PEST MANAGEMENT STRATEGIC PLAN
FOR
TOMATO IN GEORGIA AND SOUTH CAROLINA

Compiled from a Workshop held on
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At the Savannah Conference Center in
Savannah, GA

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Executive Summary

A Pest Management Strategic Plan was developed for tomato grown in Georgia and South Carolina during a two day workshop held in conjunction with the 2007 Southeast Regional Fruit and Vegetable Conference on January 5-6, 2007 at Savannah, Georgia. Participants included scientists from the University of Georgia, Clemson University, growers and crop consultants from Georgia and South Carolina, and representatives from the Southern IPM Center, EPA and IR4 Southern Region. General information was provided on pests of tomato prior to the meeting, but the discussion used to rank pests and develop priorities were participant-driven (see contact list in the acknowledgements). There was a general consensus that existing research, regulatory and extension agencies provided critical support for tomato production in this region and that further reduction in services through budget cuts was to be strongly avoided. There was also agreement that complex pest problems, such as insect-vectored diseases, the loss of methyl bromide soil fumigant, or pesticide-resistant organisms were difficult to manage and needed research attention in the short term. Regulatory needs identified in the workshop focused on pesticides, such as critical use exemptions. The need for extension/education was highlighted both in terms of preserving traditional outreach methods and enhancing information availability through electronic formats. The bottom line to the discussion was to provide crop managers with economically viable tactics to mitigate pest problems along with the pest management decision criteria to know when and where tactics are to be used to best manage risk. Along with this need was the desire to understand why certain critical pest problems occur in the first place, i.e., understanding the events that lead up to a major pest outbreak, so that preventative strategies can be developed. Keeping in mind that the tomato production in this region occurs in two seasons, spring and fall, season-specific pest management information that is updated every few years was also deemed important. The group thought that PMSP priorities should be updated every five years.

Some of the more critical issues identified in this GA-SC PMSP workshop for research, regulation and extension are as follows. **Research** needs to be done on insect-vectored plant pathogens, including epidemiology and management studies. Economic thresholds, best management practices, or similar pest management decision criteria need to be established or refined for major insect, pathogen and weed pests of tomato. Host plant resistance is an important pest management tactic that should be developed for major diseases and arthropod pests of tomato. The effect of methyl bromide alternatives on soil-borne disease pathogens and weeds needs to be investigated to provide economically viable options for soil treatment in plastic-mulch productions systems. Pesticide resistance, pest resurgence and other negative consequences of pesticide use need to be investigated to supplement existing positive efficacy information for a more balance and informed approach to use. Post harvest pest problems need more research than is currently being done for tomato. **Regulatory** priorities include developing a more science-based approach to use restrictions such as buffers, and critical use exemptions. Also, pesticide labeling should continue to promote resistance management and State regulators should monitor tomato to enforce label restrictions. Information on all pesticide labels and restrictions should be easily available, i.e., in a user-friendly and searchable database, for end users. Consequences of label changes that have significant effects on production, such as labels for copper, need to be documented and considered in labeling of alternatives. Seed-borne and transplant-borne pest problems should be monitored to reduce the spread of pests. **Extension/Education** priorities include web-based and hard-copy publications need to be developed that compile the latest information on tomato pest management in a user-friendly format which is updated annually. Funds for such publications need to be made available. This should particularly target information on high profile pest problems such as thrips-vectored Tomato spotted wilt virus. Even though this information is important, on-farm demonstrations are critical to the implementation of pest management programs. Hands-on training is a priority. Pesticide resistance management education and implementation programs are needed for insect, pathogen and weed pests.

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General Tomato Production Information and Economic Impact

Production Regions

Georgia ranking in U.S. Tomato Production (Fresh Market) is fourth.
South Carolina ranking in U.S. Tomato Production (Fresh Market) is about eighth.

Georgia's contribution to Total U.S. Production is 4.8 %.
South Carolina's contribution to Total U.S. Production is 2.4%

Yearly production in:		GA	SC
	acres grown	6,100	3,000
	acres harvested	6,100	3,000
	cash value	80.6 million	39.6 million

Production and harvest costs (annually): Plasticulture costs about $13,100 per acre.

Crop Destination (%)		GA	SC
	fresh market	>99%	>99%
	processing	<1%	<1%
	other	0%	0%

Tomato production regions in Georgia cover the highest to the lowest elevations. The primary production areas are in the southwestern and south central parts of the state. The primary counties producing tomatoes in these areas include Decatur, Seminole, Brooks, Colquitt, Grady, Echols and Tift. However, Rabun County in the far north east corner of the state also produced a significant amount of tomatoes for the summer market. The South Carolina production occurs mostly on a few large farms in the Coastal Plain region. Georgia and South Carolina tomato production experiences quite a different set of pest problems as compared to southern Florida tomato production, even though there is some overlap in pest problems between these two regions.

Cultural Practices

Tomato is grown almost exclusively with plastic mulch and drip irrigation and is produced primarily on loamy sand to sandy loam soil types in the Coastal Plain area. Those produced in the mountain area are grown on loam to clay loam soils. Planting dates for spring production range from early March to late March in the Coastal Plain and from early to late May in the mountains. Most fall production plantings are made in late July to early August. There is no fall crop in the mountain region. Land prepared for tomato is limed to a pH of 6.2 to 6.8. Planting sites are deep turned and bedded. Pre-plant fertilizers, usually about 25 to 40% of total nitrogen and potassium, and all phosphorous and minor nutrients are incorporated into beds prior to planting. The remaining nutrients are applied through drip irrigation. A total of 200 to 250 pounds of nitrogen are used per crop. A total of 90 to 120 pounds of potassium and phosphorous are applied per acre depending on soil test results. Tomatoes are always transplanted, usually with a starter fertilizer application that is high in phosphorous. Plant spacing averages six feet between rows with 22 inches between plants. This arrangement is usually oriented with one row on beds that are six feet from center to center with plants spaced 22 inches apart in the row. Irrigation is supplied as needed with the highest demand for water occurring during fruit set and enlargement. Foliar applications of calcium and boron are commonly applied to enhance plant growth and reduce the chance of deficiency. Tomatoes in Georgia are harvested primarily for the vine-ripe market. This means they have attained at least a mature green stage and show little if any pink or red color. Tomatoes are generally hand-picked and taken to a packing house in bin boxes where they are sized and graded before being packed in 25-pound boxes. Per acre yields average about 1500 to 2000 boxes per acre on plastic mulch.

Figure 1. Commercial tomato field in southwestern Georgia.

Overall Research, Regulatory and Education Priorities for Tomato

Research

1) Basic biology of all of the major pest complexes of tomato should be further elucidated, especially difficult-to-manage complexes such as insect-vectored plant pathogens.
2) In tomato, we still need to establish economic thresholds and refine existing action threshold for most pests. For arthropod pests we need to re-examine curative thresholds for Lepidoptera (e.g. beet armyworm, tomato fruit worm, tobacco hornworm), aphids, thrips (distinct thresholds for virus transmission prevention or blossom and fruit damage), spider mites, stinkbugs, other plant bugs. For disease and weed pests, best management practices based on quantifiable risk continue to be needed. This information is critical for precision agriculture.
3) Host plant resistance studies for diseases, insect vectors, and other pests are sorely needed since it is a highly desirable pest control tactic that reduces the overall pesticide load.
4) Effect of methyl bromide alternatives on soil-borne diseases—Rhizoctonia, Phytopthora, nematodes, Pythium is also needed as quickly as possible.
5) Seed-borne diseases such as bacterial spot and seed borne viruses need to be investigated.
6) Effect of methyl bromide alternatives on purslane and other weeds such as morning glory, nutsedges, and pigweed needs to be studied relative to new chemistries and tactics.
7) Science-based justification for use restrictions (buffers, etc) needs more investigation before being applied to regulation practices.
8) Other specific research priorities are listed with the pest sections of this report.

Regulatory and Education

1) Pesticide Regulatory decisions should thoroughly consider resistance management concerns. It is imperative to maintain multiple modes of action for use against key pests. Support for pesticide resistance management is of vital concern to both growers and the pesticide industry.
2) Databases for registered pesticides by state and commodity are needed that are highly user friendly and easily accessible.
3) New miticides with different modes of action (rotations); or other insecticides for same purpose need to be registered. Again, maintaining multiple modes of action for resistance management and requiring compliance to regulations designed to stave off resistant pests should be a priority for regulators.
4) On-site extension visits including hands-on training need more support, not less. It is a mistake to think that regionalization of services and web-based delivery is an adequate substitute for traditional extension services.
5) Maintain the local-level (county) delivery system. This was repeated more than once in the discussion.
6) Consequences of labeling changes of copper (bacterial spot) need to be looked into, i.e. reduction in number of applications.
7) Web-based and hard copy publications of pest identification and management (that are user friendly) should be promoted and used by regulators.
8) Support for research on post-harvest problems associated with diseases and other pests need to be provided. Post harvest pest problems need regulator oversight, not just industry self-regulation.
9) Critical-use exemptions need to be continued for methyl bromide.
10) Provide more funding for research and extension programs targeted at tomato and other economically important vegetables in Georgia and South Carolina.

Insect General Overview

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Insect pests can damage tomato throughout the growing season, but severity varies with location and time of year. While many insects that feed on tomato are only occasional pests in Georgia and South Carolina, a few species are common pests and occur every season. The severity of damage to tomato by insect pests is largely due to abundance of the pests, which is related to environmental conditions. With most insects it is difficult to predict when outbreaks will occur and even more difficult to predict if control measures will be required. However, a working knowledge of their habits, careful pest monitoring, and timely use of effective control measures will enable growers to avoid or at least reduce the damage they suffer. Thus, tomato is well suited for insect pest management as long as a wide variety of control tactics are available, including labeling for diverse insecticide classes, host plant resistance, cultural controls, biological controls and others.

Because a variety of insects may attack tomato, scheduled sprays are frequently considered for insect management. However, scouting two to three times per week, allowing for early detection of infestations, and timely application of pest specific control measures, is the most cost-effective management strategy. Possible exceptions to this are the management of thrips which vector Tomato Spotted Wilt Virus or fields with a history of specific pest problems that require preventive control or are difficult to manage with curative treatments.

When insecticidal control is determined to be necessary, use the Georgia or South Carolina *Pest Management Handbook* to aid in selecting the correct insecticide for control of specific insect pests described in the following text beginning with thrips and lepidopterous larvae as the highest priority pests and then by tomato stage attacked. The following discusses insect pests by early mid and late season to illustrate this point.

Insects Attacking Tomato Crop Seedlings (Early Season)

Tomato is typically transplanted from greenhouse plant production sites on the same farm or from commercial plant producers. Since all of these crops are susceptible to frost damage, early planting in greenhouses followed by transplanting into the field avoids freeze damage. This is particularly important for tomato in the spring when early planting takes advantage of early favorable market windows. It also can avoid early season pests. Additionally, greenhouse or shade house transplant production concentrates expensive chemical treatments into a much smaller area and guarantees more uniform plant stands in the field. Since most of the acreage of these crops is currently in plastic culture, which is very expensive, plant uniformity is critical to maintaining production efficiency. However, these types of high input, uniform production practices also can lead to specific insect problems that can be exacerbated in these controlled environments. For example, insecticide treatment in greenhouses can concentrate selection for pesticide resistance to that insecticide if resistant insects survive the greenhouse production and are carried with transplants to the field. Some of the more easily controlled pests of tomato crop seedlings are flea beetles [species: tobacco, southern tobacco, pale striped] that cause small shot-holes in leaves, wireworms [species: southern potato, tobacco, gulf], or white grubs, that attack the stem and roots causing the plant to wilt, and cutworms [species: black and granulate] that clip the plant off at the soil line. The treatment timing for soil insects, such as wireworms, is usually at bed formation using soil fumigants. For later invading cutworms, it is at the time that damage is first detected, and for defoliators, it is at 10% defoliation. Currently, the most difficult early season pest to control is thrips [species: tobacco, westernflower] that transmit tomato spotted wilt virus (TSWV) which causes a severe wilt disease in most solanaceous crops. Tobacco thrips usually settle on tomato very early in the season beginning at transplant. Control options for this include host plant cultivars resistant to the virus, metallic reflective mulch (shown to be effective in tomato), early-season insecticides targeting thrips and reducing thrips feeding at transplant, and plant activators that chemically induce resistance. Pre-season weed monitoring for thrips and TSWV can help to predict risk at a given location.

Insects Attacking Tomato Crops during Vegetative Growth and Flowering (Mid-Season)

Probably the most severe insect problem in early spring in the Coastal Plain is thrips that transmit TSWV. Early season, preventative treatments are effective at reducing thrips and TSWV. However, mid-season insecticide treatments are ineffective for reducing TSWV and only partially effective against flower thrips to reduce direct damage to the fruit. In the early spring, usually no Lepidoptera pests attack tomato, but can occur at the end of the spring season. The main species of Lepidoptera that attack tomato foliage include the various species of armyworms [beet armyworm, Southern armyworm, yellow-striped armyworm]. Other Lepidoptera pests include tobacco hornworm, and tomato fruitworm. Southern armyworm can occur later in the spring and throughout the summer, whereas beet armyworm, corn earworm, and tobacco hornworm are more prevalent during the late summer and fall. Other important chewing insects that can occasionally occur on tomato and eggplant are Colorado potato beetle and vegetable weevil.

Other groups of insects that can reduce the quality of foliage during mid-season in the spring include aphids [species: potato and green peach] which secrete honeydew thus promoting the presence of sooty mold on leaves. During early to mid-season in the late summer and fall, sweetpotato whiteflies can transmit geminiviruses that severely stunt plant growth and affect fruit quality. Whiteflies also can produce honeydew that results in sooty mold when adult and nymph numbers are high. Two other foliage feeders that have been increasing in importance in recent years are spider mites [mostly two spotted] and less frequently, leafminers. Spider mites can occur in the spring and fall growing seasons. Insects that should be controlled mid-season to avoid bloom drop and damage to fruit buds include stink bugs [species: southern, brown and green], leaffooted bugs, and other plant bugs.

Thresholds for initiating control actions against insect pests in Georgia and South Carolina closely follow those recommended by UF IFAS at http://ftsg.ifas.ufl.edu/ACTBOD.HTM and include the one Lepidoptera larva or bug per six plants threshold prior to fruit formation. The recent exception to this is beet armyworm which should be controlled early in the season at 1 larva per 40 plants. Thrips populations greater than 5 per blossom can cause direct damage, but again, most of the damage occurs at much lower levels when thrips vector TSWV, and this must be prevented at an earlier plant growth stage. Broad mite thresholds have not been established for Georgia and South Carolina, but we recommend a single treatment at the first sign of mite damage.

Insects Attacking Mature Tomato Crops (Late Season fruit feeders)

Insect control becomes critical once developing fruit are present. Most of the Lepidoptera pests previously mentioned can damage the fruit either by surface feeding or boring directly into fruit. In Georgia, tomato fruitworm and beet armyworm are both typical summer pests that bore into tomato fruit. Other occasional pests that can attack the fruit include: European corn borer, tomato pinworm, and tobacco budworm. Worms that feed on fruit surfaces after extensive foliar damage late in the season include tobacco hornworm and various armyworms. The treatment threshold for worms that attack the fruit is very low. Depending on the amount of scouting done, the presence of worms in the field usually signals the need for treatment. Another important group of insects that directly attacks solanaceous fruit are the true bugs (including stink bugs and leaffooted bugs) that cause a dimpling, speckling and blotchy discoloration of the fruit. This type of damage often does not become apparent until the fruit begins to ripen (for example, the pink and red stages of tomato ripening).

An important insect that cause dimpling and scarring of tomato fruit is western flower thrips. This has been an economically important problem in recent years. Insects that cause irregular ripening of tomato include whiteflies. This can be directly from whitefly feeding or indirectly through the transmission of geminiviruses. Thrips vectored tomato spotted wilt virus also causes distinctive irregular ripening with circular patterns on the fruit. Spider mite damage to fruit can appear as a bronzing or russeting of the fruit surface.

Tomato Insect Management Research, Regulatory and Education Priorities

Research

1) The population dynamics of thrips vectors of Tomato spotted wilt virus of tomato should be further elucidated, particularly with regard to prediction of TSWV outbreaks and economically viable management practices.
2) Economic thresholds and refinement of existing action threshold for most insect pests need investigating. Specifically, for arthropod pests we need to re-examine curative thresholds for Lepidoptera (e.g. beet armyworm, tomato fruit worm, tobacco hornworm), aphids, thrips (distinct thresholds for virus transmission prevention or blossom and fruit damage), spider mites, stinkbugs, other plant bugs, beet armyworm, tomato fruitworm, aphids, thrips (relative to dimpling and scarring of fruit), spider mites, stinkbugs
3) Host plant resistance studies for disease, insect vectors and other insect pests are sorely needed since is a highly desirable pest control tactic that reduces the overall pesticide load.
4) Efficacy trials of insecticides are needed that include behavioral studies, for example, reduced feeding or settling that reduces pathogen transmission.
5) Production practices and plant nutrition influences on pest populations are needed.
6) Cultural practices for reducing key pests need to be investigated to reduce the overall reliance on pesticides in vegetables such as tomato.
7) The effectiveness of beneficial insects and interactions with pesticides need further investigation.
8) Emerging pests, especially due to loss of certain pesticides (including biology and management) need to be studied.
9) Factors leading to mite outbreaks and mite population dynamics need to be clearly identified, such as determining if this is an induced pest from pesticide use.
10) Movement and control of pests from surrounding plants and adjacent areas to the crop production site needs investigation to improve farmscape pest management.

Regulatory

1) Pesticide regulators should promote the dissemination of information on labels relative to secondary pest outbreaks from the use of certain insecticides.
2) A database for registered pesticides by state and commodity needs to be easily accessible and user friendly.
3) New miticides with different modes of action (rotations); or other insecticides for resistance management purposes need to be registered.
4) Application technology for existing and new chemistries (chemigation) needs to be promoted, but also regulated relative to crop-stage effects, per acre versus actual target application, etc.

Education

1) Current information on tomato IPM for each State needs to be centrally linked on a university maintained Tomato IPM website and then linked between States.

2) On-site extension visits including hands-on training need to be maintained and increased in frequency.
3) Need to maintain local-level (county) delivery system.
4) Need to maintain insect diagnostic services.
5) Need user friendly, web-based (and hard copy) pest identification and management publications.
6) Training of other government agencies (IPM training) needs to be promoted.
7) Database for registered pesticides by state and commodity needs to be linked with extension services since they have to answer questions on this all of the time.
8) Fact sheets and training are needed for resistance management (e.g., rotation by mode of action).
9) Tools for monitoring pests continue to be needed. Scouting is the foundation for all IPM activities.

Ranking specific insect pests discussed at meeting on January 5, 2007
From the worst pest (1) to lesser pests

1. Tobacco thrips*
2. Western flower thrips*
3. Two-spotted spider mites
4. Beet armyworm
5. Southern armyworm
6. Fall armyworm
7. Whiteflies (transmit geminiviruses)
8. Leafminers
9. Yellow striped armyworm
10. Tomato fruitworm
11. Flea beetles
12. Southern green stinkbug
13. Leaffooted bugs
14. Tobacco hornworm
15. Aphids (transmit mosaic viruses)
16. European corn borer
17. Tobacco budworm

Other pests discussed, but not ranked:

Carmine spider mites, Tumid spider mites, Brown stinkbug, Plant bugs, Wireworms, Whitegrubs, Cutworms, Colorado potato beetle

* Note that the ranking of thrips was primarily related to its role as a vector of Tospoviruses, particularly Tomato spotted wilt virus.

Insect Pest-by-Pest Profiles

Pest Name: Thrips (Order: Thysanoptera; Family: Thripidae)
Tobacco thrips (*Frankliniella fusca* (Hinds))
Western flower thrips (*Frankliniella occidentalis* (Pergande))
Flower thrips (*Frankliniella tritici* and *Frankliniella bispinosa***)**
Onion thrips (*Thrips tabaci* Lindeman)
Thrips species are the most significant pests on tomato primarily because they vector tomato spotted wilt virus (TSWV). Several species infest tomato annually including: tobacco thrips, *Frankliniella fusca,* and western flower thrips, *Frankliniella occidentalis* both vectors of TSWV. The flower thrips, *Frankliniella tritici,* infests tomato annually, but it does not vector TSWV in the field where as *Frankliniella bispinosa* may to a limited extent. *Adult:* The adults are tiny insects, generally measuring only 1 to 2 mm in length. They have thin bodies and vary in color from near black to straw colored. Although some species are generally darker than others, color is not a good characteristic for identification. Adults have two pair of wings that consist primarily of fringe hairs. Mouthparts pierce plant tissues and remove plant sap, but are frequently described as rasping. Separation of species requires microscopic examination. *Immature stages:* Larval thrips are similar in body structure to adult thrips but lack well developed wings. Wing pads are visible on prepupae and pupae. Larval thrips are generally lighter colored than the adults and vary from near white to tan to pink. *Life cycle:* The life cycle of thrips is greatly influenced by host plant, temperature, and diet. Females lay from 10 to over 100 eggs dependant on species and host plant. Flower thrips reproduction is greatly increased with pollen added to the diet. Eggs are placed into plant tissue and generally hatch in 3 to 5 days, but they can last 10 to 12 days under cold conditions. The two larval instars are the only feeding immature stages and last 3.6 to 12 days dependant on species and temperature. The prepupa and pupal stages generally occur in the soil and last 2.5 to 13 days. The life cycle from egg to adult is 2 to 3 weeks during favorable weather but can be greatly extended during the winter. Adults can live for about one month.

Distribution, damage, and importance: This problem is widespread and severe through the coastal plain region of the Southeastern USA. While thrips can cause direct damage to foliage and fruit, their roll as vectors of tomato spotted wilt is of primary concern, especially in tomato and tomato. Thrips are cryptic in nature, preferring to feed in tight secluded places such as the plant terminal and blooms. Immatures are rarely seen outside of these sights. Feeding on foliage causes young leaves to curl upward and gives older leaves a silvery or speckled appearance. Feeding within blooms on the ovary of flowers can result in malformed, student or discolored fruit, and oviposition into small fruit can also cause deformities. Generally, any direct damage is overshadowed by the impact of TSWV transmission in tomato. Tomato spotted wilt virus (TSWV) is transmitted exclusively by thrips and especially by western flower thrips and tobacco thrips. The initial symptoms of this disease are usually a spotting of the leaf, as illustrated in the photo. This is followed by a wilting of the plant, and by mid season this can clearly be seen as short plants in the row. The fruit from an infected plant is usually unmarketable and can display irregular ripening symptoms. This ripening problem can show up after tomatoes have been treated with ethylene for the ripening process. For this reason, TSWV infected plants are typically not harvested at all. Thus, every infected plant represents a total loss in yield for that plant. All the above species can cause mechanical damage to the foliage and fruit. Damage to the fruit varies from superficial blistering on immature pods to large brown blisters on mature pods. If the market is weak or the damage is severe, buyers will reject the tomato. Thrips overwinter in the soil but, can emerge anytime it is significantly warm in the winter. Thrips may infest seedlings in the greenhouse and are quick to infest tomato immediately after planting. Populations vary from year to year but, the greatest numbers generally occur in the blooms during the spring plantings. Fall plantings are infested at lower levels than in the spring but, TSWV incidence is higher because thrips populations are exposed to significant virus reservoirs during the spring and summer. Estimated total losses including cost of control and damage for thrips in 1997 was $940,000, cost of control at $455,000 and damage at $485,000. This **does not include** estimates for losses from TSWV infections.

Chronology: Thrips are present and generally active throughout the year in the coastal plain. There are 3 to 5 generations in Georgia. In fruiting vegetables, tobacco thrips will tend to dominate the population prior to blooming as they readily feed and reproduce on foliage. Flower thrips species populations can increase dramatically in the crops once blooming and pollen availability increases. Thrips become viruliferous prior to the growing season, often as they over winter on TSWV weed hosts. Prediction is critical to tomato spotted wilt management because most of the management options must be decided on prior to or at planting for most of the aforementioned host crops. These preseason management options such as elimination of weed host plants of thrips vectors like common chick weed, must be done at least one month before transplant in the spring. Even in the fall growing season, decisions on control tactics must be made pre-season.

Control measures used and recommended: Control tactics include host plant resistant cultivar of tomato, metallic reflective mulch, at-planting insecticide or SAR product treatments, early season post-transplant insecticides and possibly adjusting planting density, location and dates to try to avoid TSWV prone areas and/or periods. Thrips populations can be monitored in a variety of ways including various methods of beating plants to dislodge thrips into a collection device (styrofoam cup, white tray, sticky trap), collection of blooms, plant terminal washes for larvae, or colored sticky traps for adults. UV-reflective plastic mulch has proven useful in suppressing thrips populations and TSWV. Insecticides are generally used in a preventative method to suppress thrips populations where TSWV is of concern.

Cultural/mechanical: Host plant resistant cultivar of tomato, metallic reflective mulch, and possibly adjusting planting density, location and dates to try to avoid TSWV prone areas and/or periods.

Biological: Predators, such as *Orius* spp., contribute to control of thrips, but likely do not affect initial infection of TSWV only secondary infection by reducing the vector population. Also, parasitic nematodes have been shown to be partially effective.

Chemical: At-planting neonicotinoid insecticides or treatments with SAR products such as Messenger, as well as early season post-transplant insecticides such as those indicated below plus methamidophos (Monitor), lambda cyhalothrin (Warrior) and methomyl (Lannate).

Chemicals used:
- Acetamiprid (Assail) 30SG
- Dinotefuran (Venom) 20 SG
- Spinosad (SpinTor) 2SC

State/local pesticide restrictions or limitations, export issues, etc.: Methamidophos (Monitor) is 24c, and Warrior and Lannate not labeled specifically for thrips in tomato.

Critical Issues: Insecticide resistance is known to occur in thrips, so insecticide tactics alone are not sufficient to manage this pest. Timing of use relative to vector activity is critical. Imidacloprid use at transplant followed by foliar treatments of methamidophos and lambda cyhalothrin has been partially effective. Metallic mulch can delay tomato maturity, but consistently provide significant yield increase in when high numbers of thrips vectors of TSWV are present. Sources of host plant resistance to the virus and thrips are effective, but more sources are needed.

Research
1) The population dynamics of thrips vectors of Tomato spotted wilt virus of tomato should be further elucidated (such as the effect of tree pollen on vector numbers in the spring), particularly with regard to prediction of TSWV outbreaks
2) Host plant resistance needs to be developed as a primary control tactic, but other tactics such as reflective mulch and insecticide treatments should also be further evaluated.

Regulatory
1) Pesticide regulators should promote the dissemination of information on labels relative to secondary pest outbreaks from the use of certain insecticides

Education
1) Current information on thrips-TSWV management in tomato needs to be centrally linked on a university maintained site such as www.tomatospottedwiltinfo.org

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Pest Name: Spider mites (Order: Acari, Family: Tetranychidae)
Twospotted spider mite (*Tetranychus urticae* (Koch))
Carmine spider mite (*Tetranychus cinnabarinus* (Boisduval))
Tumid spider mite (*Tetranychus tumidus* (Banks))
Spider mites appear to be developing into a more consistent pest in southern Georgia. They generally feed on the underside of leaves, but can cover the entire leaf surface when populations are high. The minute eight-legged mites appear as tiny, reddish, greenish, or

yellow moving dots on the undersides of leaves (Figure 27). Because of their size, the first detection of spider mite infestations is usually damage to the leaves. Leaves of tomato plants infested with spider mites are initially lightly stippled with pale blotches (Figure 28). In heavy infestations, the entire leaf appears light in color, dries up, often turning reddish-brown in blotches or around the edge and may be covered with webbing. Greatest damage to tomatoes occurs during dry, hot weather which is favorable for development of extremely large mite populations. Spider mites are also generally considered a secondary pest, with damaging populations frequently occurring after application of broad spectrum insecticides. *Adult:* Adults are 0.4 to 0.5 mm long, with females being slightly larger, more robust (oval shaped), and more plentiful. Adults have four pairs of legs with long hairs on the legs. Actively feeding females are clear to greenish with dark spots on the body (except tumid mite). The tumid mite female is usually reddish with dark markings. Although color and number of spots is frequently used for rough identification of spider mite species, accurate identification requires microscopic evaluation by an expert. Adult female carmine mites are red. *Immature stages:* Eggs are whitish, almost clear, and spherical with a diameter of 0.1 to 0.15 mm. The first instar is called a larva. It is colorless when it hatches, but turns yellowish or pinkish after feeding. The larva has three pairs of legs. There are two nymphal instars after the larva called the protonymph and deutonymph. These both have 4 pairs of prolegs. Each immature stage lasts 1 to 3 days depending on temperature. Near the end of each stage, there is a non-feeding resting stage called the nymphochrysalis or protochrysalis (between the larva and protonymph), the deutochrysalis (between the two nymph stages) and the teliochrysalis (between the deutonymph and adult stages). *Life cycle:* Spider mites generally feed and reproduce on the lower leaf surface, but when populations are high will readily infest the upper leaf surface. Spider mites complete a life cycle in 8 to 12 days at 30^{o} C and in about 17 days at 20 degrees. Overwintering may occur on many weed hosts in warmer climates, but females may also overwinter in debris in a state of diapause. Eggs are laid singularly, with females depositing 5 to 6 eggs per day, with a total of 60 to 100 eggs per female. Eggs hatch in 3 to 6 days depending on temperature. Larva and nymphs complete development in 4 to 9 days depending on temperature and the females have a pre-oviposition period of 1 to 2 days. Adults live about 30 days.

Distribution, damage, and importance: Sometimes a problem in the fall at various locations in the coastal plain production region. Spider mites generally feed on the underside of leaves but will cover the entire leaf surface when populations are high. They pierce plant cells and withdraw the cell contents. Feeding can result in small clumps of dead cells that give a speckled appearance of the infested leaves. Wilting, leaf deformity, desiccation, and abscission occur with prolonged, high density infestations. Disruption of photosynthesis results in plant stunting and reductions in yield.

Chronology: Spider mites prefer hot dry conditions, so they tend to increase in population during the summer. They have an extremely wide host range, including numerous weed hosts, and may be present in the field when vegetables are planted but seldom require control early in the production season. More typically, they build populations later in the season and are likely aided by multiple applications of broad spectrum insecticides which impact natural enemies without controlling spider mites.

Control measures used and recommended: In general, treatments for mite control should be applied when mites become numerous and their damage appears excessive. However, some of the newer acaricides are slow acting or effective only on selective stages of mites. If these acaricides are used, a more preventive approach to management is required. Where a history of mite problems exists, this preventive approach may be justified in tomato which is a favored host of spider mites. To check for spider mites, observe plant foliage for characteristic damage. Look on the undersides of leaves for mites. Pay close attention to field borders and weedy areas. Mites frequently get started and reach their highest density along field margins adjacent to roads where the plants are covered with dust. Spider mites are often considered a secondary pest, with damaging populations frequently occurring after application of broad spectrum insecticides (particularly carbaryl and pyrethroids with the exception of bifenthrin and fenpropathrin). A growing set of data also indicates increased problems with spider mites following soil applications of neonicotinoid insecticides. While use of these products is frequently recommended for other pest situations, when spider mites are present in the field, potential influence on mites should be considered in the decision.

Cultural/mechanical: Mites are often associated with dry conditions.

Biological: Pirate bugs, big eyed bugs, predatory mites and fungi such as *Hirsutella thompsonii* (under moist conditions) provide high levels of control of mites. Predacious mites provide excellent control, including commercially available *Phytoseiulus persimilis*.

Chemical: Chemicals are only used when natural control of mites fails (usually because of other pesticide usage) and populations explode.

Chemicals used:

- Abamectin (Agri-Mek) 0.15EC
- Bifenazate (Acramite) 50WS
- Bifenthrin (Capture) 2EC
- Dicofol (Kelthane) MF and (Dicofol) 4EC
- Spiromesifen (Oberon) 2SC

Critical Issues: There is concern that intensive pesticide usage for other arthropod pests is the cause for mite outbreaks since mites tend to flare up in intensively treated fields.

Research:

1) Need to determine the cause of mite outbreaks in tomato for possible prevention

Regulatory:

2) None identified

Education:

3) Current information on the causes of outbreaks of this pest and management options need to be published and disseminated to end users

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Lepidopterous Pest Group

Pest Name: Beet armyworm
(Order: Lepidoptera, Family: Noctuidae *Spodoptera exigua* (Hubner))
Beet armyworm appears to be becoming a more consistent pest. Historically, it is considered a secondary pest, with large populations usually occurring only after multiple applications of broad spectrum insecticides. However, this pest is now a fairly consistent pest in the summer and fall. Beet armyworms feed on both the foliage and fruit of tomato plants. Eggs are laid in masses on the undersides of the foliage. Young larvae remain near the site of hatching, feeding in groups that cause characteristic foliar damage referred to has 'hits'. After feeding on foliage for a few days, medium sized larvae (3^{rd} instar) may migrate to the fruit. They may tunnel into the fruit under the calyx or eat directly through the fruit wall. Because beet armyworms start as foliage feeders, treatments can be delayed until hits are detected but should be applied prior to third instar. In practice, treatments are generally begun with first detection of egg masses or hits. *Adult:* Moths are medium sized with a wingspan of 25-30 mm. The forewings are a mottled gray and brown with irregular banding and a light colored bean shaped spot near the center. The hind wings are a more uniform white or dirty white with a dark line near the margin. *Immature stages:* Eggs are laid in clusters of 50-150, greenish to white and are covered with a layer of whitish scales that give the egg mass a fuzzy or cottony appearance. Larvae are pale green to yellow during the first two instars. Larger larvae vary in appearance. Large larvae tend to be green to dark green dorsally and may have a series of dashes that give the appearance of longitudinal lines on the back. Large larvae generally have a dark line along the side of the body with a light line below the dark line. The underside of large larvae is generally pink or yellow. *Life cycle:* Egg clusters are usually deposited on the underside of leaves. Females normally deposit 300-600 eggs during their lifetime. Eggs hatch in 2-3 days during warm weather. Early instar larvae are gregarious, feeding as a group and skeletonizing leaves. Larvae are primarily foliage feeders or surface fruit feeders during the first two instars which require about 4 days. Third instar larvae disperse and will attack fruit but can complete development on foliage in the absence of fruit. Normally, larvae develop through 5 instars in 9-10 days. Larvae reach a maximum size of about 22.5 mm. Pupation occurs in the soil and the pupal stage generally last 6-7 days. Total generation time is about three weeks.

Distribution, damage, and importance: Mostly a problem in the summer to fall production season throughout the southern coastal plain, but not consistently a problem in all years. The first two instar larvae are gregarious and feed in groups on foliage. The clumped skeletonizing of foliage is known as a beet armyworm 'hit' in many crops. Third and later instar larvae disperse and may continue feeding on foliage but will bore into fruit.

Chronology: Beet armyworm generally does not overwinter in Georgia but can migrate readily from Florida. While the potential from significant infestations are more likely in the fall, this pest can be a problem in the spring production season as well. This pest is generally considered a secondary pest, with significant infestations usually occurring only after repeated use of broad spectrum insecticides which decimate its parasites and have little impact on the beet armyworm because of resistance to older insecticide chemistries.

Control measures used and recommended: Beet armyworms are generally controlled with insecticides when they appear in significant numbers during the growing season. Beet armyworm moths can be monitored with pheromone traps, but adult abundance does not always correlate with subsequent larval problems. Scouting for beet armyworms generally involves inspection of foliage for egg masses, larvae, and 'hits'. Egg masses can be difficult to locate because of their clumped nature. In fruiting vegetables, insecticide applications based on the detection of 'hits' generally provides ample protection as the early instars do not attack fruit and 'hits' can be detected prior to fruit loss.

Cultural/mechanical: Mostly be aware that the beet armyworm populations are seasonal, generally a summer to fall problem, not a spring problem.

Biological: *Bacillus thuringiensis*, *Nomuraea rileyi*, and nuclear polyhedrosis viruses are effective against beet armyworm and preserve beneficial predators such as the spined soldier bug and parasitoids like braconid wasps.

Chemical: Newer chemistries (such as the soon to be registered metaflumizone) tend to be more effective than older chemistries since older insecticides have had resistance problems in the pasts in the southern USA, but this is not always the case.

Chemicals used:

- Emamectin benzoate (Proclaim) 5WDG
- Indoxacarb (Avaunt) 30WDG
- Methoxyfenozide (Intrepid) 2F
- Spinosad (SpinTor) 2SC

State/local pesticide restrictions or limitations, export issues, etc.: 24 c for methamidophos

Critical Issues: No major concerns other than continued emphasis on IPM

Research:

1) Need to re-evaluate threshold treatments for lepidopteran pests of tomato for greater precision in IPM

Regulatory:

2) None identified

Education:

3) Current information on thresholds for beet armyworm need to be published and disseminated to end users

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Pest Name: Other armyworms (Order: Lepidoptera, Family: Noctuidae)
Southern armyworm (*Spodoptera eridania* (Cramer))
Yellowstriped armyworm (*Spodoptera ornithogalli* (Guenée))
Adult: Southern armyworm moths are medium sized with a wingspan of 33-38 mm, while yellowstriped armyworm moths have a wingspan of 34-41 mm. The forewings of both are grayish brown with light and dark colored markings. The hind wings are a more uniform white or with a narrow brown margin. *Immature stages:* Eggs are laid in clusters of 200-500, greenish to white and are covered with a layer of whitish scales that give the egg mass a fuzzy or cottony appearance. Southern armyworm eggs have ribs which radiate out from the center. Larvae are pale green to yellow during the first two instars. Larger larvae of both species are similar in appearance. Large southern armyworms are tan brown to dark green with a reddish brown head. They have white lines on the back and additional stripes on the side interrupted by a dark spot on the first abdominal segment. The yellowstriped armyworm has two yellow colored bands down each side of the back with a series of strong black triangular markings down either side. The head capsule tends to be darker than the southern armyworm. *Life cycle:* Egg clusters are usually deposited on the underside of leaves. Females normally deposit 200-500 eggs during their lifetime. Eggs hatch in 3-6 days during warm weather. Early instar larvae are gregarious, feeding as a group and skeletonizing leaves. Larvae are primarily, if not entirely, foliage feeders but can attack the fruit, feeding primarily on the surface. Normally, larvae develop through 6 instars in 14-20 days. Larvae reach a maximum size of about 35 mm. Pupation occurs in the soil and the pupal stage generally last 11-18 days. Total generation time is about one month.

Distribution, damage, and importance: Mostly in summer to fall production seasons and occasionally late spring, but not consistently. The first two instar larvae are gregarious and feed in groups on foliage. The clumped skeletonizing of foliage is known as an armyworm ‘hit’ in many crops. Third and later instar larvae disperse and may continue feeding on foliage but can also scar the surface of the fruit.

Chronology: Armyworms generally do not overwinter in Georgia but can migrate readily from Florida. There is an estimated four generations per year in Florida. While the potential from significant infestations are more likely in the fall, this pest can be a problem in the spring production season as well. This pest is generally considered a secondary pest, with significant infestations usually occurring only after repeated use of broad spectrum insecticides which decimate its parasites and have little impact on the armyworm because of resistance to older insecticide chemistries.

Control measures used and recommended: Armyworms are generally controlled with insecticides when they appear in significant numbers during the growing season. Armyworm moths can be monitored with pheromone traps, but adult abundance does not always correlate with subsequent larval problems. Scouting for armyworms generally involves inspection of foliage for egg masses, larvae, and 'hits'. Egg masses can be difficult to locate because of their clumped nature. In fruiting vegetables, insecticide applications based on the detection of 'hits' generally provides ample protection as the early instars do not attack fruit and 'hits' can be detected prior to fruit damage.

Cultural/mechanical: Cultural and mechanical controls are generally not used.

Biological: *Bacillus thuringiensis*, *Nomuraea rileyi*, and nuclear polyhedrosis viruses are effective against armyworms and preserve beneficial predators such as the spined soldier bug and parasitoids like braconid wasps.

Chemical: Newer chemistries (such as the soon to be registered metaflumizone) tend to be more effective than older chemistries since older insecticides have had resistance problems in the pasts in the southern USA, but this is not always the case.

Chemicals used:

- Bifenthrin (Capture) 2EC
- Deltamethrin (Decis) 1.5EC
- Emamectin Benzoate (Proclaim) 5WDG
- Gamma-cyhalothrin (Proaxis) 0.5EC
- Methomyl (Lannate) 2.4LV and 90SP
- Methoxyfenozide (Intrepid) 2F
- Spinosad (SpinTor) 2SC
- Zeta-cypermethrin (Mustang Max) 0.8EC

State/local pesticide restrictions or limitations, export issues, etc.: 24 c for methamidophos

Critical Issues: No major concerns other than continued emphasis on IPM

Research:

1) Need to re-evaluate threshold treatments for lepidopteran pests of tomato for greater precision in IPM

Regulatory:

2) None identified at the present time

Education:

3) Current information on thresholds for these armyworms need to be published and disseminated to end users

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Pest Name: Sweetpotato and silverleaf whitefly (Order: Hemiptera, Family: Aleyrodidae, *Bemisia tabaci* or *argentifolii* - silverleaf) *Adult:* The adult is small, about 0.9 to 1.2 mm in length and holds its solid white wings roof-like over a pale yellow body while at rest. *Immature stages:* Immature stages begin with a pointed oblong yellow egg (0.2 mm) which darkens at the apex just before hatching. The first instar or crawler stage (0.2-0.3 mm) settles down on the underside of leaves close to the egg shell and goes through three more molts as a sessile, flattened oval nymph. Late third and fourth instars begin to develop eye spots and are often referred to as red-eyed nymphs. The last instar, or "pupal stage" (0.7-0.8 mm), has very distinct eye spots. *Life cycle:* The life cycle from egg to adult may be 18 days under warm temperatures (86^{o}F) but may take as long 2 months under cool conditions. The number of eggs produced is also greater in warm weather than in cool weather. The rate of reproduction ranges from 50 to 400 eggs (avg. 160, of which about ⅔ are female) per generation, hence a high capacity for reproduction.

Distribution, damage, and importance: Mainly a late summer and fall problem, but can be widespread and if geminiviruses are present, it can have widespread severe impact on tomato. In tomato crops in Texas, economic loss has almost only been associated with the transmission of geminiviruses which can render tomato plant unproductive. If whitefly transmitted viruses are not present, then yield losses are not likely with light infestations of an average of less than 6 adults per leaf.

Chronology: In Georgia, whiteflies are generally not an economic problem in the spring growing season, unless the production is in an infested greenhouse. In the late summer and fall, whiteflies numbers increase dramatically in some years.

Control measures used and recommended: Use preventative management first and only curative insecticide treatments when geminivirus is present or populations consistently exceed and average of 6 adults per leaf.

Cultural/mechanical: The lack of host plant material can cause abrupt declines in whitefly populations. Thus removal of infested plant residue is important in the management of this pest. If delayed planting can be used in the fall, planting after whitefly migrations (often associated with cotton defoliation) have declined should be practiced.

Biological: Natural sources of mortality for the whitefly include predation by beneficial insects such as lacewing or coccinelid larvae, parasitization by wasps such as *Encarsia* or *Eretmocerus* species, mechanical injury, desiccation, insect pathogens such as *Beauvaria*, *Paecilomyces* or *Verticillium* species

Chemicals: The neonicotinoids have been the mainstay of whitefly control in vegetables for the last decade. This is usually applied preventatively in the fall (when whiteflies are more prevalent) as a soil drench or drip injection at the time of transplant.

Chemicals used:

- Acetamiprid (Assail) 30SG
- Bifenthrin (Capture) 2EC
- Dinotefuran (Venom) 20SG
- Pyriproxyfen (Knack) 0.86EC
- Spiromesifen (Oberon) 2SC
- Thiamethoxam (Actara) 25WG

Critical Issues: Whiteflies are occasionally important in Georgia and South Carolina as vectors of geminivirus. Also, Q-strain whitefly has been found in greenhouses which is resistant to neonicotinoid insecticides

Research:

1) Need to evaluate the effectiveness of whitefly control tactics in terms of reducing geminivirus transmission
2) Need to monitor for Q-strain whitefly and develop a management strategy if it becomes prevalent.

Regulatory:

3) None identified at the present time

Education:

4) Current information on whitefly management needs to be disseminated to end users if geminivirus and or Q-strain whiteflies become prevalent

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Pest Name: Leafminers (Order: Diptera, Family: Agromyzidae)
Vegetable leafminer (*Liriomyza sativae* (Blanchard))
Liriomyza trifollii (*Liriomyza trifollii* (Burgess)**)**

Adult: Leafminer adults are tiny yellow and black flies. The yellow markings on the head, thorax, and legs are useful in identifying species. The abdomen is mostly gray and black. Adults are less than 2 mm long with a wing span of less than 2 mm. Wings are transparent. *Immature stages:* Eggs are oval, small, and change color from clear to creamy white as they age. They are laid singly into leaf tissue just below the epidermis. The larvae appear as small maggots within the leaf, starting at about 1.0 mm in length and reaching a length of about 1.9 mm. The pupa is initially golden brown and turns darker. *Life cycle:* Leafminers have a short life cycle, completing a generation in 21 to 28 days in a favorable climate. Eggs are placed into leaf tissue and hatch in about 3 days. Larvae feed and grow between the upper and lower surface of the leaf and develop through three instars in about 4.6 days. As the larvae grow, the 'tunnels' created by their feeding increase in diameter, creating the characteristic winding mines in the leaf. Larvae emerge from the leaf and fall to the ground to pupate. The pupal stage lasts about 9 days. The adult has a preoviposition period of about 1 day. Adult longevity is about 2 weeks, with estimated oviposition of 35 to 39 eggs per day on a favorable host. Females make numerous punctures of the leaf with their ovipositor and use these sites for both feeding and oviposition, with 10 to 25 percent of punctures used for oviposition dependent on host quality.

Distribution, damage, and importance: An occasional pest. With severe infestations, heavy leaf loss may lead to sun scald of fruit. The numerous punctures caused by females can result in a stippled appearance on foliage, but is of little consequence at low levels. The primary damage is the mining of leaves by larvae. Mining results in destruction of leaf mesophyll. Mining can greatly depress photosynthesis but generally does not lead to direct yield loss as most fruiting vegetables can withstand considerable leaf damage. Extensive mining can result in premature leaf drop, leading to lack of shading and sun scalding of fruit.

Chronology: Leafminers are generally considered secondary pests. Natural enemies generally maintain populations at non-damaging levels, but populations can increase rapidly following multiple insecticide applications.

Control measures used and recommended: Leafminer densities can be monitored in a variety of ways including counting mines in leaves, counting live larvae in mines, sticky traps for adults, or pan traps to catch larvae as they fall to the ground to pupate. Counting mines in leaves may overestimate leafminer activity as many mines may be empty, but this is the easiest and probably most frequently used method for monitoring. Insecticidal control of leafminers is difficult because of the protected environment of the larvae and severe insecticide resistance. Use of broad spectrum insecticides against other pests frequently contributes to leafminer problems through disruption of natural biological control.

Cultural/mechanical: None used commercially.

Biological: Several parasites attack this pest and can keep leafminer populations under control. Leafminers rarely pose a serious threat to tomato production in Georgia except in fields where their natural enemies are reduced by early, repeated insecticide applications.

Chemical: Begin treatments for leafminer control when populations reach an average of fivemines/leaf with at least 25 percent of the mines containing live larvae.

Chemicals used:

- Abamectin (Agri-Mek) 0.15EC
- Cyromazine (Trigard) 75WP
- Spinosad (SpinTor) 2SC

Critical Issues: None identified at the present time.

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Pest Name: Tomato fruitworm (Corn earworm)
(Order: Lepidoptera, Family: Noctuidae, *Helicoverpa zea* (Boddie))
Among the most serious pests of tomato is the tomato fruitworm or corn earworm, particularly in the summer and fall. Several generations of tomato fruitworm may develop each year. *Adult:* Adults are medium sized moths with wingspans of 32-45 mm. Adults are variable in color, but the front wings are usually yellowish-brown and bear a small dark spot near the center. The forewings usually have a darker band near the end of the wings, but the margin of the wing is not darkened. The hind wings are creamy white with a broad dark band near the wing margins, but the margin of the hind wing is creamy white. *Immature stages:* Eggs are pale green when first deposited, turn yellowish and then darken with age. Eggs are shaped like a somewhat flattened sphere with ridges (> 20) radiating from the top-center. Eggs are laid singly on the terminals or close to flowers or small fruit. The eggs hatch in 3 to 5 days and the larvae can attack buds and fruit shortly after hatching. The larvae vary greatly in color from a light green to brown or nearly black and are lighter on the underside. They are marked with alternating light and dark stripes running lengthwise on the body. Early instar larvae have stout hairs which gives them a somewhat spiny appearance as compared to the smooth skin of most other caterpillars found on tomatoes. Larvae range in size from 1.5 mm at hatching to 25mm at maturity. The head tends to be orange or light brown with a white net-like markings and the thoracic plate is black. Larval body color may be brown, green, pink or sometimes yellow or near black. The larva usually has a broad dark lateral line above the spiracles and a light line below the spiracles. Two dark lines may also occur along the center of the back. A key characteristic that will separate corn earworm larvae from most other species encountered in vegetables is the presence of black microscopic spines on the cuticle. The pupal stage occurs in the soil. Pupae are 17-22 mm in length and mahogany-brown. *Life cycle:* Eggs are deposited individually on leaf tissue and corn silks and hatch in 3-4 days. Females can lay about 35 eggs per day with 500 - 3000 over their lifetime. Larvae can feed and develop on foliage but preferentially feed on fruiting structures. Older larvae are aggressive and cannibalistic, thus, individual fruit usually produce a single larvae. Larvae usually develop through 5 or 6 instars in 14 to 21 days in field conditions. Larvae fall to the ground and burrow into the soil to pupate. The pupal stage last about 13 days in the summer and serves as the overwintering stage in the late fall.

Distribution, damage, and importance: This pest is very common in the coastal plain region. Corn earworm damage is caused only by the larvae. Larvae have chewing mouthparts and remove plant tissue. Although larvae can feed and develop on leaf tissue, the preferred feeding sites in most crops are reproductive structures, such as corn ears and tomato and tomato fruit. Early instar larvae will attack fruit without any leaf feeding. In corn, a single larva generally develops on a single ear of corn. In fruiting vegetables, a single larva frequently damages more than one fruit.

Chronology: Corn earworm can attack vegetable crops throughout most of the production season, but early planted spring crops avoid heavy pest pressure. Late spring crops and fall crops of favored hosts can experience greater fruit damage.

Control measures used and recommended: Treatment is usually with insecticides and only when the pest is present, so detection is important. Adults can be monitored with pheromone or blacklight traps to estimate when moths are active. This can provide a measure of relative densities or peak activity. In sweet corn, corn earworm is generally controlled with scheduled applications of insecticides (frequently daily) during the silking period. Eggs are frequently deposited on the silks and hatching larvae will immediately feed on silks. Once the larvae enter the silk channel of the ear, they are protected from insecticides. While applications every two days can provide protection equal to daily applications, under heavy pest pressure any disruption of this schedule can result in significant damage. In fruiting vegetables, larvae generally remain partially exposed or move from fruit to fruit providing exposure, and better control can be obtained with insecticides. Thus, scouting for eggs, larvae, and damage, and treating with insecticides as needed is generally practiced. Although thresholds used are frequently presence/absence, generally treatments for tomato fruitworm control should be applied when one percent of fruit are infested with larvae or if eggs are easily found.

Cultural/mechanical: Generally not used commercially.

Biological: *Bacillus thuringiensis* is effective against earworm and preserve beneficial predators such as the spined soldier bug and parasitoids like braconid wasps or Trichogramma egg parasitoids.

Chemical: There have been recent concerns about insecticide resistance in corn earworm populations in the Southeast. The older chemistries are more likely to experience resistance problems.

Chemicals used:

- Bifenthrin (Capture) 2EC
- Cyfluthrin (Baythroid) 2EC
- Deltamethrin (Decis) 1.5EC
- Emamectin benzoate (Proclaim) 5WDG
- Esfenvalerate (Asana) .66EC
- Gamma-cyhalothrin (Proaxis) 0.5EC
- Indoxacarb (Avaunt) 30 WDG
- Lambda-cyhalothrin (Warrior) 1CS
- Permethrin (Pounce) 3.2EC
- Spinosad (SpinTor) 2SC
- Zeta-cypermethrin (Mustang Max) 0.8EC

State/local pesticide restrictions or limitations, export issues, etc.: 24 c for methamidophos

Critical Issues: No major concerns other than continued emphasis on IPM

Research:

1) Need to re-evaluate threshold treatments for lepidopteran pests of tomato for greater precision in IPM

Regulatory:

2) None identified at the present time

Education:

3) Current information on thresholds for this pest need to be published and disseminated to end users

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Pest Name: Flea beetles (Order: Coleoptera, Family: Chrysomelidae/Alticinae)
Tobacco (*Epitrix hirtipennis* (Melsheimer))
Southern tobacco (*Epitrix fasciata* (Blatchley))
Pale striped (*Systena blanda* (Melsheimer))
The name flea beetle applies to a variety of small beetles, with enlarged hind legs, which jump vigorously when disturbed. Their injury consists of small, rounded or irregular holes eaten through or into the leaf. The most common flea beetles are about 1/16 inch long and nearly a uniform black in color. Flea beetles may attack tomatoes at any time during the growing season but are often most numerous and of greatest concern early in the season. Insecticides for control of flea beetles should be applied when flea beetles become numerous and defoliation is greater than 10 percent. Flea beetles generally do not require control once plants are beyond the 5 leaf stage. *Adult:* The tobacco and southern tobacco adults are small (1.4-2.2 mm in length) and reddish, yellow brown, with a brown patch across the width of the elytra. The southern tobacco adult is slightly smaller and wider than the tobacco flea beetle. The pale striped flea beetle adult is larger (3.0-4.3 mm long) and has a pair of pale yellow stripes lengthwise down the back, one stripe on each elytron. *Immature stages:* All of the above species have three larval instars that are whitish with darker heads, and all feed on fine roots near the soil surface or occasionally tunnel into larger roots. The tobacco flea beetles range from 1 mm after hatching to 4.2 mm at maturity, while the pale stripe larvae range from 1 to 11 mm. *Life cycle:* Tobacco flea beetle females can lay up to 200 eggs which hatch in 6-8 days. The larval development typically last from 16-20 days under warm conditions. The last instar larva forms a small cell in the soil where it pupates, and the adult emerges 4-5 days later for a total of 26-33 days. The pale striped flea beetle requires a longer time to develop from egg to adult, 28-54 days total.

Distribution, damage, and importance: Not a widespread problem. Typical flea beetle damage occur in the foliage of young crop plants, and damage usually manifests itself as numerous small shot holes through the leaves. This occurs early in the growing season and can show up soon after transplanting depending on the date.

Chronology: There are 3-4 generations of the tobacco flea beetles per year. High number have been observed in south Georgia in late

June in Solanceous crop transplants, and we think that this is likely a second generation. Up to two generations of pale striped flea beetle have been reported per year.

Control measures used and recommended: Significant yield loss has been reported for levels of flea beetles at five adults per plant very early in the growing season. We suspect that 5-10% defoliation is sufficient reason for controlling this foliar feeder early in the growing season. Late season control is seldom if ever warranted.

Cultural/mechanical: Flea beetles may carry over from previous crops.

Biological: Natural enemies of the tobacco flea beetle adults include the bigeyed bug, *Geocoris punctipes*.

Chemicals: Only use insecticides if damage reaches 10% defoliation and usually a single application will suffice.

Chemicals used:

- Acetamiprid (Assail) 30SG
- Carbaryl (Sevin) 80S
- Cyfluthrin (Baythroid) 2EC
- Deltamethrin (Decis) 1.5EC
- Dinotefuran (Venom) 20 SG
- Endosulfan (Endosulfan/Thionex) 3EC
- Gamma-cyhalothrin (Proaxis) 0.5EC
- Imidacloprid (Provado) 1.6F
- Lambda-cyhalothrin (Warrior) 1CS
- Spinosad (SpinTor) 2SC
- Thiamethoxam (Actara) 25WG
- Zeta-cypermethrin (Mustang Max) 0.8EC

Critical Issues: None identified at the present time.

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True Bugs Group

Pest Name: Stink bugs (Order: Heteroptera, Family: Pentatomidae**)**
Southern green stink bug (*Nezara viridula* (Linnaeus))
Green stink bug (*Acrosternum hilare* (Say))
Brown stink bug (*Euschistus servus* (Say))
Adult: Stink bugs are generally medium sized shield-shaped insects with broad 'shoulders', relatively straight sided, bluntly rounded abdomen. Stink bugs possess a dorsal, triangular shaped, shield on their backs. All stink bugs have piercing-sucking mouthparts. Probably the most common stink bug in vegetables in Georgia is the Southern Green Sting Bug. Adults are a uniform dull light green, thought the ventral

surface is paler. They are 13-17 mm long and about 8 mm wide. The green stink bug appears similar to the southern green but has a pointed spine between the last two legs. In the southern green stink bug, this spine is rounded. The brown stink bug and related species appear similar in shape to the southern green stink bug but are various shades of brown on the upper surface and tan to yellow on the lower surface.
Immature stages: Stink bug eggs are somewhat barrel-shaped and are deposited on end in closely packed clusters. Egg coloration, cluster size and arrangement of eggs within the cluster vary with species. The southern green sting bug lays cluster of 30-130 eggs. Clusters are deposited in hexagonal clusters with the eggs arranged in straight rows and glued together. Eggs are about 1.3 mm long, yellowish-white to pinkish-yellow, and the top of the egg is clearly indicated by a ring of tiny spines. Eggs darken near hatching. The southern green stink bug has five nymphal instars. Nymphs are shaped similar to the adults but lack wings. Wing pads are apparent and grow longer with each instar. Color varies with instar. First instar nymphs are yellowish-orange to brown. Second and third instar nymphs have a black head and throax and a reddish-black abdomen. Both the thorax and abdomen are marked with yellowish spots. The forth instar nymph may appear similar to the second and third instar or may be greenish with the thorax light green with black markings and the abdomen dark green with salmon shading and white markings. Coloration of the fifth instar is also variable. The head, thorax and wing pads range from light green to almost black. The abdomen is colored similar to the thorax and marked with rose and white spots. (Southern green stink bug) *Life cycle:* Eggs clusters are generally laid on the underside of leaves and hatch in about 5 days. Typically all eggs in a cluster will hatch within 1-1.5 hours. The southern green stink bug develops through five instars in about 32 days. Females begin oviposition about 14-20 days after attaining the adult stage.

Distribution, damage, and importance: Several species of stink bugs can damage tomatoes. Stink bugs have piercing-sucking mouthparts with which they puncture plant tissue and remove sap. The greatest damage results from feeding on fruiting structures. As it heals, the feeding site becomes hard and darkens. Seeds fed upon may be shriveled, deformed and shrunken, or may simply bear a dark spot and depression at the feeding site, depending on the stage of development when attacked. Similarly, damage to ears of corn and fruit varies greatly with the development stage at which the produce is fed upon. Damage early in development can lead to severe deformities and abscission while damage near harvest may result in small dark spots at the feeding site. Stink bugs can also introduce bacteria and yeast, or simply provide a site of entry for disease organisms, as they feed, resulting in fruit decay.

Chronology: Stink bugs are rarely of concern in flower vegetables prior to flowering. Although they can feed in leaves and stems, reproductive structures, such as corn ears, tomato and tomato fruit, seeds, and pods are preferred feeding sites. Populations can build rapidly once flowering is initiated.

Control measures used and recommended: Stink bugs are typically controlled with insecticides used throughout the fruit production period of susceptible crops. Identification of stink bug species involved prior to selection of insecticide is important as different species respond differently to insecticides and there are predatory species of stink bugs found in vegetables. Although sweep net sampling is an effective means of sampling stink bugs in beans and similar crops, in most vegetable crops sampling is conducted with visual examination of plants and fruiting structures.

Cultural/mechanical: Proximity to other host crops, such as cotton, can increase numbers.

Biological: Biological control of the southern green stink bug is provided by parasites, usually wasps and flies. In Florida a tachinid fly, *Trichopoda pennipes*, parasitizes adults and nymphs, and a wasp, *Trissolcus basalis*, parasitizes eggs. These two parasites have been introduced as biological control agents in places such as Australia and Hawaii to control the southern green stink bug. Recently California used *T. basalis* in an effort to control its southern green stink bug population.

Chemical: Stink bugs are typically controlled with insecticides particularly throughout the fruit production period when the tomato fruit are the most susceptible.

Chemicals used:

- Bifenthrin (Capture) 2EC
- Cyfluthrin (Baythroid) 2EC
- Lambda-cyhalothrin (Warrior) 1CS
- Zeta-cypermethrin (Mustang Max) 0.8EC

Critical Issues: No major concerns other than continued emphasis on IPM

Research:

1) Need to re-evaluate threshold treatments for bug pests of tomato for greater precision in IPM

Regulatory:

2) None identified at the present time

Education:

3) Current information on thresholds for bug pests need to be published and disseminated to end users

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Pest Name: Leaffooted bugs
(Order: Heteroptera, Family: Coreidae, *Leptoglossus* spp.)
Leaffooted bugs are brown, medium sized bugs which get their common name from the flattened leg segment of the hind leg, which gives this segment a leaf-like appearance. There are seven recorded species in the southeastern United States with *Leptoglossus phyllopus* being very common. They are medium sized bugs, usually about 20 mm long.

Adults are brown. Some species have a broad white strip across the body about midway between the head and tip of the abdomen. Most also have white markings on the leaf-like section of the hind leg. *Immature stages:* Eggs are about 1.4 mm long, barrel shaped, bronze to dark brown, and deposited in rows. Nymphs are orange, red, or reddish-brown and similar to adults in shape but lack wings. *Life cycle:* Eggs are deposited in rows on foliage or stem tissue and hatch in 5-7 days. Nymphs develop through 5 instars in 25-30 days. Typically only one generation has been observed per year in Georgia, with the long lived adults serving as the overwintering stage.

Distribution, damage, and importance: Can be an important pest of organic tomato production systems, but less common in commercial tomato. Leaffooted bugs have piercing-sucking mouthparts and damage crops similarly to stinkbugs. The greatest damage results from feeding on fruiting structures. As it heals, the feeding site becomes hard and darkens. Seeds fed upon may be shriveled, deformed, and shrunken, or may simply bear a dark spot and depression at the feeding site, depending on the stage of development when attacked. Similarly, damage to ears of corn and fruit varies greatly with the development stage at which the produce is fed upon. Damage early in development can lead to severe deformities and abscission, while damage near harvest may result in small dark spots at the feeding site.

Chronology: Adults emerge from overwintering under plant trash or mulch in late spring. Some species reproduce only on weeds while others will reproduce on vegetables. As fruit damage is the primary concern, movement into fields after flowering is the time of greatest concern.

Control measures used and recommended: Leaffooted bugs appear to be developing into a more consistent pest in Georgia, particularly on organic forms where they can readily overwinter under organic mulches, but are still considered as sporadic pests. Visual plant examination for all stages is the most common sampling method. Some species of leaffooted bug reproduce only on thistle, and weed management may reduce damage potential. When populations move into susceptible crops, they are generally controlled with insecticides.

Cultural/mechanical: A simple solution is to remove overwintering sites, such as organic mulches, but in organic production systems, water can drive bugs out of the mulch where they can be collected or destroyed mechanically.

Biological: Egg parasites, *Gryon* spp., often keep populations of leaffooted bug below economically damaging levels.

Chemical: Insecticides used for stinkbug control generally control this pest.

Chemicals used:

- Bifenthrin (Capture) 2EC
- Cyfluthrin (Baythroid) 2EC

- Lambda-cyhalothrin (Warrior) 1CS
- Zeta-cypermethrin (Mustang Max) 0.8EC

State/local pesticide restrictions or limitations, export issues, etc.: certified organic farmers have very few to no control options

Critical Issues: No major concerns other than continued emphasis on IPM

Research:

1) Need to re-evaluate threshold treatments for bug pests of tomato for greater precision in IPM
2) Need to identify organic control options

Regulatory:

3) None identified

Education:

4) Current information on thresholds for bug pests and organic control options need to be published and disseminated to end users

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Pest Name: Hornworms (Order: Lepidoptera, Family: Sphingidae)
Tomato hornworm (*Manduca quinquemaculata* (Haworth))
Tobacco hornworm (*Manduca sexta* (Linnaeus))
Hornworms are large, green, caterpillars with white diagonal markings. They reach a length of 3 inches. The most distinguishing characteristic of hornworms is the slender horn projecting backward from the rear of the body. Hornworms may feed on green fruit, but primarily feed on the foliage of tomato plants and may cause enough defoliation to allow sun scald of fruit. The adult moths deposit spherical translucent eggs, singly on the undersides of leaves. Treatments for hornworm control should be applied when one larva is found on 4 percent of the plants examined. *Adult:* These two species are similar in appearance. Both are large moths with a wingspan of 80 to 130 mm. The front wings are larger and much longer than the hind wings. Both species are grayish-brown or dull-gray moths with the abdomen marked by a series of orange-yellow spots down each side (six paired spots on the tobacco hornworm and 5 paired spots on the tomato hornworm). The abdomen tapers to a point. *Immature stages:* Eggs are spherical to oval and 1.25 to 1.5 mm in diameter. They are light green or yellow when laid and turn white at maturity. The larva is cylindrical, with 5 pair of prolegs (4 abdominal plus anal prolegs) and three pair of thoracic legs. Young larvae are yellowish-white but turn green with white diagonal markings on each side of abdominal segments. The most striking characteristic of these larvae is the presence of a thick pointed structure or 'horn' projecting backward from the top of the last abdominal segment. Last instar larvae are large, averaging about 8 cm in length. The large brown to reddish-brown pupae (45-60 mm long) possess a pronounced maxillary loop, which looks similar to a flattened handle on a teacup. *Life cycle:* There are likely 2 to 4 generations of these pests in Georgia. Both species overwinter in the

pupal stage. Females are reported to lay 250 to 350 eggs but can produce nearly 1400 eggs under favorable conditions. Eggs are laid singularly on foliage and hatch in about 5 days. Larvae go through 5 or 6 instars, starting at about 6.7 mm and reaching a length of about 8 cm. Larval development time averages about 20 days. The pupal stage occurs in the soil at a depth of 10 to 15 cm. The pupal stage in the summer generations averages about 51 days but can extend greater than 100 days.

Distribution, damage, and importance: Tobacco hornworm is an occasional pest in the summer fall production season. While these pests can occur on all the fruiting vegetables, they are common only on tomatoes. Although common, they generally are not of economic concern except in home gardens. The larvae are defoliators, generally attacking the upper portion of plants first. They generally consume entire leaves rather than chewing holes in leaves. About 90% of the foliage consumption occurs in the last instar. The color of the larvae makes them difficult to detect as they blend with the foliage. They are frequently not detected until they consume considerable foliage at the end of their development.

Chronology: There are 3-4 generations per year in northern Florida. Damage is much more severe in the fall production season.

Control measures used and recommended: Insecticides are the main tactic for control. While individual larvae can consume considerable foliage, populations of these pests seldom reach a level that justifies corrective action in commercial production

Cultural/mechanical: On one occasion, the use of metallic silver mulch was observed to result in more Lepidoptera pests. In home gardens, where individual plants are more valuable, hand picking usually provides adequate control.

Biological: *Bacillus thuringiensis* is effective against hornworm and preserve beneficial predators such as the spined soldier bug and parasitoids like braconid wasps or Trichogramma egg parasitoids.

Chemical: Insecticides used for armyworms generally control this pest.

Chemicals used:

- Acephate (Orthene) 97
- Bifenthrin (Capture) 2EC
- Carbaryl (Sevin) 80S
- Cyfluthrin (Baythroid) 2EC
- Deltamethrin (Decis) 1.5EC
- Esfenvalerate (Asana) .66EC
- Gamma-cyhalothrin (Proaxis) 0.5EC
- Lambda-cyhalothrin (Warrior) 1CS
- Methomyl (Lannate) 2.4LV and 90SP
- Methoxyfenozide (Intrepid) 2F
- Permethrin (Pounce) 3.2EC and (Pounce, Ambush) 25WP

- Spinosad (SpinTor) 2SC
- Zeta-cypermethrin (Mustang Max) 0.8EC

State/local pesticide restrictions or limitations, export issues, etc.: 24 c for methamidophos

Critical Issues: No major concerns other than continued emphasis on IPM

Research:

1) Need to re-evaluate threshold treatments for lepidopteran pests of tomato for greater precision in IPM

Regulatory:

2) None identified

Education:

3) Current information on thresholds for this pest need to be published and disseminated to end users

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Pest Name: Aphids (Order: Homoptera, Family: Aphididae)
Potato (*Macrosiphum euphorbiae* (Thomas)**)**
Green peach (*Myzus persicae* (Sulzer))
Aphids or plant lice are small, soft-bodied insects that may feed on tomato plants from time of planting until last harvest. Aphids cluster in shaded places on leaves, stems and blossoms. While winged migrants move from field to field spreading virus diseases such as Cucumber Mosaic Virus (CMV), host plant resistance in tomato has helped minimize this problem. CMV was a fairly widespread problem in the fall of 2006. Large populations of aphids on young plants can cause wilting and stunting but rarely occur. At harvest, infestations can become contaminations both through their presence and through production of honeydew which gives rise to sooty mold. Establishment of aphid colonies on tomato is often reduced by wet weather, but during cool, dry weather, large numbers of aphids may develop quickly. Aphid feeding causes newly formed leaves to be crinkled and malformed. While several species of aphids can occur on fruiting vegetables, the most frequent species of concern on these crops is the green peach aphid, and potato aphids can occur first in the spring in southern Georgia. *Adult:* Greenpeach aphid: Winged (alate) adults have a black head and thorax and a yellowish-green abdomen with a large dark patch in the middle of the abdomen as viewed from above. They measure about 2 mm in length. A key characteristic that separates GPA from other species of aphids found on vegetables are rounded projections at the base of the antennae (tubercles) that point toward the midline of the head. These projections are found on all stages. Wingless adults are yellowish, greenish, or reddish. The cornicles are long and colored similar to the body. Potato aphid: The adults vary in appearance occurring in a green or pink form. The wingless adult is 3-4 mm long, and the typical form in Georgia in the

spring is the pink form. The base of the antennae is smooth unlike the green peach aphid. *Immature stages:* Nymphs are very similar to wingless adults in shape and color but are smaller. Unlike most aphids, green peach aphids do not tend to form large colonies, but will generally be more evenly distributed across leaves. The pink form of the potato aphid is common in the spring in Georgia. *Life cycle:* In northern climates, the life cycle of the GPA is very complex with winter hosts and summer hosts. In vegetable crops in Georgia, winged adults invade fields and can do so throughout the production seasons. Both winged and wingless adults give birth to live young without mating (parthenogentic reproduction) on vegetable crops. Under favorable conditions, the aphids develop through 4 or 5 instars in about 1 week and give birth to offspring shortly thereafter, with generation time as short as 10 to 12 days. Females are reported to produce 1.6 to 3.75 nymphs per day over a 15 to 20 day reproductive cycle. The potato aphid life cycle is similar.

Distribution, damage, and importance: Aphid transmitted CMV was a fairly widespread problem in the fall of 2006 in South Georgia and aphids are common throughout the Southeast. Green peach aphids can build large populations on a variety of crops. On young plants they can cause wilting and stunting. At harvest they can represent a contaminant both through their direct presence and through production of honeydew which gives rise to sooty mold. In many crops, their greatest threat is transmission of viral diseases. This species transmits over 100 plant viruses, with both persistent and non-persistent transmission. Both adults and nymphs can transmit viruses, but winged adults are of greatest importance because of their mobility

Chronology: Green peach aphid can invade fruiting vegetables throughout the spring and fall production season, but typically are more of a problem in cooler parts of the fall season. In the spring, potato aphids disperse off of winter crops such as kale and spinach to solanaceous crops.

Control measures used and recommended: Green peach aphids are generally controlled with application of insecticides; however, insecticide resistance has been widely documented in this species. The red phase of this pest is reported to generally be more difficult to control. Potato aphids are often controlled by the natural occurrence of predators such as Coccinellid larvae. Aphid populations can be assessed by examining terminals and the undersides of leaves. Treatments for aphids in early spring plantings may be postponed until distinct colonies of immature aphids are found on greater than 10 percent of the plants. Aphids in late summer plantings are usually controlled by treatments for whiteflies; however in 2006, we experienced a high incidence of CMV even with controls such as Admire, so we have a recent, unresolved problem.

Cultural/mechanical: Use CMV resistant cultivars if available.

Biological: Many beneficials attack aphids, but in the case of virus transmission, this may not help the initial infection.

Chemical: Labeled insecticides are given below, but there can be varying degrees of efficacy and label restrictions. For preventative control, the neonicotinoids are usually applied at transplanting.

Chemicals used:

- Acephate (Orthene) 97
- Acetamiprid (Assail) 30SG
- Dimethoate 4EC and 2.67EC
- Dinotefuran (Venom) 20SG
- Disulfton (Di-Syston) 15G
- Endosulfan (Endosulfan/Thionex) 3EC
- Imidacloprid (Provado) 1.6F, (Admire) 2F, and (Admire Pro) 4.6F
- Lambda-cyhalothrin (Warrior) 1CS
- Malathion 8EC and 5EC
- Metasystox-R
- Oxamyl (Vydate) 2L
- Pymetrozine (Fulfill) 50WDG
- Thiamethoxam (Actara) 25WG and (Platinum) 2SC

State/local pesticide restrictions or limitations, export issues, etc.: A lot older chemistries tend to select for resistance quickly or may be losing registration.

Critical Issues: Determine the cause of this new aphid-transmitted CMV outbreak.

Research

1) We thought whiteflies might be involved somehow in the CMV outbreak this last fall, but the initial attempt to transmit CMV with whiteflies was unsuccessful, so we need to clearly determine the species and role of aphids or other possible vectors involved in the CMV outbreaks
2) Aphid vector biology and management studies are needed to address mosaic virus problems affecting vegetables in the Southeaster USA

Regulatory

1) Older insecticide chemistries may be losing registration which could be a problem for rotations used for resistance management

Education

1) Need general information disseminated to growers on aphid-transmitted viruses and their management

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European corn borer (*Ostrinia nubilalis* (Hubner)) The moths are fairly small, with males having a wingspan of 20-26 mm and females 25-34 mm. Adults caught in south Georgia are generally smaller than the ‘typical’ European Corn Borer from the mid-west corn belt. Females are pale-yellow to light brown, with darker zig-zag lines across the forewing and hind wing. Males are darker, usually pale brown, with dark zig-zag lines across the forewing and hind wing. Both sexes also have yellowish to gold colored patches on the wings which are more apparent against the darker background in the male. Eggs are oval, flattened and creamy white when first laid and darken with age. They are deposited in small clusters with the eggs overlapped like fish scales. Larvae tend to be light brown or pinkish-gray, with a brown to black head capsule. Full grown larvae are about 2 cm in length. The body is marked with darker circles on each segment along the midline of the back. Larvae are frequently referred to as having a 'greasy' look. Larvae can be easily confused with other borers present in plant stalks. *Life cycle:* Eggs are generally deposited in irregular clusters of about 15 to 20 on the underside of leaves and hatch in 4 to 9 days depending on the temperature. Larvae usually develop through 5 or 6 instars with a development period of over 30 days and a pupal stage of about 12 days. There are probably 3 or 4 generations in Georgia. European corn borer is considered to be the most important sweet corn pest in northern production regions. In Georgia, this pest is usually controlled by insecticide applications targeted at corn earworm.

Distribution, damage, and importance: In Georgia, the level of damage from ECB in pepper is usually minimal, but the presence of this pest in these crops restricts shipment to some states. ECB can attack all above ground parts of a corn plant including the leaves, stalk, tassels, silk, kernels, and cob. Older larvae tend to bore into the stalk, base of the ear, cob, or kernels. Larvae damage both the stem and fruit of beans and pepper. Trapping and treatment programs allow for shipment of these crops to California and Texas. For regulations associated with shipment of these crops to California or Texas, contact the Georgia Department of Agriculture. GDA currently maintains a monitoring program.

Chronology: European corn borer overwinter in the larval stage, with pupation and emergence of adults in early spring. Populations in Georgia generally do not reach very high levels, but are of concern in sweet corn, peppers and snap beans because of shipping restrictions associated with the presence of this pest. Where present, corn borer can attack vegetable crops throughout most of the production season, but early planted spring crops avoid pest pressure. Late spring crops and fall crops of favored hosts likely have more pressure.

Control measures used and recommended: In Georgia, European corn borer is generally controlled by insecticide applications targeting other pests. The regulatory programs for sweet corn, pepper, and snap bean require monitoring of ECB with pheromone traps, insecticide applications, and phyto-sanitary certificates depending on the crop involved and the state to which the produce will be shipped. For regulations associated with shipment of these crops to California or Texas, contact the Georgia Department of Agriculture.

Cultural/mechanical: Monitoring and sanitation can be used.

Biological: *Bacillus thuringiensis* is effective against corn borer and preserve beneficial predators such as the spined soldier bug and parasitoids like braconid wasps or Trichogramma egg parasitoids.

Chemical: This pest is usually controlled when other Lepidoptera pests are being treated. Control is mainly used to address the quarantine problem for peppers grown in Georgia that are bound for the west coast.

Chemicals used:

- Bifenthrin (Capture) 2EC
- Cyfluthrin (Baythroid) 2EC
- Deltamethrin (Decis) 1.5EC
- Emamectin benzoate (Proclaim) 5WDG
- Esfenvalerate (Asana) .66EC
- Gamma-cyhalothrin (Proaxis) 0.5EC
- Indoxacarb (Avaunt) 30 WDG
- Lambda-cyhalothrin (Warrior) 1CS
- Permethrin (Pounce) 3.2EC
- Spinosad (SpinTor) 2SC
- Zeta-cypermethrin (Mustang Max) 0.8EC

Critical Issues: None identified at the present time

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Pest Name: Tobacco budworm
(Order: Lepidoptera, Family: Noctuidae, *Heliothis virescens* (Fabricius))
Adult: Adults are medium sized moths with wingspans of 28-35 mm. Adults are variable in color, but the front wings are usually yellowish-brown and are crossed transversely by three dark bands. The hind wings are creamy white with a broad dark band near the wing margins, but the margin of the hind wing is creamy white. *Immature stages:* Eggs are pale green when first deposited, turn yellowish, and then darken with age. Eggs are shaped like a somewhat flattened sphere with ridges (18-25) radiating from the top-center. Larvae range in size from 1.5 mm at hatching to 25-36 mm at maturity. The head tends to be yellowish-brown, and the body color may be brown, green, pink, or sometimes yellow or maroon. The larvae closely resemble corn earworm larvae. A key characteristic that will separate corn earworm larvae from most other species encountered in vegetables is the presence of black microscopic spines on the cuticle. The pupal stage occurs in the soil. Pupae are 18 mm in length and mahogany-brown. *Life cycle:* Eggs are deposited individually on leaf tissue and hatch in 3-4 days. Females can lay about 300-500 eggs with as many as 1500 over their lifetime. Larvae can feed and develop on foliage but preferentially feed on buds. Larvae usually develop through 5-7 instars in 17-18 days at 25° C. Larvae fall to the ground and borrow into the soil to pupate. The pupal

stage last about 13 days in the summer and serves as the overwintering stage in the late fall.

Distribution, damage, and importance: Tobacco budworm is an occasional pest whose damage is caused only by the larvae. Larvae have chewing mouthparts and remove plant tissue. Although larvae can feed and develop on leaf tissue, the preferred feeding site in most crops is the buds in fruiting structures.

Chronology: Tobacco budworm can attack vegetable crops throughout most of the production season, but it has rarely been a problem in tomato.

Control measures used and recommended: Although this pest is significant in tobacco, it is rarely a problem in tomato. Adults can be monitored with pheromone or blacklight traps to estimate when moths invade or emerge, and relative densities or peak activity. In fruiting vegetables, larvae generally remain partially exposed or move from bud to bud providing exposure and better control can be obtained with insecticides. This pest is usually controlled when other Lepidoptera pests are being treated.

Cultural/mechanical: No specific methods used.

Biological: *Bacillus thuringiensis* is effective against budworm and preserve beneficial predators such as the spined soldier bug and parasitoids like braconid wasps or Trichogramma egg parasitoids.

Chemical: This pest is usually controlled when other Lepidoptera pests are being treated.

Chemicals used:

- Bifenthrin (Capture) 2EC
- Cyfluthrin (Baythroid) 2EC
- Deltamethrin (Decis) 1.5EC
- Emamectin benzoate (Proclaim) 5WDG
- Esfenvalerate (Asana) .66EC
- Gamma-cyhalothrin (Proaxis) 0.5EC
- Indoxacarb (Avaunt) 30 WDG
- Lambda-cyhalothrin (Warrior) 1CS
- Permethrin (Pounce) 3.2EC
- Spinosad (SpinTor) 2SC
- Zeta-cypermethrin (Mustang Max) 0.8EC

Critical Issues: None identified at the present time

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Tarnished Plant Bugs and Lygus Bugs. Tarnished plant and related bugs are sucking insects that primarily attack the young flower buds causing them to abort. Young flower buds turn yellow to black after tarnished plant bug feeding. Infestations may be heavy in spring plantings and fruit set can be poor if the bugs are not controlled. Both nymphs and adults feed on tomato. The nymphs are difficult to find unless high numbers are present. Scouting for the adults is relatively simple. Visually examine plants and treat if one adult per six plants is found.

Control measures used and recommended: Control has traditionally been limited to insecticides and only when noticeable damage is occurring in the field. Bugs are generally controlled when sprays for other insect pests are made.

Cultural/mechanical: None currently used in commercial tomato.

Biological: None currently used in commercial tomato.

Chemical:

Chemicals used:

- Bifenthrin (Capture) 2EC
- Cyfluthrin (Baythroid) 2EC
- Lambda-cyhalothrin (Warrior) 1CS
- Zeta-cypermethrin (Mustang Max) 0.8EC

Critical Issues: None identified at the present time, but reduced pesticide usage could lead to greater activity of bug pests in tomato.

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Pest Name: Wireworms (Order: Coleoptera, Family: Elateridae)
Southern potato (*Conoderus falli* (Lane))
Tobacco (*Conoderus vespertinus* (Fabricius))
Gulf (*Conoderus amplicollis* (Gyllenhal))

Description:
Adult: Adult click beetles are long, dark brown, and measure 6 to 10 mm long. The elytra, or wing covers, are striated with parallel small channels. When flipped on their back, the beetles will snap their head and abdomen in order to flip themselves over, making a click sound, hence the name click beetle. *Immature stages:* The larvae are called wireworms and are initially light colored but turn creamy to dark yellow with the head and pronotum becoming reddish orange. Mature larvae are about 17 mm long and 2 mm wide. *Life cycle:* The immature stages of wireworms occur in the soil and typically

feed on plant roots. The number of instars is 3-4, and development time in the spring and summer is 40-70 days, but the overwintering larvae can take 200 days to develop. The pupal stage occurs in the upper 10 cm of the soil.

Distribution, damage, and importance: Not a widespread problem. Wireworms feed on seeds, roots, stems, and tubers of many vegetable crops. In tomato and other solanaceous crops the main damage caused is crop stand loss. This typically occurs in non-fumigated production systems, such as organic production, and is generally not a problem in plastic culture production.

Chronology: There is one generation per year of the above species. Oviposition by adults occurs mainly March through September.

Control measures used and recommended: Grass cover crops, such as sorghum, are highly attractive to wireworms. Thus, it is not recommended to follow solanaceous crops after grass crops or fallow land without proper treatment to remove wireworms from the soil. Since there is only a single generation per year, soil treatment prior to the growing season can be very effective. In organic situations, flooding of fields for six weeks can remove wireworm infestations. Rotating with legume crops, which are not attractive to wireworms, can also help. Occasionally, baiting with whole corn, potato, carrots, or other attractive food buried in the top 10-15 cm of the soil can be useful in detecting a wireworm infestation.

Cultural/mechanical: Wireworms are associated with weeds and also tend to be greater following grass production in the field recently prepared for tomato.

Biological: None currently used in commercial tomato.

Chemicals used: Fumigation under plastic mulch beds eliminates this problem

State/local pesticide restrictions or limitations, export issues, etc.: Loss of methyl bromide

Critical Issues: None identified at the present time

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Pest Name: Cutworms (Order: Lepidoptera, Family: Noctuidae)
Black (*Agrotis ipsilon* (Hufnagel))
Granulate (*Agrotis subterranea* (Fabricius))
Adult: The moths of both cutworm species described here are fairly large, the black has a 40-55 mm wingspan and the granulate has a 31-43 mm wingspan. The forewing of the black is dark brown throughout, and that of the granulate cutworm is gray to light brown with a distinct double spot (one small round the other bean-shaped) located centrally.
Immature stages: Both species have small (<1mm in length) white eggs that are oviposited on the plant foliage. The granuate cutworm oviposites either singly or in small

clusters. The black cutworm lays eggs in clusters. There are usually six larval instars for each species, but this can vary from 5 to 9. Both have dark brown pupae that occur 3-12 cm below the soil surface.
Life cycle: The development from egg to adult is 35-66 days for black and 35-57 days for granulate cutworm. The duration of the larval (feeding) stages is 20-40 days for black and 22-32 days for granulate cutworm, so if detected in the field at planting, they can cause damage for the entire seedling stage of the crop.

Distribution, damage, and importance: Not a widespread problem. These cutworms, like their name indicates, cut the seedling plant off at the soil surface. This early season damage is the most important, because it causes direct stand loss and often results in reseeding or resetting transplants.

Chronology: Both cutworm species likely have four generations per year in Georgia, and moths are present from when they emerge from overwintering in March to October (overlapping generations).

Control measures used and recommended: If the season that one is planting in coincides with cutworm activity annually, then preventative or curative actions can be taken. Monitoring for adult flights can be done with pheromone traps in the spring and light traps in the summer and fall.

Cultural/mechanical: Cutworms are associated with weeds and also tend to be greater in wet spots in the field.

Biological: There are some natural enemies of cutworm, but they often need to be augmented and kept in moist conditions to be effective, such as the addition of entomopathogenic nematodes.

Chemical: Baits, insecticide treated bran-molasses mixtures are very effective when broadcast over the soil surface at the time of seeding or transplant. Sprays of soil treatments are also used at the first sign of cutworm activity.

Chemicals used:

- Bifenthrin (Capture) 2EC
- Cyfluthrin (Baythroid) 2EC
- Deltamethrin (Decis) 1.5EC
- Gamma-cyhalothrin (Proaxis) 0.5EC
- Lambda-cyhalothrin (Warrior) 1CS
- Permethrin (Pounce) 3.2EC
- Zeta-cypermethrin (Mustang Max) 0.8EC

State/local pesticide restrictions or limitations, export issues, etc.:

Critical Issues: None identified at the present time

Diseases and Nematodes General Overview

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The diseases that affect tomato include the following. Nematodes are small, slender, microscopic round worms which live in the soil. The root-knot nematode is the most common type affecting tomato in Georgia. If not managed, this pest can cause serious damage in light, sandy-textured soils. Three species of Root-Knot nematode (*Meloidogyne incognita*, *M. hapla*, *M. arenaria*) are the most damaging on tomato in Georgia. There are some soilborne diseases that affect tomatoes. These diseases can attack the crop from seedling stage through harvest and are referred to as crown-rot diseases. Many of these diseases, however, attack the foliage and fruit and are deposited there by water splash or by physical contact between the fruit and the soil**.** There are several foliar diseases of tomato, such as anthracnose and bacterial spot, which can cause losses each year. Some of these diseases are soilborne, some are seedborne, and some are carried to fields on air currents. Finally, there are virus induced diseases that have been a severe limiting factor in tomato production in Georgia for several years. Most virus diseases cause stunting, leaf distortion, mosaic leaf discoloration, and spots or discoloration on fruit. The distribution of virus-infected plants is usually random with symptomatic plants often bordered on either side by healthy, non-symptomatic plants. Virus diseases are almost always transmitted by insect vectors and the severity of a virus disease is usually tied to the rise and fall in the populations of these vectors from season to season and within a given season. However, some virus diseases are seed and mechanically transmitted. Only the viruses that have been the most problematic on tomato in Georgia will be covered in this section. These include Cucumber mosaic virus, Tobacco mosaic virus, Tobacco etch virus, Potato y virus, and Tomato spotted wilt virus.

Tomato Disease Management Research, Regulatory and Education Priorities

Research

1) Phytophthera management tactics need to be developed and validated for efficacy in commercial tomato production systems.
2) Effect of methyl bromide alternatives on soil-borne diseases—rhizoctonia, phytopthora, nematodes, pythium need investigation.
3) Host plant resistance needs to be further developed—TSWV, bacterial spot; including relationship of TSWV to fruit quality and irregular ripening
4) Seed-borne disease—bacterial spot, viruses need investigation.
5) Annual evaluations of efficacy continue to be critical.
6) Disease agent/insect vector interactions need much more study.
7) Application of chemicals using drip irrigation/chemigation needs refinement.

Regulatory

1) Monitoring by the departments of agriculture of diseases that could affect shipment of live materials into and out of the State should be increased.
2) Database for registered pesticides by state and commodity are needed.
3) Consequences of labeling changes of copper (bacterial spot) i.e. reduction in number of applications needs to be looked at.
4) Maintaining multiple modes of action for resistance management is critical.
5) Science-based buffer restrictions are needed accounting for impact on agricultural land usage.
6) Monitoring and regulation is needed of seed-borne diseases and transplants—including importation from other countries.

Education

1) Current information on tomato disease best management practices for each State needs to be centrally linked on a university maintained Tomato IPM website and then linked between States.
2) Web-based or hard copy publications of pest identification are needed that are user friendly.
3) Greater information and outreach is needed on post-harvest problems associated with diseases and other pests.
4) Field visits and hands-on IPM training of governmental regulatory personnel could result in better interaction regulators and end users.
5) Fact sheets for resistance management (mode of action) are needed.
6) Modeling of diseases (prediction), epidemiology of virus and vectors needs both research and extension efforts.
7) Need more public awareness of impacts of use restrictions on products and crops.

Ranking specific disease pests discussed at meeting on January 5, 2007
From the worst pest (1) to lesser pests

1. Bacterial Spot (Xanthomonas)
2. Tomato Spotted Wilt
3. Cercospora Leaf Spot
4. Target Spot
5. Southern Blight
6. Bacterial Wilt
7. Phythopthera capsici
8. Pythium
9. Rhisoctonia
10. Meloidogyne incognita - Root-Knot
11. Meloidogyne arenaria - Root-Knot
12. Fusarium Wilt
13. Cucumber Mosaic Virus
14. Geminiviruses
15. Cladisporium Leaf Mold
16. Pythnecrosis
17. Bacterial Speck
18. Tomato curl viruses

Other diseases discussed by not ranked:

Tobacco Etch Virus, Potato Y Virus, Anthracnose (Colletotrichum), Meloidogyne hapla - Root-Knot

Disease Pest-by-Pest General Profiles

<u>FOLIAR DISEASES</u>

There are several foliar diseases of tomato that can cause losses each year. Some of these diseases are soilborne, some are seedborne, and some are carried to fields on air currents.

Bacterial Spot

Bacterial spot is the most common and often the most serious disease affecting tomatoes in Georgia. This disease is caused by the bacterium *Xanthomonas axonopodis* pv. *vesicatoria*. Bacterial spot lesions can be observed on leaves stems and fruit and occurs during all stages of plant growth. Leaf lesions usually begin as small water-soaked lesions that gradually become necrotic and brown in the center. During wet periods the lesions appear more water-soaked. Lesions generally appear sunken on the upper surface and raised on the lower surface of infected leaves. During periods of favorable weather, spots can coalesce and cause large areas of chlorosis. Premature leaf drop is the ultimate result of leaf infection. Fruit lesions appear as small, round, dark brown to black spots.

The bacterium is primarily seed-borne and most epidemics can be traced back, directly or indirectly, to an infected seed source. Infected seedlings carry the disease to the field where it spreads rapidly during warm, wet weather. Workers working in wet fields can also be a major source of disease spread. All tomato seed planted for transplants, or direct seeded field grown tomatoes should be tested by a reputable seed testing company. Transplants should be inspected for bacterial spot lesions before being sold or planted in the field.

Prevention is the best method for suppressing losses to bacterial spot. Seed should be purchased from companies that produce the seed in areas where the disease is not known to occur. Hot water seed treatment can also be used and tomato seed can be soaked in water that is 122 degrees F for 25 minutes to kill the bacterium. Transplant production should take place in areas away from commercial production so as to avoid contamination from production fields or vice versa.

Unlike pepper, tomatoes have little to no commercially available cultivars resistant to bacterial spot. Rotate away from fields where tomatoes have been grown within the last year and use practices that destroy volunteer plants that could allow the disease to be carried over to a subsequent crop. Cull piles should be located away from production fields or transplant houses. Copper fungicides used in conjunction with maneb will suppress disease losses if applied on a preventive schedule with a sprayer that gives adequate coverage.

Anthracnose

There are really two anthracnose diseases of tomato caused by *Colletotrichum acutaum* and *gloeosporioides*. Both of these fungi cause diseases primarily on fruit. *C. gloeosporioides* causes disease on ripe fruit and *C. acutatum* causes disease on both immature and ripe fruit. Lesions are usually round and sunken and can be over an inch in diameter depending on the size of the fruit. Initially, lesions will contain a small area of tan to pink sporulation near the center. In Georgia, *C. acutatum* has recently been associated with the more serious outbreaks. Anthracnose can be introduced to a field through contaminated seed or be sustained infested plant debris. This disease is favored warm, wet, humid weather. This disease controlled by using disease-free seed and rotating away from fields with a known of losses to anthracnose. Preventive fungicide applications are also recommended.

DISEASES CAUSED BY VIRUSES

Virus diseases have been a severe limiting factor in tomato production in Georgia for several years. Most virus diseases cause stunting, leaf distortion, mosaic leaf discoloration, and spots or discoloration on fruit. The distribution of virus-infected plants is usually random with symptomatic plants often bordered on either side by healthy, non-symptomatic plants. Virus diseases are almost always transmitted by insect vectors and the severity of a virus disease is usually tied to the rise and fall in the populations of these vectors from season to season and within a given season. However, some virus diseases are seed and mechanically transmitted. Only the viruses that have been the most problematic on tomato in Georgia will be covered in this section.

Tomato spotted wilt virus (TSWV)

TSWV is on the most common viruses affecting tomato in the southeastern U.S. This virus is transmitted by thrips and can affect tomato at any stage of development. The extensive host range of TSWV in weeds allows for a continual source of inoculum for infection. However, as with any virus disease, early infections tend to cause more yield losses than those occurring later in plant development. TSWV causes plant stunting, ringspots, and bronzing on infected plants. Tomato fruit produced on infected plants may be misshapen, have dark streaks, or have chlorotic spots. TSWV in Georgia tomato has been suppressed through the use of black plastic and other colored mulches as well as resistant varieties.

Cucumber mosaic virus (CMV)

CMV is a very common disease of tomato and can be very devastating where it occurs. This virus is transmitted by aphids and can be maintained in several weed species that surround production fields. The characteristic symptom for CMV is severely stunted, distorted, and strapped (faciated) leaves, stems, and petioles. Symptoms of CMV can also cause an oak-leaf type pattern on leaves by causing necrosis and/or leaf discoloration along leaf veins. Few options are available for suppressing losses to CMV, however, destruction of weed hosts that harbor the virus will aid in suppressing disease spread.

Recommended practices in chronological order are as follows:

1. Rotation with non-solanaceous crops reduces potential inoculum from anthracnose.
2. Use bacterial spot resistant varieties if available.
3. Avoid stringing or staking tomatoes when field are wet.
4. Spray copper + maneb beginning at transplanting and carry through harvest for bacterial spot.
5. Begin alternating in Quadris, Cabrio, or Tanos prior to fruit formation for anthracnose. **Note** (be sure to follow label on high fungicide resistance risk products like these).

SOILBORNE DISEASES

There are some soilborne diseases that affect tomatoes. These diseases can attack the crop from seedling stage through harvest and are referred to as crown-rot diseases. Many of these diseases, however, attack the foliage and fruit and are deposited there by water splash or by physical contact between the fruit and the soil.

Phytophthora fruit and crown rot

This disease is caused by the organism *Phytopthora capsici*. Phytopthora is a fungus-like organism that is in a separate kingdom than the fungi. It is a water-mold, oomycete organism that has a mobile swimming-spore stage as part of it's life cycle. This particular disease is one of the most common and arguably the most destructive of tomato in Georgia, rivaled only by bacterial spot and TSWV in order of importance and yearly yield losses. Symptoms of Phytophthora fruit and crown rot are usually dead or wilted plants that begin dying in the section of the field that is most poorly drained. The crown region of the plant near the base is usually darkened, sunken and necrotic. Vascular discoloration can be observed in tissues above the ground. The disease generally spreads to other areas of the field through moving water (either irrigation or rain), equipment or workers. The foliar and fruit phase of the disease is rarely observed in Georgia. Control of Phytophthora fruit and crown rot is achieved by avoiding fields with a history of the disease, both in tomato and other crops. If ponds are used for irrigation they may be contaminated with the disease and should be identified and avoided. Resistant varieties have recently been made available that show good to fair resistance to this disease. Fungicide applications have been recommended and do show some benefits but fungicide resistance problems coupled with the subterranean nature of the organism hinder consistent performance of preventive or remedial fungicide treatments.

Pythium Damping-Off and Root Rot

Soilborne diseases like *Pythium* and *Rhizoctonia* can cause early season stand losses by attacking the young, juvenile tissues and roots of young plants. In seedlings, a watery soft-rot (Pythium) or a sunken, dark, dry lesion (*Rhizoctonia*) occurs at the soil line and results in the wilting and sometimes sudden death of seedlings. Many times affected roots appear dark and slough off easily when infected with *Pythium*.

These diseases are best controlled by using disease-free transplants, and rotating tomatoes behind non-legume crops that tend to increase populations of both pathogens. Other control measures are avoiding poorly drained fields, over-irrigation, and using mefenoxam-containing fungicides (*Pythium*) or PCNB or azoxystrobin-containing fungicides (*Rhizoctonia*) at or just prior to planting. Fumigation with methyl bromide, chloropicrin, or metam sodium will reduce losses to these diseases as well.

Southern stem rot

Southern stem rot (*Sclerotium rolfsii*) is a common destructive disease of tomatoes in Georgia. Since most tomatoes are rotated with peanuts, soybeans and other susceptible crops, the disease has become a major problem. The fungus attacks the stem of the plant near or at the soil line and forms a white mold on the stem. Later in the season, small, round brown bodies appear in the mold. Infected plants wilt and slowly die. Vascular discoloration can be observed on stem tissues above the lesion.

The severity of this disease can be lessened by following good cultural practices: rotation, litter destruction and deep turning with a moldboard plow are the best cultural defenses against this disease. Fumigation as well as at-plant and drip-applied fungicides are also effective in reducing losses to southern stem blight.

Recommended practices in chronological order are as follows:

1. Rotation with non-solanaceous crops reduces potential inoculum of all of the above diseases.
2. Deep turning with a moldboard plow will help with all diseases except *Pythium*.
3. Plant varieties resistant to known Fusarium wilt races.
4. Fumigation with methyl bromide will suppress all soilborne diseases to some degree but bacterial wilt and Fusarium wilt will continue to cause significant problems. Alternatives to methyl bromide that suppress diseases are Telone C-35, K-Pam, Vapam, and chloropicrin. Telone products are nematicidal. However, roots will grow out of the treated zone and may still be susceptible to Fusarium wilt.
5. Terraclor can be used as an at-plant drench to suppress Southern stem rot.
6. Products containing mefenoxam (Ridomil, UltraFlourish) can suppress losses to *Pythium.*

NEMATODES

Nematodes are small, slender, microscopic round worms which live in the soil. The root-knot nematode is the most common type affecting tomato in Georgia. If not managed, this pest can cause serious damage in light, sandy-textured soils. Three species of Root-Knot nematode (*Meloidogyne incognita*, *M. hapla*, *M. arenaria*) are the most damaging on tomato in Georgia.

Symptoms

Root-knot nematodes enter young tomato feeder roots during their common feeding process, causing the roots to swell. The most common below-ground symptom is the formation of galls or knots on the roots. Nematode injury interferes with the uptake of water and nutrients, thus giving the top portion of the plants an appearance which resembles a lack of moisture or a fertilizer deficiency. Stunting, yellow, irregular growth of plants in the field and rapid decline are also above ground symptoms of nematode injury. Nematode feeding damage may also predispose plants to other soilborne diseases.

Management Options

Rotating tomato with a grass crop, such as rye, is somewhat beneficial in controlling root-knot, but this practice is no substitute for nematicidal fumigants if nematode levels are high. Nematicides currently used are methyl bromide, Telone II, Telone C-35, chloropicrin, and metam-sodium Depending on the weather, nematicidal fumigants must be applied 10 days to 3 weeks prior to planting to avoid phytotoxicity to young tomato plants. Oxamyl is a non-fumigant insecticide/nematicide that can be used at-planting and post-planting on tomatoes but generally is not as suppressive against nematodes as fumigants.

Fungicide Use Table

	Area Applied[1]	Number of Applications	Rate Per Application (lbs. a.i./acre)	Rate Per Season (lbs. a.i./acre)	Total Applied (1,000 lbs.)
copper	99	10	0.35-0.79	1.05-2.37	19.0.0-43.0
maneb	99	10	1.5-2.25	3.0-4.5	81.6-122.4
mefenoxam	40	1	1.0	1.0	2.2
azoxystrobin	25	4	0.1	0.6	0.55
pyraclostrobin	25	4	0.11	1.2	0.60
pentachloronitrobenzene	25	1	4.8-7.5	4.8-7.5	6.6-10.3
1,3-d dichloropropene	20	1	29.5-39.4	29.5-39.4	32.4-43.4
famoxadone + cymoxanil	10	3	0.25	2.25	.41

[1] The acreage estimate for 2005 was near 5500 acres.

Disease Pest-by-Pest Specific Chemicals Used

Pest Name: bacterial leaf spot (Xanthomonas axonopodis pv. vesicatoria)

Chemicals used:

- Bonide Liquid Copper Fungicide (H)
- Cabrio
- Champ (DP, 2F, F)
- Citcop 4-E (H)
- Copper Count-N (H)
- Cuprofix Disperss
- Dragon Copper Fungicide (H)
- Endura
- Forum
- Hi-Yield Copper Fungicide .
- Kocide (101, DF, LF, 4.5, LF, 2000)
- Manex (75DF, 80WP)
- Nu-Cop (50DF, 3L)
- Tanos - (3 day PHI)
- Top Cop Tri-Basic (H)
- Tri Basic Copper (H)

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Pest Name: Virus Diseases [Tobacco Mosaic Virus (TMV), Tobacco Etch Virus (TEV), Potato Virus Y (PVY), Cucumber Mosaic Virus (CMV), Tomato Spotted Wilt Virus (TSWV), geminiviruses and others]

Chemicals used: SAR materials such as Messenger®

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Pest Name: Southern Blight (*Sclerotium rolfsii*)

Chemicals used:

- Terraclor or PCNB 75WP (H)

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Pest Name: Crown and Fruit Rot (*Phytopthora capsici*)

Chemicals used:

- Bonide Liquid Copper Fungicide (H)
- Cabrio
- Champ (DP, 2F, F)
- Citcop 4-E (H)
- Copper Count-N (H)
- Cuprofix Disperss
- Dragon Copper Fungicide (H)
- Endura
- Forum
- Hi-Yield Copper Fungicide .
- Kocide (101, DF, LF, 4.5, LF, 2000)
- Manex (75DF, 80WP)
- Nu-Cop (50DF, 3L)
- Tanos - (3 day PHI)
- Top Cop Tri-Basic (H)
- Tri Basic Copper (H)

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Pest Name: damping off and root rot seedling diseases (Pythium and Rhizoctonia spp.)

Chemicals used:

- Ridomil Gold EC
- Ridomil Gold /Copper
- Previcur Flex
- Tanos

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Pest Name: nematodes

Chemicals used:

- Methyl bromide 67%
- Chloropicrin 33%
- Nemacur 15% G
- Vydate L
- Telone II
- Telone EC
- Telone C-17
- Sectagon
- K-Pam
- Chloropicrin
- Vapam
- Terr-O-Gas 67
- Inline

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Pest Name: Anthracnose (*Gloeosporium piperatum*)

Chemicals used:

- Bonide Liquid Copper Fungicide (H)
- Cabrio
- Champ (DP, 2F, F)
- Citcop 4-E (H)
- Copper Count-N (H)
- Cuprofix Disperss
- Dragon Copper Fungicide (H)
- Endura
- Forum
- Hi-Yield Copper Fungicide
- Kocide (101, DF, LF, 4.5, LF, 2000)
- Manex (75DF, 80WP)
- Nu-Cop (50DF, 3L)
- Tanos - (3 day PHI)
- Top Cop Tri-Basic (H)

- Tri Basic Copper (H)

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Pest Name: Alternaria

Chemicals used:

- Bonide Liquid Copper Fungicide (H)
- Cabrio
- Champ (DP, 2F, F)
- Citcop 4-E (H)
- Copper Count-N (H)
- Cuprofix Disperss
- Dragon Copper Fungicide (H)
- Endura
- Forum
- Hi-Yield Copper Fungicide
- Kocide (101, DF, LF, 4.5, LF, 2000)
- Manex (75DF, 80WP)
- Nu-Cop (50DF, 3L)
- Tanos - (3 day PHI)
- Top Cop Tri-Basic (H)
- Tri Basic Copper (H)

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Pest Name: Blossom End Rot

Chemicals used:

- CAB (H)

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Tomato Weed Management General Overview

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Effective weed management is one of many critical components of successful tomato production in Georgia. Weeds compete with tomato for light, nutrients, water, and space as well as interfere with harvesting practices. Additionally, weeds can harbor deleterious insects and diseases. Severe weed infestations can reduce yield at least 50% even when tomato are produced on plasticulture.

Weeds that usually cause problems in tomato are summer annual weeds including yellow and purple nutsedge, morningglory, purslane, nightshade, pigweeds, and annual grasses.

One of the most effective tools for suppressing weeds in tomato is a healthy, vigorous crop. Good crop management practices that result in rapid tomato canopy development help minimize the effects of weeds.

Cultural Control Methods

Site selection can play a significant role in weed management. Rotation away from fields infested with troublesome weeds, such as nutsedge, may minimize the presence of these weeds and allow for the use of alternative crops and control methods. Additionally, so as to prevent weed spread from field to field during harvest, equipment and personnel should be cleaned when moving from heavily infested areas. This precaution can be of significant consequence in preventing or minimizing the introduction of new weeds species into ‘clean areas’.

Mechanical Control Methods

Mechanical control methods include field preparation by plowing or discing, cultivating, mowing, hoeing and hand pulling of weeds. Most of Georgia’s and South Carolina’s tomatoes are produced on mulch thereby limiting the practicality of most mechanical control methods. Of course, hoeing and hand pulling of weeds is quite common. For those growers producing tomato on bareground, mechanical control practices such as cultivation and primary tillage are very beneficial for managing weeds.

Biological Controls

Biological controls do not exist at this time for weed pests of tomato common to Georgia.

Mulching

The use of polyethylene mulch increases yield and earliness of vegetables. Mulches act as a barrier to the growth of most weeds. Nutsedge, however, is one weed that can and will penetrate through the mulch. Additionally, weeds that emerge in the transplant hole will greatly reduce yield and quality of the crop. Thus, fumigants and or herbicides are often used in conjunction with mulch.

Fumigants

Currently, methyl bromide is the fumigant of choice in tomato production because it is extremely effective in controlling diseases, nematodes, and weeds and most growers are comfortable applying this fumigant. Unfortunately, methyl bromide is being removed from the market place. The University of Georgia has been and continues to conduct many research trials searching for suitable methyl bromide alternatives. Large acreage on farm trials evaluating potential alternatives began during 2006. Contact your local extension office for up-to-date information on alternatives to methyl bromide. In general, fumigants are restricted use chemicals and must be handled carefully by a certified applicator. Apply all fumigants in full compliance with label recommendations and precautions.

Herbicide Control Options

For herbicide recommendations contact your local extension office or view the most recent Georgia Pest Control Handbook or the Southeastern US Vegetable Crop Handbook.

Specific herbicides and their use patterns:

- **Carfentrazone** (Aim 2.0 EC or 1.9 EW)
  - *Target weeds:* Morningglory, pigweed, and spiderwort.
  - *Percent acres treated:* 25
  - *Average rate and frequency of application:* 1 application of 0.023 lb ai/A per crop
  - *Use rate and application method:* Aim 2 EC -- 0.013 to 0.023 lb ai/A (0.8 to 1.5 fl. oz of product/A). Applied prior to planting, as a row middle application, or as a post harvest application. Primarily used for post-harvest application.
- **Clethodim** (Select 2 EC, numerous generic formulations)
  - *Target weeds:* Annual and perennial grasses.
  - *Percent acres treated:* 30
  - *Average rate and frequency of application:* 1 application of 0.13 lb ai/A per crop
  - *Use rate and application method:* Select 2 EC -- 0.09 to 0.25 lb ai/A (6 to 16 fl oz of product/A). Applied overtop of crop up until 20 days of harvest.

- **Glyphosate** (4 SL, 5 SL, 5.5 SL, 6 SL)
  - *Target weeds:* Annual and perennial grass and broadleaf weeds.
  - *Percent land acres treated:* 90
  - *Average rate and frequency of application:* 1 application of 1.0 lb ai/A per crop
  - *Use rate and application method:* Numerous glyphosate brands available (0.5 to 1.5 lb ai/A). Applied preplant, row middle, or post harvest. Primary used for post-harvest.
- **Halosulfuron-methyl** (Sandea 75 DG)
  - *Target weeds:* Yellow and purple nutsedge and pigweed.
  - *Percent acres treated:* 30
  - *Average rate and frequency of application:* 1 application at 0.036 lb ai/A per crop
  - *Use rate and application method:* Sandea 75 DG – 0.024 to 0.036 lb ai/A (0.5 to 0.75 oz of product/A). Applied preplant, overtop of crop, or in row middles. Primary use is topical applications.
- **Metam Sodium** (Vapam HL 42%)
  - *Target weeds:* Annual grasses, broadleaf weeds, and nutsedge.
  - *Percent acres treated:* 40
  - *Average rate and frequency of application:* 1 application at 16 lb ai/A per crop
  - *Use rate and application method:* Vapam HL – 15.7 to 31.5 lb ai/acre (37.5 to 75 gal. of product/A). Applied preplant or post harvest through drip injection.
- **Methyl Bromide** (MB 67:33)
  - *Target weeds:* Annual and perennial weeds.
  - *Percent acres treated:* 75
  - *Average rate and frequency of application:* 1 application of 235 lb ai/A
  - *Use rate and application methods:* Methyl Bromide 67:33 -- 235 lb ai/A (350 lb of product/A). Applied preplant with usually two additional cropping systems after this fumigation.
- **Metribuzin** (Sencor DF 75 WDG)
  - *Target weeds:* Annual grasses and broadleaf weeds.
  - *Percent acres treated:* 15
  - *Average rate and frequency of application:* 1 application at 0.25 lb ai/A per crop
  - *Use rate and application method:* Sencor DF 75 WDG – 0.25 to 0.5 lb ai/A (0.3 to 0.66 lb of product/A). Applied preplant, topically, or as a row middle application. Primary use is row middle applications.
- **Napropamide** (Devrinol 50 WDG)
  - *Target weeds:* Annual grasses and small-seeded broadleaf weeds.
  - *Percent acres treated:* <2%.
  - *Average rate and frequency of application:* 1 application of 1.5 lb ai/A per crop
  - *Use rate and application methods:* Devrinol 50 WDG -- 1.0-2.0 lb ai/A (2-4 lbs of product/A). Applied preplant prior to transplanting.

- **Paraquat** (Gramoxone Inteon 2 SL)
  - *Target weeds:* Contact kill of all green foliage, effective on many annual weeds.
  - *Percent land acres treated*: 50
  - *Average rate and frequency of application:* 1 applications of 0.56 lb ai/A per crop
  - *Use rate and application method:* Gramoxone Inteon 2 SL – 0.56 to 1.0 lb ai/A (2.5 to 4.0 pt of product/A). Applied preplant, in row middles, or post harvest. Primarily used in row middles and post harvest.
- **Trifluralin** (Treflan, others)
  - *Target weeds:* Annual grasses and small-seeded broadleaf weeds.
  - *Percent land acres treated:* <1%
  - *Average rate and frequency of application:* 1 application of 0.5 lb ai/A per crop
  - *Use rate and application method:* Treflan – 0.5 lb ai/A (1 pt of product/A). Applied as a preplant application.
- **Rimsulfuron** (Matrix 25 WDG)
  - *Target weeds:* Broadleaf weeds including wild radish, common purslane, pigweeds and some annual grasses.
  - *Percent land acres treated:* <5
  - *Average rate and frequency of application:* 1 application of 0.2 lb ai/A
  - *Use rate and application method:* Matrix 25 WDG – 0.015 to 0.03 lb ai/A (1 to 2 oz of product/A). Applied as a row middle or topical application.
- **S-metolachlor** (Dual Magnum 7.62 EC)
  - *Target weeds:* Annual grass and broadleaf weeds, yellow nutsedge suppression.
  - *Percent land acres treated:* 30
  - *Average rate and frequency of application:* 1 application of 0.95 lb ai/A per crop
  - *Use rate and application method:* Dual Magnum 7.62EC – 0.7 to 0.95 lb ai/A (12 to 16 fl. oz of product/A). Applied preplant or as a row middle application.
- **Sethoxydim** (Poast 1.53 EC)
  - *Target weeds:* Annual and perennial grasses.
  - *Percent acres treated:* 10%
  - *Average rate and frequency of application:* 1 application of 0.3 lb ai/A per crop
  - *Use rate and application method:* Poast 1.53 EC– 0.19 to 0.3 lb ai/A (1 to 1.5 pt of product/A). Applied overtop of crop up until 20 days of harvest.
- **Trifloxysulfuron** (Envoke 75 WG)
  - *Target weeds:* Nutsedge and annual *Ipomoea* morningglory.
  - *Percent acres treated:* <1%
  - *Average rate and frequency of application:* 1 application of 0.0047 lb ai/A per crop

- *Use rate and application method:* Envoke 75 WG – 0.0047 to 0.0094 lb ai/A (0.1 to 0.2 oz of product/A). Applied as a hooded spray for row middles only.

Stale Seedbed

Herbicide options in tomato are limited, thus, the use of a stale seedbed approach prior to planting tomato on bareground or prior to transplanting into mulch can be useful. A stale seedbed approach is one where the weeds are allowed to emerge and then treated with a non-selective herbicide (glyphosate or paraquat usually) prior to planting. Both glyphosate and paraquat can be removed from mulch with a rainfall or irrigation event of at least 0.5 inch which must occur prior to planting.

Post Harvest Control Options

Glyphosate, paraquat, carfentrazone, and metam sodium are all used as post harvest tools to manage both weeds and the previously grown tomato crop. The current program recommended by the University of Georgia is an application of metam sodium injected through drip irrigation followed by a topical application of glyphosate plus carfentrazone, assuming drift issues are addressed properly. This program should provide the grower with a clean plant bed for the following crop.

Weed Identification and Weed Species Commonly Found Throughout Georgia Tomato

Identification of weeds: Correct identification of a weed species can be obtained through the county agent and several publications. Online resources such as the weed management links include the following: http://www.weeds.iastate.edu/weed-id/weedid.htm, http://www.ppws.vt.edu/weedindex.htm

Weed species in Georgia in tomato landscapes.

Common name	Family	Genus	species	Type
Asiatic dayflower	Commelinaceae	Commelina	communis L.	Annual
bristly starbur	Asteraceae	Acanthospermum	hispidum DC.	Annual
carpetweed	Aizoaceae	Mollugo	verticillata L.	Annual
chickweed, common	Caryophyllaceae	Stellaria	media(L.) Vill.	Annual
coffee senna	Fabaceae	Cassia	occidentalis L.	Annual
crabgrass sp.	Gramineae	Digitaria	sanguinalis L.	Annual
cudweed sp.	Asteraceae	Gnaphalium	sp.	Annual
cutleaf	Onagraceae	Oenothera	laciniata Hill	Annual

eveningprimrose				
dayflower, spreading	Commelinaceae	Commelina	diffusa Burm. f.	Annual
eclipta	Asteraceae	Eclipta	prostrata L.	Annual
fleabane	Asteraceae	Erigeron	sp.	Biennial
Florida beggarweed	Fabaceae	Desmodium	tortuosum (Sw.) DC.	Perennial
Florida pusley	Rubiaceae	Richardia	scabra L.	Annual
goosegrass	Gramineae	Eleusine	indica	Annual
groundcherry sp.	Solanaceae	Physalis	sp.	Perennial
henbit	Laminaceae	Lamium	amplexicaule L.	Annual
horseweed	Asteraceae	Conyza	canadensis (L.) Cronq.	Annual
lambsquarters, common	Chenopodiaceae	Chenopodium	album L.	Annual
livid amaranth	Amaranthacea	Amaranthus		Annual
morningglory, entireleaf	Convolvulaceae	Ipomoea	hederacea var. integriuscula Gray	Annual
morningglory, ivyleaf	Convolvulaceae	Ipomoea	hederacea (L.) Jacq.	Annual
morningglory, pitted	Convolvulaceae	Ipomoea	lacunosa L.	Annual
morningglory, smallflower	Convolvulaceae	Jacquemontia	tamnifolia (L.) Griseb.	Annual
palmer amaranth	Amaranthaceae	Amaranthus	palmeri S. Wats.	Annual
Pennsylvania smartweed	Polygonaceae	Polygonum	pensylvanicum L.	Annual
pigweed, redroot	Amaranthaceae	Amaranthus	retroflexus L.	Annual
pigweed, smooth	Amaranthaceae	Amaranthus	hybridus L.	Annual
pink purslane	Portulacaceae	Portulaca	pilosa L.	Annual
pokeweed, common	Phytolaccaceae	Phylotacca	americana L.	Perennial
prickly sida	Malvaceae	Sida	spinosa L.	Annual
ragweed, common	Asteraceae	Ambrosia	artemisiifolia L.	Annual
redweed	Polygonaceae	Melochia	corchorifolia L.	Perennial
sicklepod	Fabaceae	Senna	obtusifolia (L.) Irwin and Barneby	Annual
spiny amaranth	Amaranthaceae	Amaranthus	spinosus L.	Annual
spiny sowthistle	Asteraceae	Sonchus	asper (L.) Hill	Annual
spurge	Euphorbiaceae	Euphorbia	sp.	Annual
swinecress	Brassicaceae	Coronopus	didymus (L.) Sm.	Annual
Texas panicum	Gramineae	Panicum	texanum	Annual
tropic croton	Euphorbiaceae	Croton	glandulosus var. septentrionalis Muell	Annual
Virginia pepperweed	Brassicaceae	Lepidium	virginicum L.	Annual
wild poinsettia	Euphorbiaceae	Euphobia	heterophylla L.	Annual
wild radish	Brassicaceae	Raphanus	raphanistrum L.	Annual

Other Issues

Herbicide options are extremely limited in tomato because the potential for herbicide injury and related liability issues far outweigh potential sales returns.

Tomato Weed Management Research, Regulatory and Education Priorities

Research

1) Herbicide resistance in weeds needs to be monitored and its distribution mapped for the State.
2) Effect of methyl bromide alternatives on common weeds such as morning glory, nutsedges, and pigweed (including new chemistries and tactics) needs research.
3) Science-based justification for fumigant use restrictions (buffers, etc) should be further studied.
4) Geo-reference mapping of emerging pests (herbicide resistant and exotic weeds) needs to be done in Georgia and South Carolina.
5) Weed host interaction with disease, insect, and nematode pests needs further investigation to help with farmscape management.
6) Research for IR-4 labeling continues to be critical.

Regulatory

1) Pesticide regulators should consider new labeling requirements for the management of herbicide resistance in the State.
2) Critical use exemptions should be continued for methyl bromide.

Education

1) Current information on tomato IPM for each State needs to be centrally linked on a university maintained Tomato IPM website and then linked between States.
2) Web based or hard copies of pest identification are needed that are user friendly.
3) Fact sheets and training for resistance management (mode of action) especially for glyphosate resistance are needed.
4) On-site extension visits including hands-on training needs to be expanded.
5) Maintain local-level (county) delivery system!

Ranking of specific weed pests which we discussed on January 5, 2007
From the worst pest (1) to lesser pests

1. Yellow and purple nutsedges
2. Goosegrass
3. Purslane species
4. Prickly sida
5. Redweed
6. Nightshade
7. Morning Glory
8. Wild radish
9. Parthenium
10. Pennsylvania
11. Lambsquarters
12. Palmer amaranth
13. Smartweed
14. Cutleaf evening primose
15. Eclipta
16. Florida pusley
17. Pink purslane
18. Bristley starbur
19. Crabgrass sp.
20. Groundcherry sp.
21. Common ragweed
22. Sicklepod
23. Spurge
24. Swinecress
25. Henbit
26. Chickweed
27. Carpet weed
28. Tropic croton

Other weed discussed but not ranked:

Redroot pigweed, Smooth pigweed, Spiny amaranth, Barnyardgrass, Ryegrass, Panicums, Johnsongrass, Narrowleaf cudweed, Purple cudweed, dayflower spreading, fleabane, Florida beggarweed, horseweed, common pokeweed, Asiatic dayflower, Carolina geranium, Golden rod, Coffee senna, Spiny sowthistle, Virginia pepperweed, Wild poinsettia

Appendix

Seasonal Pest Occurrence for Tomato in Georgia and South Carolina														
			Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Insects / Mites														
Thrips														
Leaf footed bugs														
Aphids														
Whiteflies														
Armyworms														
Tomato fruitworm														
Tobacco hornworm														
Mites														
Stinkbugs														
Diease														
Nematodes														
Virus Disease														
Crown-Rot and Fruit -Rot Disease														
Soil Borne Disease														
Foliar Disease														
Weeds														
Yellow and Purple Nutsedge														
Morningglory														
Purslane														
Pigweeds														
Annual Grasses														
Nematodes														
Root-knot nematode														
		is light			is heavy									

General Time of Crop Stages, Worker Activities, and Key Pests in Tomato in Georgia and South Carolina

	January	February	March	April	May	June	July	August	September	October	November	December
Crop Stage												
Vegetative			■	■			■	■	■			
Fruiting					■	■			■	■		
Worker Activities												
Fumigate fields	■	■					■					
Transplanting		■	■				■					
Irrigation		■	■	■	■		■	■	■	■		
Fertilization	■	■					■					
Cultivation	■	■					■					
Pesticide application		■	■	■	■		■	■	■	■		
Monitoring		■	■	■	■		■	■	■	■		
Harvest					■	■			■	■		
Insect Pests												
Thrips			■	■	■			■	■	■		
Mites								■	■	■	■	
Aphids					■		■	■	■	■		
Whiteflies							■	■	■	■		
Beet Armyworm							■	■	■	■		
Other Leps					■		■	■	■	■	■	
Pepper weevil					■	■	■	■	■	■	■	
Insecticide Application		■	■	■	■		■	■	■	■		
Nematodes		■	■	■	■	■	■	■	■	■	■	
Virus Disease		■	■	■	■	■	■	■	■	■	■	
Crown-Rot and Fruit -Rot Disease		■	■	■	■	■	■	■	■	■	■	
Soil Borne Disease		■	■	■	■	■	■	■	■	■	■	
Foliar Disease		■	■	■	■	■	■	■	■	■	■	
Other Diseases												
Fumigant Application	■	■					■					
Pre-emerg. weed control	■	■					■					
Post-emerg. weed control			■	■	■	■		■	■	■		

Efficacy Tables for Pest Management Tools in Tomato

Insecticides & Miticides

pest:	thrips	mite	whitefly	aphid	armyworm	fruitworm	hornworm	stinkbugs
Abamectin (Agri-Mek) 0.15EC		E						
Acephate (Orthene) 97	G							
Acetamiprid (Assail) 30SG			E					
Admire 2F and Pro 4.6F	F (Fusca)	P	F-E	E	P	P	P	P
Bifenazate (Acramite) 50WS	P	G	P		P	P	P	P
Bifenthrin (Capture) 2EC			F-G					
Carbaryl (Sevin) 80S	P	P	P		P	P	P	F-G
Cyfluthrin (Baythroid) 2EC								
Cyromazine (Trigard) 75WP								
Deltamethrin (Decis) 1.5EC								
Dicofol (Kelthane) Me and Dicofol 4EC		F						
Dimethoate 4EC and 2.67 EC								
Dinotefuran (Venom) 20 SG								
Disulfton (Di-Syston) 15G				G				
Emamectin benzoate (Proclaim) 5WDG			P		E	E		
Endosulfan (Endosulfan / Thionex) 3EC	F-G	P	F-G		G-E	G-E	G-E	G-E
Esfenvalerate (Asana) .66EC								E
Gamma-cyhalothrin (Proaxis) 0.5EC								
Imidacloprid (Provado) 1.6F			G-E					
Indoxacarb (Avaunt) 30 WDG					E	E	E	
Lambda-cyhalothrin (Warrior) 1CS	F-G	P	P		F	F	F	G-E
Malathion 8EC and 5EC								
Metasystox-R				G				
Methomyl (Lannate) 2.4LV and 90SP	G-E	P	P		P	P	P	F-G
Methoxyfenozide (Intrepid) 2F					G	G		
Oxamyl (Vydate) 2L			F-G	E				

Permethrin (Pounce) 3.2EC	F-G	P	P		F	F	F	G-E
Platinum 2SC			G-E					
Pymetrozine (Fulfill) 50WDG								
Pyriproxyfen (Knack) 2SC			E					
Spinosad (SpinTor) 2SC	G-E	P	P		P	P	P	P
Spiromesifen (Oberon) 2SC								
Thiamethozam (Actara) 25WG	P	P	P		P	P	P	P
Zeta-cypermethrin (Mustang Max) 0.8EC					E	E	E	

Fungicides, Bacteriacides, Nematicides ***pest:***	nematode	crown rot (Phytophthora)	Cercospora	Anthracnose	Bacterial Spot	Botryis Gray Mold	Southern Blight	Early Blight	Pythium	Powdery Mildew	Septoria Leaf Spot
Acrobat, Forum			P	P	P	P	P	P	GC	P	P
Actigard (can be phytotoxic)			U	G	G	P	P	P	P	P	P
Bonide Liquid Copper Fungicide (H)											
Bravo, Equus, Echo			P	P	P	P	P	G	G	F-P	G
Cabrio			P	P	P	G		E	P	E	E
Champ (DP, 2F, F)											
Chloropicrin 33%											
Citcop 4-E (H)											
Copper Count-N (H)											
Cuprofix Disperss					F	F					
Dithane, Manzate, ect			P	P	P	P	P	G	G-F	P	G-F
Dragon Copper Fungicide (H)											
Endura			P	P	P	G	P	E-G	P	U	P
Fixed Copper			G-F	FR	GR	P	P	F	G-F	P	G-F

Forum											
Gavel			P	P	P	P	P	G-F	G-F	P	G-F
Hi-Yield Copper Fungicide											
Inline											
Kocide (101, DF, LF, 4.5, LF, 2000)											
K-Pam											
Manex (75DF, 80WP)			P	P	P	F	G	G	P	F	G
ManKocide			G-F	FR	GR	P	P	G-F	G-F	P	G-F
Methyl bromide 67%	E										
Nemacur 15% G	E										
Nova			P	P	P	P	E-G	P	P	E	P
Nu-Cop (50DF, 3L)											
											P
Previcur Flex			P	P	P	P	P	P	GC	P	
Quadris			P	P	P	P	U	E	G-F	E-G	E-G
Ranman			P	P	P	P	P	F	G	P	P
Reason			P	P	P	P	U	G	G	U	F
Ridomil Gold MZ			P	P	P	P	P	G-F	GR	P	F
Ridomil Gold/Bravo			P	P	P	P	P	F	GR	P	F
Ridomil Gold/Copper			F	FR	FR	P	P	P	GR	P	F
Scala			P	P	P	G	U	G	P	U	U
Sectagon											
Streptomycin sulfate			G-FR	G-RF	G-RF	P	P	P	P	P	P
Sulfur			P	P	P	P	P	P	P	G-F	P
Tanos			P	P	P	F-P	U	E-G	G	P	G-F
Tanos - (3 day PHI)											
Telone C-17	E		P	P	P	P	P	P	P	P	P
Telone EC	E		P	P	P	P	P	P	P	P	P
Telone II	E		P	P	P	P	P	P	P	P	P
Terr-O-Gas 67			P	P	P	P	P	P	P	P	P
Top Cop Tri-Basic (H)			P	P	E	P	P	P	P	P	P
Tri Basic Copper (H)					E						
Vapam	E										
Vydate L	G		P	P	P	P	P	P	P	P	P

Herbicides *pest:*	Purple Nutsedge	Yellow Nutsedge	Crabgrass	Morningglory	Pigweeds	Purslane	Annual Ryegrass					
Carfentrazone (Aim 2.0 EC or 1.9 EW)	P	P	P	G-E	G	P-F	P					
Clethodim	P	P	E	P	P	P	g-e					
Clomazone	P	P	e	P	P	G						
Glyphosate (4 SL, 5 SL, 5.5 SL, 6 SL)	F-G	F	E	F-G	E	F-G	G					
Halosulfuron-methyl (Sandea 75 DG)	E	E	P	P-F	G-E	F	P					
Metam Sodium (Vapam HL 42%)	F-G	F-G	F	F	G	F-G						
Methyl Bromide (MB 67:33)	E	E	E	E	E	E	E					
Napropamide (Devrinol 50 WDG)	P	P-F	E	P	F-G	G-E						
Oxyfluorfen (Goal 2 XL)	P-F	P-F	P-F	G-E	G-E	G	F-G					
Paraquat (Gramozone Inteon 2 SL)	P-F	P-F	F	F-G	G	G	G					
Sethoxydim (Poast 1.53 EC)	P	P	E	P	P	P	E					
S-metolachlor (Dual Magnum 7.62 EC)	P	P-F	E	P	G	G	F-G					
Trifluratlin (Treflan, others)	P	P	E	P	G-E	E	F-G					

Non-Chemical Tactics *pest:*	thrips	mite	whitefly	aphid	armyworm	fruitworm	hornworm	stinkbugs	pepper weevil	nematode	virus	crown rot
Host Plant Resistance	P	P							P		E	
Crop rotation												
Cultivation												
Sanitation									E			
Water Management												
Stale Seed Bed												
Classic Biological Control												

Augmentation Biological Control		F										
Mechanical Control												
Mulching (including metallic silver)	E										E	

*efficacy rating: E=excellent, G=good, F=fair, P=poor, ?=don't know, blank=not used, res=resistance has been document

pest:	Bacterial Canker	Bacterial Speck	Bacterial Spot	Botryis Gray Mold	Tomato spotted wilt virus	Early Blight	Late Blight	Powdery Mildew	Septoria Leaf Spot	Purple and Purple Nutsedge	Crabgrass	Morningglory
Host Plant Resistance					G-F	F						
Crop rotation	F	F	F						F			
Cultivation												
Sanitation												
Water Management												
Stale Seed Bed												
Classic Biological Control												
Augmentation Biological Control												
Mechanical Control												
Mulching (including metallic silver)												

*efficacy rating: E=excellent, G=good, F=fair, P=poor, ?=don't know, blank=not used, res=resistance has been document