than one application before rotating with a fungicide of a different mode of action. Do not tank mix with other FRAC code 11 fungicides.

5. mancozeb (Dithane, Manex II, Manzate, Penncozeb; FRAC code M3)
 - Percent acres treated: 42% (42)
 - Typical rates and frequency of application: 3.0 lb 75DF/A or OLF, 4-5 applications. Do not apply more than 25.6 lbs per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12, 24 hours PHI: 5 days
 - Efficacy: Very good; tank mix with fixed copper.
 - Use in IPM and resistance management: Rotate with FRAC code 11 fungicides on a 7-10 day spray schedule or as scheduled by Tom-Cast.

6. pyraclostrobin (Cabrio, FRAC code 11)
 - Percent acres treated: Newer material; data not available.
 - Typical rates and frequency of application: 8.0-12.0 oz 20EG/A, 4-5 applications
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 0 days
 - Efficacy: Excellent.
 - Use in IPM and resistance management: Rotate with chlorothalonil or mancozeb every 7-10 days or according to Tom-Cast for resistance management. Do not make more than one application before rotating with a fungicide of a different mode of action. Do not tank mix with other FRAC code 11 fungicides.

7. zoxamide + mancozeb (Gavel, FRAC code 22 + M3)
 - Percent acres treated: 12.4% (42)

- Typical rates and frequency of application: 1.5-2.0 lb 75DF/A, 2-3 applications. Do not apply more than 72 oz per acre per season.
- Method of application: Foliar application with ground or aerial equipment.
- REI: 48 hours PHI: 5 days
- Efficacy: Good.
- Use in IPM and resistance management: Rotate with FRAC code 11 fungicides on a 7-10 day spray schedule or as scheduled by Tom-Cast.

Alternatives: Other materials labeled for early blight include fixed copper (FRAC code M1), mancozeb + copper sulfate (Cuprofix MZ, ManKocide; FRAC codes M1 + M3), mefenoxam + chlorothalonil (Ridomil Gold/Bravo, FRAC codes 4 + M5), maneb (FRAC code 3), azoxystrobin + chlorothalonil (Quadris Opti, FRAC code 11 + M5), *Bacillus subtilis* (Serenade, not classified), fenamidone (Reason, FRAC code 11), Oxidate (not classified), potassium bicarbonate (Armicarb, Kaligreen, Milstop; not classified), propamocarb hydrochloride (Previcur Flex, FRAC code 28), pyrimethanil (Scala SC, FRAC code 9), and ziram (FRAC code M3).

Cultural Control Practices: Use certified disease-free tomato seed and transplants. Practice good sanitation throughout the transplant production operation. Maintain a 3-4 year rotation from solanaceous crops, especially white potatoes. Rotate with small grains, corn, or legumes for best results. Eradicate weeds and volunteer tomato and white potato plants, and use tillage practices that bury all plant refuse. Maintain proper fertilization (nitrogen and phosphorus deficiencies can increase susceptibility) to keep the plants growing vigorously. Use drip irrigation or time overhead irrigation to allow plants to dry before nightfall. Provide distance and/or grassland breaks between plantings so that older plantings do not provide inoculum for the newer plantings.

Biological Controls: PlantShield HC (a *Trichoderma harzanium* biological product) used as a drench at planting, showed fair to good results on tomatoes over three seasons (4).

Post Harvest Control Practices: None.

Septoria Leaf Spot, *Septoria lycopersici* Speg.

Description and Damage: Septoria leaf spot is found in most states where tomatoes are grown, and especially in areas where wet, humid weather conditions persist. Fungal growth and development is favored by extended periods of high temperature (68-77°F), high humidity, and leaf wetness. Although Septoria leaf spot may occur during any stage of plant development, symptoms usually first appear on the lower leaves after the first fruit set. The disease spreads upward in the canopy from older growth. Lesions may also appear on the stems, petioles, and the calyx. Numerous small (about 2.6 mm) circular water-soaked lesions first appear on the undersides of the leaves. The spots enlarge to as much as 6.0 mm and have gray to tan centers bordered by dark brown margins. Black pinpoint size fruiting bodies (pycnidia) may develop in lesions. Numerous leaf lesions may coalesce and result in leaves turning yellow and then

brown. In severe cases rapid defoliation may occur. Sunscald may occur when severe leaf infections result in premature defoliation.

In New Jersey, septoria leaf spot occurs every year and all tomatoes are at risk for infection. Most years, 50% of the tomato acreage is affected although yield losses are less than 5% in fields managed for this disease. If left uncontrolled, 50% yield loss can occur. This disease is managed from transplant through harvest with cultural controls combined with a preventative fungicide program.

Monitoring and Thresholds: Record the occurrence and severity of infected plants from transplant through fruit maturation. The Tom-Cast disease forecasting system and thresholds for timing preventative fungicide applications for early blight is effective for Septoria leaf spot control.

Chemical Controls: Follow a regular 7-day spray schedule starting when crown fruit are one-third their final size, or time sprays based on a locally verified forecaster such as Tom-Cast. For resistance management, rotate chlorothalonil (FRAC code M5) or mancozeb (FRAC code M3) with azoxystrobin, trifloxystrobin, or pyraclostrobin (FRAC code 11), boscalid (FRAC code 7), or famoxadone + cymoxanil (Tanos, FRAC code 11 + 27).

1. azoxystrobin (Quadris; FRAC code 11)
 - Percent acres treated: 45.4% (42)
 - Typical rates and frequency of application: 5.0-6.2 fl oz 2.08F/A, 4-5 applications
Do not apply near apples. Do not apply more than 36 oz per acre per season of azoxystrobin containing products.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 4 hours PHI: 0 days
 - Efficacy: Very good.
 - Use in IPM and resistance management: Rotate azoxystrobin with chlorothalonil or mancozeb every 7-10 days or according to Tom-Cast for resistance management. Do not make more than one application before rotating with a fungicide of a different mode of action.
2. chlorothalonil (Bravo, Bravo Ultrex, Bravo 720, Ultrex, Echo, Equus; FRAC code M5)
 - Percent acres treated: 95% (42)
 - Typical rates and frequency of application: 2-3 pt 6F/A or OLF, 4-5 applications.
Do not apply more than 20 pts per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 0 days
 - Efficacy: Very good.
 - Use in IPM and resistance management: Rotate with a FRAC code 11 fungicide on a 7-10 day spray schedule or as scheduled by Tom-Cast.
3. famoxadone + cymoxanil (Tanos, FRAC code 11 + 27)
 - Percent acres treated: Newer material; data not available.
 - Typical rates and frequency of application: 8 oz 50WG/A, 2-3 applications.

- Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 3 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Do not make more than one application before alternating with a fungicide of a different mode of action. Do not tank mix with other FRAC code 11 fungicides.
4. mancozeb (Dithane, Manex II, Manzate, Penncozeb; FRAC code M3)
- Percent acres treated: 42% (42)
 - Typical rates and frequency of application: 3.0 lb 75DF/A or OLF, approx. 4-5 applications. Do not apply more than 25.6 lbs per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12, 24 hours PHI: 5 days
 - Efficacy: Good; tank mix with fixed copper.
 - Use in IPM and resistance management: Rotate with a FRAC code 11 fungicide on a 7-10 day spray schedule or as scheduled by Tom-Cast.
5. pyraclostrobin (Cabrio, FRAC code 11)
- Percent acres treated: Newer material; data not available.
 - Typical rates and frequency of application: 8.0-12.0 oz 20EG/A, 4-5 applications
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 0 days
 - Efficacy: Very good.
 - Use in IPM and resistance management: Rotate with chlorothalonil or mancozeb every 7-10 days or according to Tom-Cast for resistance management. Do not make more than one application before alternating with a fungicide of a different mode of action. Do not tank mix with other FRAC code 11 fungicides.
6. zoxamide + mancozeb (Gavel, FRAC codes 22 + M3)
- Percent acres treated: 12.4% (42)
 - Typical rates and frequency of application: 1.5-2.0 lb 75DF/A, 2-3 applications. Do not apply more than 72 oz per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 48 hours PHI: 5 days
 - Efficacy: Poor.
 - Use in IPM and resistance management: Rotate with a FRAC code 11 fungicide on a 7-10 day spray schedule or as scheduled by Tom-Cast.

Alternatives: Other materials labeled for septoria include fixed copper (FRAC code M1), mancozeb + copper (Cuprofix MZ , ManKocide; FRAC codes M1 + M3), mfenoxam + chlorothalonil (Ridomil Gold/Bravo, FRAC code 4 + M5), maneb (FRAC code M3), azoxystrobin + chlorothalonil (Quadris Opti, FRAC code 11 + M5), fenamidone (Reason, FRAC code 11), potassium bicarbonate (Armicarb, not classified), ziram (FRAC code M3), and trifloxystrobin (Flint, FRAC code 11).

Cultural Control Practices: Use certified seed. Practice good greenhouse sanitation in transplant production (remove weeds, disinfect greenhouse surfaces and trays, etc.). Rotate fields at least 1-2 years between tomato crops. Control susceptible weeds like horsenettle, jimsonweed, smooth groundcherry, and black nightshade. Thoroughly incorporate crop refuse immediately after harvest. Use drip irrigation instead of overhead irrigation to minimize leaf wetness. Stake plants with new or disinfected stakes to improve air circulation and reduce contact between foliage and soil. Keep workers and equipment out of fields with wet foliage.

Biological Controls: None.

Post Harvest Control Practices: None.

Buckeye Rot and Phytophthora Root Rot *Phytophthora parasitica* Dastur, *P. capsici*

Description and Damage: Buckeye fruit rot is a soil-borne fungal disease found in all parts of the world where high relative humidity, high soil moisture, and warm weather favor fruit infections. Symptoms first appear as a tan or brownish spot, where green fruit contacts the soil. As the spot becomes larger a series of light and dark brown concentric rings develop. The lesion may enlarge to cover more than half the fruit, and under moist conditions a white cottony fungal growth may appear on the lesion. The pathogen does not infect the foliage. Buckeye rot is most common during periods of prolonged warm, wet weather and is spread by surface water and splashing rains.

The symptoms of a root infection, caused by *P. parasitica* and *P. capsici*, include water soaked lesions on the stems which gradually dry and turn dark brown. Severely infected roots may be girdled by the lesions. Infected plants usually have much reduced vigor and eventually wilt and die, often in groups by row or in a circular pattern. Plants with root rot that do survive usually do not produce marketable fruit.

In New Jersey all fields are at risk from *Phytophthora* root and fruit rot each year, although typically less than 10% are affected each year. Yield losses are usually less than 5% and there are no regional differences. This disease is more prevalent in tomatoes grown on bare ground (all processing acres).

Monitoring and Thresholds: Examine plants in low areas. Look at fruit near the ground. Record the occurrence and severity of fruit and root rot. Collect affected fruit to confirm diagnosis and to make sure that it is not late blight.

Chemical Controls: Apply mefenoxam (FRAC code 4) as a soil application through the drip irrigation system, or if feasible broadcast or banded under the vines 4 to 8 weeks before harvest. Irrigate after application.

1. mefenoxam (Ridomil Gold, Ultra Flourish; FRAC code 4)
 - Percent acres treated: 20.6% (18.8% Ridomil Gold; 1.8% Ultra Flourish) (42)
 - Typical rates and frequency of application:

- Ridomil Gold: 1 pt 4E/A, 1 application OR
- Ultra Flourish: 1 qt 2E/A, 1 application
- Method of application: For plastic culture, inject the material through the drip irrigation system or if feasible apply broadcast or banded 4 to 8 weeks before harvest.
- REI: 48 hours PHI: 14 days
- Efficacy: Variable.
- Use in IPM and resistance management: Insensitivity to mefenoxam is known in New Jersey. In fields where resistance to mefenoxam is known use a fungicide with a different mode of action (i.e. FRAC code).

As an alternative to the soil application apply a foliar treatment when crown fruit are one-third their final size and repeat every 14 days up to a total of 3 times:

1. mefenoxam + chlorothalonil (Flouronil, Ridomil Gold Bravo; FRAC code 4 + M5)
 - Percent acres treated: 17.1% (42)
 - Typical rates and frequency of application: 2 lbs 76WP/A, 3 applications.
 - Method of application: Apply as a foliar spray by ground or aerial equipment when crown fruit are one-third their final size and repeat on a 14-day schedule.
 - REI: 48 hours PHI: 14 days
 - Efficacy: For suppression only.
 - Use in IPM and resistance management: This material is a preventative application if the soil application is not utilized.

2. mefenoxam + copper hydroxide (Ridomil Gold Copper, FRAC codes 4 + M1)
 - Percent acres treated: 1.2% (42)
 - Typical rates and frequency of application: 2 lbs 65WP/A, 3 applications.
 - Method of application: Foliar spray by ground or aerial equipment when crown fruit are one-third their final size and repeat on a 14-day schedule.
 - REI: 48 hours PHI: 14 days
 - Efficacy: For suppression only.
 - Use in IPM and resistance management: This material is a preventative application if the soil application is not utilized.

When conditions are favorable for disease apply one of the following between applications of the above fungicides:

1. famoxadone + cymoxanil (Tanos, FRAC codes 11 + 27)
 - Percent acres treated: Newer material; data not available.
 - Typical rates and frequency of application: 8 oz 50WG/A, 2 applications.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 3 days
 - Efficacy: For suppression only.
 - Use in IPM and resistance management: When conditions favor disease apply this material between applications of Ridomil Gold/Bravo (mefenoxam + chlorothalonil) or Ridomil Gold/Copper (mefenoxam + copper hydroxide).

2. zoxamide + mancozeb (Gavel, FRAC codes 22 + M3)
 - Percent acres treated: 12.4% (42)
 - Typical rates and frequency of application: 1.5-2.0 lb 75DF/A, 2-3 applications. Do not apply more than 72 oz per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 48 hours PHI: 5 days
 - Efficacy: For suppression only.
 - Use in IPM and resistance management: When conditions favor disease apply this material between applications of mefenoxam + chlorothalonil (Ridomil Gold/Bravo) or mefenoxam + copper hydroxide (Ridomil Gold/Copper).

Alternatives: There are few effective materials for this disease. Azoxystrobin (FRAC code 11) is labeled for buckeye rot and fosetyl-AI (FRAC code 33) is labeled for phytophthora root rot control.

Cultural Control Practices: Practice a minimum of a three year rotation away from tomatoes, eggplants, peppers, and cucurbits. Planting cereals as a rotational crop may help reduce infestation levels in the soil (51). Avoid poorly drained and compacted fields. Plant tomatoes on ridged or raised, dome-shaped beds. Low areas in fields are particularly prone to heavy losses from buckeye fruit rot and phytophthora root rot. Use mulch and stake plants to limit fruit contact with the soil. Avoid over watering fields.

Biological Controls: None.

Post Harvest Control Practices: None.

Damping-off, *Pythium* spp., *Rhizoctonia* spp.

Description and Damage: Common soil-borne fungal pathogens that cause damping-off include *Pythium* spp. and *Rhizoctonia* spp. Most losses from damping-off and root rot occur in greenhouse transplant production or soon after transplanting in the field. Symptoms depend on the time of infection. Damping-off can kill seedlings before they emerge from the soil line (pre-emergent damping-off) or kill seedlings soon after they emerge (post-emergent damping-off). A less severe root attack may result in stunted growth. The fungus may survive for long periods in the soil and may persist in plant debris or on roots of weeds. Conditions of high soil moisture, overcrowding, soil compaction, poor air circulation or ventilation, and cool, damp, cloudy weather promote damping off. Damping-off may spread from infected to healthy plants when infested soil is disseminated through soil splashing. The potential exists for damping off to occur every year in transplant production. The extent of the damage depends on greenhouse management, although typically less than 5% of the transplants are affected. Economic loss occurs from the reduced number of transplants available for planting and the cost of replanting in the field.

Monitoring and Thresholds: Growers monitor the transplants as they water the greenhouses. This disease is typically managed with cultural controls combined with preventative fungicide use.

Chemical Controls:

1. metam-sodium (Vapam), metam-potassium (K-PAM)
 - Percent acres treated: 0.3% (42)
 - Typical rates and frequency of application: 0.75 qt HL/100 square feet, one application.
 - Method of application: In the greenhouse, apply to the seed beds via sprinkler irrigation or soil injection prior to seeding.
 - REI: 48 hours PHI: Not applicable
 - Efficacy: Variable.
 - Use in IPM and resistance management: Soil fumigation would be used in the greenhouse if soilless planting mix is not used. Fumigation is recommended when producing bare root transplants or placing trays directly on the soil. Soil fumigation in the field for other diseases will provide damping off control.

Alternatives: There are few effective materials available for this disease. SoilGard may be an alternative for plants grown in soilless mix. Hydrogen dioxide (Oxidate, not classified), mono- & di-potassium salts of phosphorus acid (Fosphite, FRAC code 33), and propamocarb hydrochloride (Previcur Flex, FRAC code 28) are also labeled for damping off control in the greenhouse and field. Fosetyl AI (Aliette, FRAC code 33) is labeled for a field application.

Cultural Control Practices: Use treated high quality seed for growing transplants. Good sanitation (sterilized planting trays, proper soil pasteurization, and weed control in and around the greenhouse) will help reduce damping off incidence. Soilless planting mixes are recommended. Maintain low humidity and adequate but not excessive fertility and irrigation.

Biological Controls: Soilless mixes are available that contain microorganisms that suppress damping-off fungi. SoilGard (*Gliocladium virens*) is a commercially available naturally occurring soil fungus that is an antagonist to the fungi that cause damping-off. SoilGard 12G (1-1.5 lb/cu yd of soilless mix) is added during the blending of soilless mixes. One day of incubation is needed prior to seeding or transplanting. Other biological controls are commercially available for controlling *Rhizoctonia* and *Pythium* in the greenhouse, but their efficacy has not been well established. *Streptomyces*, a bacterium, is reported to provide suppression and *Gliocladium spp.* is a fungus sold as a substitute for conventional fungicides. These control agents should be applied preventatively and reapplied at appropriate intervals (1).

Post Harvest Control Practices: None.

Gray Mold, *Botrytis cinerea*

Description and Damage: Gray mold occurs wherever tomatoes are grown, in both field and greenhouse culture. It has a wide host range and can be present on perennial plants, in plant debris in the soil, or seed-borne on some crops. Free water, high relative humidity, and moderate temperatures (65-75°F) are necessary for spore production. Humid, cool conditions within the tomato canopy at night are sufficient for disease development. Spores are spread through splashing rain and winds. Gray mold can occur on all aboveground parts of the plant. The characteristic sign is a fuzzy, gray-brown felt-like appearance associated with necrotic tissue. Infection usually begins where leaves are in contact with infested soil or are wounded by handling or weather contingencies. Leaf lesions may expand to include the leaflet and petiole, and girdle the stem and kill the plant. Senescent flowers are also susceptible, and as a result the disease often occurs at the stem or blossom end of the fruit. Lesions on the fruit are typical of soft rot, with decaying areas turning white with skin rupturing in the center of the decayed area. Eventually the whole fruit becomes affected and mummifies. Botrytis also causes ghost spot on green tomato fruit causing whitish rings and spots 1/8-1/4 inch in diameter on the fruit surface. No fruit rot occurs, but the halos make the fruit unmarketable.

Occasionally the disease can be major cause of post-harvest rot of tomatoes in storage. In New Jersey, botrytis is a problem especially in greenhouse and high tunnel production, where conditions of high humidity and low air movement favor disease development. Although all acreage is at risk, typically less than 5% of field tomatoes and 25% of greenhouse/high tunnel production is affected by this disease. Yield losses are usually less than 5% if proper preventative measures are followed. This disease is not usually a problem for processing tomatoes.

Monitoring and Thresholds: While scouting for other diseases record the occurrence and severity of gray mold. The threshold is disease presence.

Chemical Controls: Begin fungicide applications when diseased fruit appears and repeat at seven to 14 day intervals for the rest of the season as needed. Most fungicides are protective and will not suppress an established infection.

1. boscalid (Endura, FRAC code 7)
 - Percent acres treated: Newer material; data not available.
 - Typical rates and frequency of application: 9.0-12.5 oz 70WG/A, 2 applications applied before harvest when conditions are wet and cool. Do not make more than 2 applications or apply 25 oz total per acre per season.
 - Method of application: Foliar greenhouse or field application with ground or aerial equipment.
 - REI: 12 hours PHI: 0 days
 - Efficacy: Provides suppression (see label).
 - Use in IPM and resistance management: Begin applications at the first sign of disease. Do not make more than one application before rotating with a fungicide of a different mode of action.

2. chlorothalonil (Bravo, Bravo Ultrex, Bravo 720, Ultrex, Echo, Equus; FRAC code M5)

- Percent acres treated: 95% (42)
- Typical rates and frequency of application: 2.0-2.75 pt 6F/A or OLF, 2 applications applied shortly before harvest when conditions are wet and cool. Do not apply more than 20 pts per acre per season.
- Method of application: Foliar application with ground or aerial equipment. Not for greenhouse use.
- REI: 12 hours PHI: 0 days
- Efficacy: Poor.
- Use in IPM and resistance management: Begin applications at the first sign of disease.

Alternatives: Dicloran (Botran, FRAC code 14), famoxodone + cymoxanil (Tanos, FRAC code 11 + 27), fenhexamid (Decree, FRAC code 17), hydrogen dioxide (Oxidate, not classified), potassium bicarbonate (Armicarb, Kaligreen, etc.; not classified), and pyrimethanil (Scala SC, FRAC code 9) are materials labeled for control of gray mold that can be used for botrytis control in greenhouses and high tunnels.

Cultural Control Practices: Provide adequate spacing and ventilation in the greenhouse and avoid high humidity and cool temperatures during transplant production. Inspect transplants before planting them into the field and rogue plants with symptoms. Select fields with good air circulation. Avoid unnecessary late irrigations and keep the tops of the beds dry when fruit is present to help reduce the chance of infection. Plastic mulch and staking plants improves disease prevention. Increasing the calcium-to-phosphorus ratio to 2 or higher in leaf petiole tissues reduces the susceptibility of tomato plants (27).

Biological Controls: *Bacillus subtilis* (Serenade, Rhapsody), *Bacillus pumilis* (Sonata), *Streptomyces griseoviridis* (Mycostop, Mycostop Mix), and *Trichoderma sp.* (Plantshield HC, SoilGard, RootShield) are also labeled for control gray mold in greenhouses and high tunnels.

Post Harvest Control Practices: During packing, maintain chlorine concentration at 75-150 ppm and pH 6.5-7.5. Avoid wash water temperature differences of more than 10°F from field temperatures. Disinfect packing lines at the end of each day. Maintain storage temperatures at 59-68°F. Disinfect picking containers.

Late Blight, *Phytophthora infestans*

Description and Damage: Late blight is a very serious and highly destructive disease of tomatoes and white potatoes. This disease has caused numerous epidemics on tomatoes and white potatoes, especially in areas where the weather stays consistently cool and wet. The late blight pathogen survives between cropping seasons in association with volunteer and abandoned white potato and tomato plant material in fields, cull piles, and gardens. Infected transplants and seed potatoes may also be a source of inoculum. Under favorable environmental conditions (leaf wetness for more than 10-12 hours at temperatures of 60-70°F) the pathogen rapidly spreads by water

and wind movement. The fungus attacks all above ground plant parts. The initial symptoms appear on the leaves as pale green to brown lesions, usually with a halo of lighter green tissue surrounding the lesion. Under dry conditions no sporulation occurs and the lesion has a brown dead center surrounded by tissue that has collapsed and appears either water soaked, gray-green, or chlorotic. When conditions are favorable a ring of white, moldy growth is present on the undersides of the lesions. Infected foliage dies and plants defoliate. In addition, fruit can become infected, causing dark green greasy lesions that eventually turn brown and enlarge to cover the entire fruit. Stem lesions occur and as they expand they girdle the plant. When conditions are favorable the fungus can spread rapidly and destroy large areas of the crop. As the plants decay, soft rot invades the tissue, causing a foul odor.

The potential for a late blight epidemic is present every year. New strains of the pathogen are resistant to FRAC code 4 fungicides (metalaxyl and mefenoxam) and are more virulent on tomatoes than older strains. Late blight infections can rapidly spread through a field, resulting in 100% crop loss when environmental conditions are favorable. In most years less than 5% of the fields become infected due to current control strategies. Tomatoes grown in the northern counties are more at risk to late blight infections due to the more favorable weather conditions.

Monitoring and Thresholds: Fields should be scouted weekly from transplant through maturity for the presence of disease. Suspected infections should be confirmed with a specialist or lab. Forecasting systems that are locally verified (Blitecast) can be used to schedule preventative fungicide applications. If late blight is detected in the area preventative fungicide schedules should be initiated if not already in place.

Chemical Controls: When plants are 6 inches tall apply one of the following protectant fungicides and repeat every 7 days throughout the season, or follow a locally verified disease forecasting system like Blitecast to schedule the fungicide applications.

1. chlorothalonil (Bravo, Bravo Ultrex, Bravo 720, Ultrex, Echo, Equus; FRAC code M5)
 - Percent acres treated: 95% (42)
 - Typical rates and frequency of application: 1-3 pt 6F/A or OLF, 8-10 applications. Do not apply more than 20 pts per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 0 days
 - Efficacy: Very good.
 - Use in IPM and resistance management: Tank mix with high-risk fungicides. Prior to disease development apply as a protectant as scheduled by Blitecast.
2. mancozeb (Dithane, Manex II, Manzate, Penncozeb; FRAC code M3)
 - Percent acres treated: 42% (42)
 - Typical rates and frequency of application: 3.0 lb 75DF/A or OLF, approx. 4-5 applications. Do not apply more than 25.6 lbs per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12, 24 hours PHI: 5 days
 - Efficacy: Good.

- Use in IPM and resistance management: Tank mix with high-risk fungicides. Prior to disease development apply as a protectant as scheduled by Blitecast.
3. zoxamide + mancozeb (Gavel, FRAC codes 22 + M3)
 - Percent acres treated: 12.4% (42)
 - Typical rates and frequency of application: 1.5-2.0 lb 75DF/A, 2-3 applications. Do not apply more than 72 oz per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 48 hours PHI: 5 days
 - Efficacy: Poor.
 - Use in IPM and resistance management: Prior to disease development apply as a protectant as scheduled by Blitecast.

Once late blight is detected in the area or found in the field use one of the following translaminar fungicides with a protectant fungicide. When conditions no longer favor the development of late blight return to the use of protectant fungicides (see above). Always alternate the following materials for resistance management:

1. cyazofamid (Ranman, FRAC code 21)
 - Percent acres treated: Newer material; data not available.
 - Typical rates and frequency of application: 2.1-2.75 fl oz 400SC/A, 2-3 applications in a tank mix with a protectant fungicide. Do not apply more than 3 consecutive sprays or a total of 6 sprays or 16.5 fl oz per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 0 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Apply with a protectant fungicide and rotate with materials with a different mode of action.
2. dimethomorph (Forum, FRAC code 40)
 - Percent acres treated: Newer material; data not available.
 - Typical rates and frequency of application: 6.0 fl oz 4.18SC/A, 2-3 applications in a tank mix with a protectant fungicide. Do not exceed 30 oz per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 4 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Apply with a protectant fungicide and rotate with materials with a different mode of action.
3. famoxadone + cymoxanil (Tanos, FRAC codes 11 + 27)
 - Percent acres treated: Newer material; data not available.
 - Typical rates and frequency of application: 8 oz 50WG/A, 2-3 applications in a tank mix with a protectant fungicide.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 3 days
 - Efficacy: Very good.

- Use in IPM and resistance management: Apply with a protectant fungicide and rotate with materials with a different mode of action.
4. propamocarb hydrochloride (Previcur Flex, FRAC code 28)
- Percent acres treated: 5.6% (42)
 - Typical rates and frequency of application: 1.5 pts 6F/A, 2-3 applications in a tank mix with a protectant fungicide. Do not apply more than 7.5 pts per acre per season.
 - Method of application: Foliar application with ground or aerial equipment.
 - REI: 12 hours PHI: 5 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Apply with a protectant fungicide and rotate with materials with a different mode of action.

Alternatives: Mancozeb and copper formulations (Cuprofix MZ, ManKocide, FRAC codes M3 + M1), azoxystrobin (Quadris, FRAC code 11), fenamidone (Reason, FRAC code 11), hydrogen dioxide (Oxidate, not classified), potassium salts of phosphoric acid (Fosphite, FRAC code 33), pyraclostrobin (Cabrio, Headline, FRAC code 11), and trifloxystrobin (Flint, FRAC code 11) are labeled for late blight on tomatoes.

Cultural Control Practices: No resistant varieties are available for tomatoes. Use locally grown or certified transplants from areas free of the disease. Sanitation is an important management tool. Avoid planting near white potato cull piles, destroy volunteer potato and tomato plants, bury all potato and tomato cull piles, and disk fields as soon as harvest is complete or if the field is abandoned because of late blight infection. Wash all equipment after entering infected fields.

Biological Controls: *Bacillus subtilis* (Serenade) is labeled for late blight control.

Post Harvest Control Practices: None.

Powdery Mildew, *Oidium lycopersica*

Description and Damage: Powdery mildew is a relatively new threat to greenhouse and field grown tomatoes. Three pathogens causing powdery mildew on tomatoes occur worldwide, but the recent outbreak in the Northeast in the mid to late 1990s is attributed to *O. lycopersica* (31). It has a wide host range including other solanaceous and cucurbitaceae plant species. Infection by this species of powdery mildew is dependent on plant age and environmental conditions. Symptoms include light green to bright yellow lesions on the upper leaf surface with a necrotic spot in the center of the lesion, sometimes with concentric rings. A characteristic light powdery covering appears on the lesions on the lower leaf surface. Under favorable disease conditions (relative humidity levels greater than 50% and temperatures ranging from 50-95°F) white mycelium appears on both leaf surfaces and on the stems. Dessication and defoliation of the leaves occurs. This powdery mildew is aggressive and can cause rapid death of infected leaves. The fungus survives on living plants between crops, including weed

hosts, and is spread by air currents and production activities. Leaf wetness is not necessary for infection.

Greenhouse and high tunnel conditions are ideal for powdery mildew development and spread. The disease is less commonly seen in commercial field grown tomatoes due to preventative fungicide programs and unfavorable environmental conditions. In New Jersey, powdery mildew rarely occurs in the field, but greenhouse and high tunnel tomatoes are at risk annually and about 5% are affected each year. Yield losses can be as great as 80% if uncontrolled, although losses overall are less than 5% in greenhouse and high tunnel production. This disease is more prevalent in the northern counties in the state due to more favorable weather conditions.

Monitoring and Thresholds: Check fields, greenhouses, and high tunnels weekly for this disease to identify outbreaks before it becomes widespread. Begin a fungicide program at the first sign of infection.

Chemical Controls:

Greenhouse: When powdery mildew is observed apply the following with thorough coverage of the upper and lower leaf surfaces and repeat at 7-day intervals:

1. paraffinic oil (JMS Stylet Oil, SunSpray Ultra-Fine Spray Oil; not classified)
 - Percent acres treated: 0% (42)
 - Typical rates and frequency of application: 1-2 gal/100 gal, using at least 200 psi. Do not apply to drought-stressed plants or when temperatures are above 90°F.
 - Method of application: Greenhouse foliar application.
 - REI: 4 hours PHI: 0 days
 - Efficacy: Variable.
 - Use in IPM and resistance management: Begin applications at the first sign of disease.

Field: Monitor fields for the presence of disease and when it first appears apply the following and repeat every 14 days:

1. pyraclostrobin (Cabrio, FRAC code 11)
 - Percent acres treated: Newer material; data not available.
 - Typical rates and frequency of application: 8-12 oz 20EG/A, 2-3 applications.
 - Method of application: Foliar application with ground or aerial equipment. This material is not labeled for greenhouse use.
 - REI: 12 hours PHI: 0 days
 - Efficacy: Excellent.
 - Use in IPM and resistance management: Begin applications at the first sign of disease and repeat every 14 days. For resistance management do not apply more than 2 consecutive FRAC code 11 fungicides before rotating to a fungicide with a different mode of action.
2. myclobutanil (Nova, FRAC code 3)
 - Percent acres treated: 1.5% (42)

- Typical rates and frequency of application: 2.5-4.0 oz 40WP/A, 2-3 applications. Do not apply more than 1.5 lbs per crop per year.
- Method of application: Foliar application with ground or aerial equipment. This material is not labeled for greenhouse use.
- REI: 12 hours PHI: 0 days
- Efficacy: Very good.
- Use in IPM and resistance management: Begin applications at the first sign of disease and repeat every 14 days.

Alternatives: Potassium bicarbonate (Armicarb, Kaligreen, etc.; not classified) and sulfur (Kumulus, Microthiol Disperss, Micro Sulf; FRAC code M2) are labeled for powdery mildew for field or greenhouse application. Acibenzolar-S-methyl (Actigard, FRAC code P1), azoxystrobin (Quadris, FRAC code 11) and trifloxystrobin (Flint, FRAC code 11) are labeled for powdery mildew as a field application.

Cultural Control Practices: Genetic resistance is effective for powdery mildew, but is limited in availability for tomatoes. In the greenhouse, follow good sanitation practices including elimination of all weeds in and around the greenhouse. Thoroughly clean plant production areas and remove plant debris between crops. Maintain adequate spacing between plants and rows. Promote good air circulation and maintain relative humidity levels below 93%. Remove diseased tissue as soon as it is detected and immediately place in plastic bag to avoid carrying infected material through the greenhouse. In the field, maintain good weed control and provide adequate spacing between plants and rows. Staking plants improves air circulation.

Biological Controls: In the greenhouse, Serenade (*Bacillus subtilis*) and Sonata (*Bacillus pumilis*) are listed for control. Plant Shield (*Trichoderma harzianum*) provides powdery mildew suppression in greenhouses.

Post Harvest Control Practices: None.

Timber Rot (White Mold), *Sclerotinia sclerotiorum*

Description and Damage: White mold has a wide host range (170 plant species) including beans, cabbage, white potato, lettuce, and sunflower. White mold is a soil-borne fungus with cool (59-69°F), moist weather favoring its development. High humidity and long periods of continuous wetness are required for infection and disease development. The disease usually begins during bloom, and is more prevalent in low-lying areas, in fields adjacent to heavily wooded lots, and in crops with lush vegetative growth. Following a period of 6-10 days of wet soil conditions, sclerotia produce airborne spores that colonize dead leaf or flower tissue and subsequently infect healthy stem tissue. Symptoms include water-soaked areas and a soft watery rot with a white moldy growth on the stems, petioles, and leaves. During cool moist weather a cottony growth with hard black sclerotia, characteristic to this fungus, is seen on the stems forming on the surface or within the stem pith. As the infection progresses, the stems become soft, brittle, and bleached (light gray or straw colored). A dry rot girdles the

stem at ground level and eventually the plant wilts and dies. In New Jersey this disease occurs sporadically. Typically less than 1% of the tomato acreage is affected by this disease, although yield losses can reach 10-20% of the crop if not controlled.

Monitoring and Thresholds: Record the occurrence and severity of the disease.

Chemical Controls: Thiophanate-methyl has received Section 18 status in New Jersey for control of white mold.

1. thiophanate-methyl (Topsin M WSB, FRAC code 1)
 - Percent acres treated: 0.1% (42)
 - Typical rates and frequency of application: 0.5-1.0 lbs WSB/A, 2-3 applications. Do not apply more than 4 applications.
 - Method of application: Foliar application with ground equipment.
 - REI: 12 hours PHI: 2 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Begin applications at the first sign of disease and repeat every 7 to 14 days.

Alternatives: Application of a broad-spectrum fumigant is marginally effective in destroying sclerotia in soil, but is not effective on airborne spores.

Cultural Control Practices: Rotate away from fields where snap or lima beans, peas, lettuce, or cucurbits have been grown. Follow good sanitation practices in the greenhouse including removing all infected plant parts, thoroughly cleaning and sanitizing the greenhouse and equipment, and maintaining good weed control in and around the greenhouse. Fumigate greenhouse soils to disinfest. Maintain adequate moisture but allow the soil surface to dry between watering. Subsurface drip irrigation may provide long-term control of white mold. Lower plant densities and staking plants to improve air circulation will help create unfavorable conditions for disease development.

Biological Controls: The biological fungicide Contans WG (*Coniothyrium minitans*) contains a parasite of the resting state of sclerotinia. It is applied 3-4 months prior to the onset of disease to allow the active agent to reduce inoculum levels of sclerotia in the soil. Following the application of 2-4 lbs 5.3 WG/A, incorporate to a depth of 1-2 inches. Do not plow between treatment and transplanting times so that the upper soil layer does not become infested from the lower untreated soil layer.

Post Harvest Control Practices: None.

Bacterial Soft Rot, *Erwinia* spp.

Description and Damage: Soft rot bacteria are associated with plant debris, soil, and water and are present wherever tomatoes are grown. The bacterium enters fruit through cuts, breaks, insect damaged areas, and abrasions, and dissolve the pectin that holds plant cells together. Lesions appear as small, sunken, light to dark colored water-

soaked areas. As the tissue decays it turns brown, soft, and slimy. At the favorable temperature range for infections (75-85°F) the fruit will rot within 3 to 10 days. Some losses may occur in the field, particularly during extended periods of humid weather, but soft rot is primarily a post harvest problem. This disease is also associated with poor insect control, harvesting during warm, rainy periods, and inadequate chlorination when washing fruit after harvest. In New Jersey, this problem occurs sporadically in fresh market tomatoes and although 100% of fields are at risk generally less than 5% are affected and less than 5% yield loss occurs. The disease usually occurs during August harvests due to the favorable environmental conditions. Losses in processing tomatoes can be higher due to the bare ground culture and longer production season, which exposes the fruit to more risk of infection.

Monitoring: Record the occurrence and severity of soft rot.

Chemical Controls: None.

Alternatives: None.

Cultural Control Practices: Careful handling of fruit during harvesting and packing, and controlling insects, is necessary to reduce losses from this disease. When environmental conditions are favorable for soft rot, avoid picking fruit when fields are wet, and do not pick in the heat of the day. Practice good sanitation like removing infected fruit from the field. If weather conditions are favorable and soft rot begins to appear on the stem ends, pack tomatoes dry without washing to minimize the disease.

Biological Controls: None.

Post Harvest Control Practices: During packing, maintain chlorine concentration at 75-150 ppm and 6.5-7.5 pH. Avoid wash water temperature differences of more than 10°F from field temperatures, since cold water on hot fruit will increase the movement of bacteria into the fruit. Disinfect packing lines at the end of each day. Maintain storage temperatures at 59-68°F. Disinfect picking containers.

Bacterial Wilt, *Ralstonia solanacearum* (*Pseudomonas solanacearum*)

Description and Damage: Bacterial wilt affects over 200 cultivated plants and weed species, with the most important hosts being in the Solanaceous family. Hosts for Bacterial wilt include tomatoes, white potatoes, eggplants and peppers. Bacterial wilt occurs naturally in soils of southern states (south of Maryland) and can overwinter in high tunnel and greenhouse soils in northern areas and can also be introduced on southern-grown transplants (27). The bacterium can survive for extended periods in soil free from host plants, which makes control difficult in naturally infested fields.

Bacterial wilt enters roots through wounds made by transplanting, cultivation, insects, or certain nematodes, and through natural wounds where secondary roots emerge. The bacteria multiply rapidly in the vascular system, plugging the xylem with bacterial cells

and ooze. The symptoms initially appear as wilting of the youngest leaves, without leaf yellowing, especially during the hot part of the day. As the bacteria multiply, the pith becomes water-soaked and turns brown and sometimes hollow. Under favorable conditions (high moisture and temperatures 86-95°F), wilting and plant death can occur 2 - 5 days post infection. If conditions are less favorable for disease development infected plants may become stunted and develop adventitious roots on the main stems. The lower leaves may also turn yellow before wilting symptoms occur. Bacterial wilt is disseminated by water, soil movement, or movement of infected transplants and usually occurs in areas associated with heavy soils in low lying areas where water accumulates. In New Jersey, where naturally occurring populations are not common, bacterial wilt occurs sporadically and is usually associated with infected southern transplants. Less than 1% of the acreage is affected yearly, and less than 1% yield loss occurs annually.

Monitoring and Thresholds: While scouting for other diseases record the occurrence and severity of bacterial wilt for future management.

Chemical Controls: Soil fumigation with a fumigant that contains either methyl bromide or chloropicrin will reduce disease occurrence, but neither of these materials are commonly used in New Jersey.

Alternatives: Researchers have determined that thymol, a plant derived reduced-risk chemical, used as soil fumigant reduced the incidence of bacterial wilt and increased tomato yield significantly. Application methods for commercial use of thymol in the field are under development (36).

Cultural Control Practices: Use locally grown or disease-free certified transplants and follow good greenhouse sanitation practices for transplant production. Some resistant cultivars are available. Avoid planting into infested fields and rotate with non host crops for at least one year. Avoid movement of water, equipment, or soil from infested fields to non-infested ones. Fields should not be over-irrigated, because excess soil moisture favors disease build-up. Increase of soil pH and available calcium might reduce the disease incidence (27). Control root-knot and root feeding nematodes.

Biological Controls: None.

Post Harvest Control Practices: None.

Fusarium Wilt, *Fusarium oxysporum* f. sp. *lycopersicae*

Description and Damage: Fusarium wilt is caused by a fungus that can overwinter in the soil without a host for many years. It is a warm-weather disease that is most prevalent on acid, sandy soils. Dissemination occurs by seed, infected transplants, tomato stakes, infested soils, and on farm machinery. The fungus enters the plant through wounds in the roots. Initial symptoms are yellowing of the lower leaves,

followed by downward curling, browning, and eventual death of the leaf. Sometimes only one branch or side of the plant is affected. As the infection progresses the vascular tissue turns brown and the yellowing gradually affects most of the plant and is accompanied by wilting during the hottest part of the day. Symptoms often first appear between bloom and fruit maturation. The extent of damage depends on the time of infection. Younger plants will be more severely stunted than plants infected at an older stage. When present, fusarium wilt can greatly reduce yields in highly infested fields. In New Jersey the disease occurs sporadically in less than 1% of the fields annually and yield losses are minimal due to host plant resistance.

Monitoring and Thresholds: While scouting for other diseases record the occurrence and severity of wilt for future management.

Chemical Controls: Soil fumigation is a chemical control option, but is not practiced by growers in New Jersey due to host plant resistance.

Alternatives: None.

Cultural Control Practices: Use resistant varieties and disease free seed. Maintain good greenhouse and field sanitation practices. Although fusarium is long-lived, long rotations (5-7 years) out of solanaceous crops will help reduce the inoculum level. Disinfect area where transplants will be grown, clean all greenhouse equipment, and maintain transplant production away from infested field. In the field, prevent the movement of infested soils on farm equipment, tomato stakes, tools, etc. into areas free of the disease. Avoid root knot nematode infestations. Raise the soil pH to 6.5-7.0 and use nitrate nitrogen rather than sources of ammonia nitrate. Rogue infected plants. (27)

Biological Controls: None.

Post Harvest Control Practices: None.

Leaf Mold, *Fulvia fulva* (Cooke)

Description and Damage: This fungus is found worldwide and is primarily a disease of greenhouse and high tunnel grown tomatoes. The fungus survives on previous crop residue or in the soil for at least one year. Leaf mold is primarily a foliar disease, although green and mature fruit may be attacked. Initial symptoms appear on the older leaves and include pale green or yellowish spots first noticeable on the upper leaf surface. An olive-green mold is associated with the spots on the underside of the leaf. The margins of the spots are not well defined, and when the infection is severe the spots coalesce causing the leaves to curl, dry up, and drop off the plant. Development of leaf mold is favored by high relative humidity (greater than 85%) and temperature (71-75°F). Leaf mold can spread rapidly throughout the crop with movement of water, air, worker, and insects. In New Jersey this disease occurs sporadically, and although 100% of the greenhouse and high tunnel production is at risk yearly less than 5% are

affected annually. If left uncontrolled up to 25% yield loss can occur, although losses are usually less than 1%.

Monitoring and Thresholds: Scout greenhouse and high tunnels for the presence of this disease and begin treatments at disease presence.

Chemical Controls:

1. famoxadone + cymoxanil (Tanos, FRAC code 11 + 27)
 - Percent acres treated: Newer material; data not available.
 - Typical rates and frequency of application: 8 oz 50WG/A in a tank mix with a contact fungicide.
 - Method of application: Foliar greenhouse application.
 - REI: 12 hours PHI: 3 days
 - Efficacy: Data not available.
 - Use in IPM and resistance management: Do not make more than one application before rotating with a fungicide of a different mode of action.

2. mancozeb (Dithane, Manex II, Manzate, Penncozeb; FRAC code M3)
 - Percent acres treated: 42% (42)
 - Typical rates and frequency of application: 1.5-3.0 lb 75DF/A or OLF, approx. 2 applications. Do not apply more than 25.6 lbs per acre per season.
 - Method of application: Foliar greenhouse application.
 - REI: 12, 24 hours PHI: 5 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Apply at the first sign of disease.

3. mancozeb + copper hydroxide (ManKocide, FRAC codes M3 + M1)
 - Percent acres treated: 0.7% (42)
 - Typical rates and frequency of application: 2.5-5.0 lb 61WP/A, 1-2 applications. Do not apply more than 112 lbs. per acre per crop.
 - Method of application: Foliar greenhouse application.
 - REI: 24 hours PHI: 5 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Apply at the first sign of disease.

4. maneb (Manex, FRAC code M3)
 - Percent acres treated: 16.8% (42)
 - Typical rates and frequency of application: 1.4-2.4 qts/A or OLF, approx. 2 applications. Do not apply more than 25.6 lbs per acre per season.
 - Method of application: Foliar greenhouse application.
 - REI: 24 hours PHI: 5 days
 - Efficacy: Good.
 - Use in IPM and resistance management: Apply at the first sign of disease.

5. zoxamide + mancozeb (Gavel, FRAC codes 22 + M3)

- Percent acres treated: 12.4% (42)
- Typical rates and frequency of application: 1.5-2.0 lb 75DF/A, 2-3 applications. Do not apply more than 72 oz per acre per season.
- Method of application: Foliar application with ground or aerial equipment.
- REI: 48 hours PHI: 5 days
- Efficacy: Data not available.
- Use in IPM and resistance management: Apply at the first sign of disease.

Alternatives: None.

Cultural Control Practices: Buy transplants that are locally grown or have been certified disease-free. Rotate away from tomatoes for at least 3 years. Greenhouse and field sanitation is an important cultural control. Clean up and destroy debris from infested fields and greenhouses to discourage overwintering of the pathogen. Disinfect greenhouses after debris has been removed. In the greenhouse, keep relative humidity low. Maintain night temperatures higher than outside temperatures and minimize long periods of leaf wetness through reducing irrigation and by providing good air circulation. Reduce plant density and stake and prune plants to improve air flow to reduce humidity and leaf wetness.

Biological Controls: None.

Post Harvest Control Practices: None.

Pythium Fruit Rot, *Pythium ultimum* and *P. aphanidermatum*

Description and Damage: Pythium fungi survive for long periods in soil and may persist in plant debris or on roots of weeds. In wet weather or in poorly drained areas certain species of pythium cause a fruit rot on green or ripe fruit, also called watery rot or cottony leak. The initial symptoms are a small water-soaked lesion on the fruit where green or ripe fruit contacts the soil. A heavy growth of white cottony mycelium may appear on the lesion surface during high moisture conditions. Within 72 hours the rot covers the entire fruit and the fruit collapses. This disease appears sporadically in New Jersey, and less than 1% of the acreage is affected and less than 1% yield loss occurs.

Monitoring and Thresholds: While scouting for other diseases record the occurrence and severity of pythium fruit rot.

Chemical Controls: There are no materials specifically labeled for pythium fruit rot but this disease is managed the same as buckeye rot, with preventative soil or foliar applications of mefenoxam.

Alternatives: None.

Cultural Control Practices: Avoid poorly drained areas, stake or mulch to prevent soil contact with the fruit, and maintain high domed beds to improve drainage.

Biological Controls: None.

Post Harvest Control Practices: None.

Southern Blight, *Sclerotium rolfsii*

Description and Damage: Southern blight, also known as southern wilt, southern stem rot, and sclerotium stem rot, occurs worldwide but is more common in warm climates in southern areas. Southern blight is a soil-borne fungus that can survive for many years as sclerotia in the soil and in host debris. The disease affects many crop plants, including white potatoes, eggplant, peppers, and tomatoes, legumes, and cucurbits. The fungus infects plants either directly or through wounds caused by nematodes or insects. Infection of young plants causes them to wilt suddenly and/or permanently. On older plants, the initial symptoms are a stem lesion at the soil line that girdles the plant resulting in leaf yellowing and plant wilting. A characteristic white cottony mat of fungal growth embedded with tiny (0.5 mm) light- brown sclerotia appears on the stem lesion and on organic debris nearby. Southern blight is spread by the movement of water, infested soil and plant material, machinery, and infected seedlings. Southern blight is favored by high temperatures (above 85°F) and high humidity. Under normal circumstances, infected plants may be seen scattered throughout a field.

In New Jersey this disease occurs sporadically and affects less than 1% of tomato acreage. Preventative treatments are not usually applied, and once the disease is found it is too late to apply effective control methods. Yield losses if left uncontrolled can range from 5-10%. Southern blight has mainly been found in the southern counties in fresh market tomatoes.

Monitoring and Thresholds: While scouting for other diseases record the occurrence and severity of southern blight for future management.

Chemical Controls: In areas where southern blight is more common, PCNB (Terraclor) is used in the transplant water as a preventative treatment. This material is not used in New Jersey.

Alternatives: There are control measures in the experimental stage, including biological control with certain organisms, soil amendments, and host resistance.

Cultural Control Practices: Rotate with non-host crops like corn, sorghum, or small grains for at least 2 years. Deep plowing to bury plant debris may help destroy sclerotia. Plastic mulch may help reduce contact with sclerotia on the soil surface. Maintain good weed control, avoid dense plantings, and choose well drained soils. Certain fertilizer practices (high calcium and ammonium type fertilizers) have provided some control under low disease pressure (27).

Biological Controls: Biological control with certain organisms (such as *Trichoderma harzianum*) is in the experimental stage (27).

Post Harvest Control Practices: None.

Tomato Spotted Wilt Virus (TSWV)

Description and Damage: Tomato spotted wilt (TSWV) occurs worldwide and infects a wide range of ornamental crops and vegetable crops including tomato, pepper, eggplant, melon, cucumber, bean, lettuce, and white potato. TSWV can affect tomatoes in the greenhouse and in field production. The appearance and severity of symptoms varies and depends on the cultivar, virus isolate, stage of plant growth at the time of infection and environmental conditions. Infections that occur during the transplant stage usually result in severely stunted plants that do not produce fruit. Later infections cause symptoms that may include chlorotic or necrotic flecking, or necrotic ring spots on the stems and leaves. Plants may be stunted, with systemic necrosis starting from the growing tips, which results in one-sided growth. Fruit from infected plants may exhibit undesirable fruit color, chlorotic or necrotic spots, and ring or mosaic patterns. Transmission of the virus occurs by several species of thrips. Only larval thrips can acquire TSWV, but larval and adult thrips can transmit the virus. The most common source of the virus and the vector is from ornamental and bedding plants that are brought into greenhouses from other production areas or grown in the same greenhouse as tomato transplants. TSWV occurs occasionally in New Jersey (in less than 1% of the tomato acreage) and is almost always associated with transplants that are exposed to infected ornamental plants in the greenhouse. Although 100% crop loss can occur, yield loss is generally less than 1% most years.

Monitoring: While scouting for other diseases record the occurrence and severity of TSWV. No thresholds are available.

Chemical Controls: None.

Alternatives: None.

Cultural Control Practices: Use virus-free transplants and avoid southern grown transplants. Screening for thrips exclusion in greenhouses may help prevent or delay infection in greenhouse production. Do not grow any ornamental bedding plants in the same greenhouse as tomato transplants. Rogue out TSWV-infected plants. Maintain weed control around greenhouses and in the field to reduce potential virus reservoirs.

Biological Controls: None.

Post Harvest Control Practices: None.

Verticillium Wilt, *Verticillium albo-atrum* and *V. dahliae*

Description and Damage: Verticillium wilt is a soil borne pathogen that attacks a wide range of crops including tomatoes, white potatoes, peppers, strawberries, okra, and brambles. It occurs sporadically in fields with proper crop rotations; however, it can be present in a field for up to eight years. The fungus can be transported from field to field through infested soil on machinery.

This disease attacks the vascular system, causing interveinal yellowing, wilting and drying of leaves. In tomatoes, yellow blotches on the lower leaves may be confused with alternaria infections. Symptoms often appear on one side of the leaf or plant, with older lower leaves affected first. Leaf symptoms include a characteristic V-shaped lesion at the leaf tip. Symptoms progress slowly and in late stages the plant will be permanently wilted and stunted. The pathogen is sensitive to soil moisture and temperature and is favored by cool weather. Soil temperatures must be moderate or cool for infection to take place: 75°F is optimum with 55°F minimum and 86°F maximum. The presence of root knot or root lesion nematodes may increase the severity of the disease. Verticillium wilt usually does not occur until late in the season. When present, verticillium wilt can greatly reduce yields in highly infested fields. In New Jersey tomato fields the disease occurs sporadically in less than 1% of the fields annually and yield losses are minimal due to host plant resistance.

Monitoring: While scouting for other diseases record the occurrence and severity of verticillium for future management.

Chemical Controls: Soil fumigation is a chemical control option, but is not commonly practiced by growers in New Jersey for this disease due to host plant resistance.

Alternatives: None.

Cultural Control Practices: Use verticillium tolerant tomato cultivars. Avoid planting in contaminated fields and observe a 4-5 year rotation with crops other than eggplant, white potato, pepper, strawberry or any of the brambles. Plant into well-drained soil, and maintain the minimum of soil moisture for good growth. In greenhouses or with plastic-strip mulch, soil fumigation gives good control and is feasible on high-value crops. Rogue infected plants.

Biological Controls: None.

Post Harvest Control Practices: None.

Nematodes

Description and Damage: Plant parasitic nematodes are non-segmented roundworms that live in the soil and feed on plant roots. Symptoms include a general lack of plant vigor, chlorosis, stunting, and progressive dying of the older leaves. Infestations are typically clumped in a field, resulting in patches of affected plants, although tillage will widen areas of infestations over time. Root knot (*Meloidogyne hapla*) and lesion

(*Pratylenchus penetrans*) nematodes are the two species that may be found in New Jersey tomato production. Both are widespread in agricultural areas and have a wide host plant range that includes many vegetable crops. Root knot juveniles attack the roots, penetrating as far as the vascular system. Secretions at feeding sites cause cells to enlarge and multiply, resulting in characteristic root galls. Lesion nematodes enter the root and damage the surface of the root. Infected roots may not develop properly and small lesions will be present. Nematodes are a minor pest of New Jersey tomatoes.

Monitoring: Soil samples can be taken in the fall to assess nematode populations for fields to be planted the following spring. To determine if nematodes are present in a current production field, growers take soil samples within the suspected infested area.

Chemical Controls:

1. metam-sodium (Vapam), metam-potassium (K-PAM)
 - Percent acres treated: 0.3% (42)
 - Typical rates and frequency of application:
 - Vapam: 56–75 gal HL/A, 1 application, or
 - K-PAM: 30–60 gal HL/A, 1 application.
 - Method of application: At least 3 weeks prior to planting, inject fumigant 6-8 inches into the soil and work the soil immediately after application to reduce fumigant loss; OR apply via irrigation systems (solid set sprinkler or drip/trickle), injecting fumigant with one inch of water per acre.
 - REI: 48 hours PHI: Not applicable
 - Efficacy: Good.
 - Use in IPM and resistance management: Growers do not typically treat for nematodes, however fumigation used for other diseases may control nematode population as well.

Alternatives: Oxamyl (Vydate, IRAC Group 1A) is labeled for nematode control.

Cultural Control Practices: Some cover crop plants are suppressive to nematode populations. Some antagonistic crops like marigold and asparagus produce chemicals that are toxic to nematodes. The incorporation of large amounts of organic matter (i.e., municipal leaves, compost) may help reduce population levels. The decomposition products of some plants kill nematodes, such as butyric acid from rye and timothy and isothiocyanates from rapeseed and other plants in the genus *Brassica*. The maximum benefit of these 'natural nematicides' is obtained when plant material is incorporated into the soil as green manure. Tarping the area where green manure is incorporated is likely to enhance efficacy.

Biological Controls: Biological control of nematodes is an active area of research, but at this time there are no commercially available products that are consistently effective.

Post Harvest Controls: None.

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