Commercial Tomato Production Handbook

UGA extension

Foreword

This publication is a joint effort of the seven disciplines that comprise the Georgia Vegetable Team. It is comprised of 14 topics on tomato, including history of tomato production, cultural practices, pest management, harvesting, handling and marketing. This publication provides information that will assist producers in improving the profitability of tomato production, whether they are new or experienced producers.

Tomatoes are an important crop for Georgia growers; however, successful tomato production is not easily achieved. Tomato production requires highly intensive management, production and marketing skills, and a significant investment. Per acre cost of production is high, and yields can be severely limited by pest problems or environment. Tomato production is complex. Expertise in the areas of cultural practices, soils and fertility management, pest control, harvesting, post-harvest handling, marketing, and farm record keeping is crucial to profitable production.

In writing this publication, the authors have strived to provide a thorough overview of all aspects of tomato production. However, chemical pest control recommendations are not included, as these change from year to year. For up-to-date chemical recommendations, see the current Georgia Pest Management Handbook.

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History, Significance, Classification and Growth

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The tomato (*Lycopersicon esculentum* Mill.) is the most widely grown vegetable in the United States. Almost everyone who has a garden has at least one tomato plant. They can even be produced in window box gardens or in single pots. Commercially, it is of equally great importance. From processing to fresh market, and from beefsteak to grape tomatoes, the variety and usefulness of the fruit is virtually boundless.

Tomatoes are members of the *Solanaceae* family, which includes peppers, eggplant, Irish potatoes and tobacco. The tomato originated in the area extending from Equador to Chile in the western coastal plain of South America. The tomato was first domesticated in Mexico where a variety of sizes and colors were selected. The fruit was introduced to Europe in the mid-1500s. The first ones introduced there were probably yellow since they were given the name *pomodoro* in Italy, which means "golden apple." Later the names *poma armoris* and *pomme d'amour* were used in Italy and France. These names are both translated as "love apple."

Tomatoes are members of the nightshade family and, because of this, were considered for many years to be poisonous. Indeed, many crops in this family contain highly toxic alkaloids. Tomatine occurs in toxic quantities in the tomato foliage but is converted enzymatically to a non-toxic form in the fruit. Because of these beliefs, the crop was not used for food until the 18th century in England and France. Tomatoes were introduced to the United States in 1710, but only became popular as a food item later in that century. Even as late as 1900, many people held the belief that tomatoes were unsafe to eat.

Use of the crop has expanded rapidly over the past 100 years. Today more than 400,000 acres of tomatoes are produced in the United States. The yearly production exceeds 14 million tons (12.7 million metric tons), of which more than 12 million tons are processed into various products such as soup, catsup, sauce, salsa and prepared foods. Another 1.8 million tons are produced for the fresh market. Global production exceeds 70 million metric tons. Tomatoes are the leading processing vegetable crop in the United States.

California is the leading producer of processing tomatoes in the United States. Indiana, Michigan and Ohio are other major producers. California and Florida are the leading fresh market tomato producers in the United States. Ohio, Tennessee, Virginia and Georgia produce significant amounts of fresh market tomatoes as well.

Tomatoes have significant nutritional value. In recent years, they have become known as an important source of lycopene, which is a powerful antioxidant that acts as an anticarcinogen. They also provide vitamins and minerals. One medium ripe tomato (~145 grams) can provide up to 40 percent of the Recommended Daily Allowance of Vitamin C and 20 percent of Vitamin A. They also contribute B vitamins, potassium, iron and calcium to the diet.

There are two types of tomatoes commonly grown. Most commercial varieties are *determinate*. These "bushy" types have a defined period of flowering and fruit development. Most heirloom garden varieties and greenhouse tomatoes are indeterminate, which means they produce flowers and fruit throughout the life of the plant.

Tomato is considered a tender warm season crop but is actually a perennial plant, although it is cultivated as an annual. It is sensitive to frost and will not grow perpetually outdoors in most parts of the country. Most cultivated tomatoes require around 75 days from transplanting to first harvest and can be harvested for several weeks before production declines. Ideal temperatures for tomato growth are 70-85 degrees F during the day and 65-70 degrees F at night. Significantly higher or lower temperatures can have negative effects on fruit set and quality. The tomato is a self-pollinating plant and, outdoors, can be effectively pollinated by wind currents.

Culture and Varieties

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Soil Requirements and Site Preparation

Tomatoes can be produced on a variety of soil types. They grow optimally in deep, medium textured sandy loam or loamy, fertile, well-drained soils. Avoid sites that tend to stay wet. Also, rotate away from fields that have had solanaceous crops within the past 3-4 years. Select sites that have good air movement (to reduce disease) and that are free from problem weeds.

In field production, plants depend on the soil for physical support and anchorage, nutrients and water. The degree to which the soil adequately provides these three factors depends upon topography, soil type, soil structure and soil management.

For tomato production, proper tillage is crucial for adequate soil management and optimal yields. Land preparation should involve enough tillage operations to make the soil suitable for seedling or transplant establishment and to provide the best soil structure for root growth and development.

The extent to which the root systems of tomato plants develop is influenced by the soil profile. Root growth will be restricted if there is a hard pan, compacted layer or heavy clay zone. Tomatoes are considered to be deep rooted and, under favorable conditions, some roots will grow to a depth of as much as 10 feet. The majority of roots, however, will be in the upper 12 to 24 inches of soil. Since root development is severely limited by compacted soil, proper land preparation should eliminate or significantly reduce soil compaction and hard pans.

Tillage systems using the moldboard ("bottom" or "turning") plow prepare the greatest soil volume conducive to vigorous root growth. This allows the development of more extensive root systems, which can more efficiently access nutrients and water in the soil. Discing after moldboard plowing tends to recompact the soil and should be avoided.

Compaction pans are present in many soils. They are formed principally by machinery and are normally located at or just below plow depths. Although compaction pans may be only a few inches thick, theirinhibitory effects on root growth can significantly reduce tomato yields.

If a compaction pan exists just below or near moldboard plow depth, this hard pan can be disrupted by subsoiling to a depth of 16 to 18 inches to allow the development of a more extensive root system. Subsoiling also helps increase water infiltration.

If there is an abundance of plants or plant residues on the soil surface, discing or mowing followed by discing is usually advised prior to moldboard plowing. This should be done 6 to 8 weeks ahead of planting to bury residue and allow it to decay. Immediately prior to plastic mulch installation or transplanting, perform final soil preparation and/or bedding with a rotary tiller, bedding disc or a double disc hiller in combination with a bedding press or leveling board. This provides a crustless, weed-free soil for the installation of plastic mulch or the establishment of transplants.

Tomatoes are usually transplanted into plastic mulch on raised beds. A raised bed will warm up more quickly in the spring and therefore will enhance earlier growth. Since tomatoes do poorly in excessively wet soils, a raised bed facilitates drainage and helps prevent waterlogging in low areas or in poorly drained soils. Raised beds are generally 3 to 8 inches high. Keep in mind, however, that tomatoes planted on raised beds may also require more irrigation during drought conditions.

Cover Crops and Minimum Tillage

Winter cover crops help protect the soil from water and wind erosion. When incorporated into the soil as "green manure," cover crops contribute organic matter to the soil.

Soil organic matter consists of plant and animal residues in various stages of decay. Organic matter improves soil structure (helps to reduce compaction and crusting), increases water infiltration, decreases water and wind erosion, increases the soil's ability to resist leaching of many plant nutrients, and releases plant nutrients during decomposition.The planting of cover crops and subsequent incorporation of the green manure into the soil enhances tomato production in Coastal Plains soils. Wheat, oats, rye or ryegrass can be used as winter cover crops. If these non-nitrogen fixing cover crops are to be incorporated as green manure, provide them with adequate nitrogen during their growth. This increases the quantity of organic matter produced and provides a carbon: nitrogen (C:N) ratio less likely to immobilize nitrogen during decomposition.

As a general rule, when non-leguminous organic matter having a C:N ratio exceeding 30 to 1 is incorporated, a supplemental nitrogen application (usually 20 to 30 pounds of nitrogen per acre) prior to incorporation is recommended. The exact rate required will depend on the C:N ratio, soil type and amount of any residual nitrogen in the soil. Plow green manure crops under as deeply as possible with a moldboard plow 4 to 6 weeks prior to installing mulch or transplanting tomatoes.

Planting tomatoes in reduced tillage situations has been tried with variable results in different parts of the country. Often cover crops can be killed with a burn down herbicide. Then tomatoes are either transplanted directly into the cover, or a narrow strip is tilled and prepared for transplanting while leaving the residue between rows. While these residues can protect the fruit from direct contact with the soil, currently the impediments outweigh the benefits for large-scale commercial production. Leguminous covers can provide nitrogen to the crop and there are certainly soil conservation advantages.

The primary encumbrance to success in reduced tillage systems is adequate weed and disease control. The application of phosphates, potash and lime are also more difficult in these systems, so reduced tillage is used only on a limited basis in commercial tomato production. With advances in weed and disease control technology, this type of production may become more feasible in the future.

Windbreaks

Crop windbreaks can aid in crop protection and enhance early growth and yield. Frequency or intervals between windbreaks is dictated by distance between tomato rows, spray or harvest alleyway intervals, land availability and equipment characteristics. For instance, bed arrangements may be such that a windbreak is present between every set of four, six or eight beds. Plant windbreaks perpendicular to the prevailing winddirection. When using a taller growing windbreak such as rye, you can expect the windbreak to be effective to a width of about 10 times its height. For instance, with a rye crop that is 3 feet high, the windbreaks can be effective up to 30 feet apart.

In general, close windbreaks give the best wind protection and help moderate the tomato plants' microenvironment and enhance earliness. Especially on sandy soils, windbreaks reduce damage from sandblasting of plants and small fruit during early spring. Sandblasting can be more of a problem with plastic mulch, as the soil particles are carried easily by the wind across the field. Many growers spread small grain seed after the plastic mulch is applied to reduce sand blasting. Windbreaks also conserve soil moisture by reducing direct evaporation from the soil and transpiration from the plant. This can enhance plant growth throughout the season.

Regardless of the species selected to be used as a windbreak, plant it early enough to be effective as a windbreak by the time tomatoes are transplanted. Establishment of a windbreak crop during the fall or early winter should ensure enough growth for an effective windbreak by spring tomato planting time. Wheat, oats or rye all make good windbreak crops. Windbreaks can be living or non-living. Tomato beds can be established between the windbreaks by tilling only in the bed area.

To minimize insect migration to the tomato crop, destroy windbreak crops by herbicides, mowing and/or tillage before they lose their green color and begin to die back.

Transplanting

Seeding tomatoes directly into the field is not recommended due to the high cost of hybrid seed and the specific conditions required for adequate germination. Most tomatoes are transplanted to the field from greenhouse-grown plants. Direct seeding has other disadvantages: (1) Weed control is usually much more difficult with direct seeded than with transplanted tomatoes; (2) direct seeding requires especially well made seedbeds and specialized planting equipment to adequately control depth of planting and in-row spacing; (3) because of the shallow planting depth required for tomato seed, the field must be nearly level to prevent seeds from being washed away or covered too deeply with water-transported soil; and (4) spring harvest dates will be at least 2 to 3 weeks later for direct seeded tomatoes.

At 59, 68 and 77 degrees F soil temperature, tomato seed require 14, 8 and 6 days, respectively, for emergence when planted ½ inch deep.

Typically, 5- to 6-week old tomato seedlings are transplanted into the field. As with most similar vegetable crops, container-grown transplants are preferred over bare root plants. Container grown transplants retain transplant growing medium (soil-substitute) attached to their roots after removal from the container (flat, tray). Many growers prefer this type transplant because (1) they are less subject to transplant shock, (2) usually require little if any replanting, (3) resume growth more quickly after transplanting, and (4) grow and produce more uniformly. Tomato plants produced in a 1-inch cell size tray are commonly used for transplanting. Many growers will use a 1.5-inch cell tray for transplant production in the fall when transplant stress is greater.

Tomato transplants should be hardened off before transplanting to the field. Hardening off is a technique used to slow plant growth prior to field setting so the plant can more successfully transition to the less favorable conditions in the field. This process involves decreasing water for a short period prior to taking the plants to the field. Research shows that reducing temperatures too drastically to harden tomato transplants can induce catfacing in the fruit.

For maximum production, transplants should never have fruits, flowers or flower buds before transplanting. An ideal transplant is young (6 inches to 8 inches tall with a stem approximately ¼ inch to ⅜ inch in diameter), does not exhibit rapid vegetative growth, and is slightly hardened at transplanting time. Rapid growth following transplanting helps assure a well established plant before fruit development. In most cases, it is more economically feasible to have transplants produced by a commercial transplant grower than to grow them on the farm. When purchasing transplants, be sure the plants have the variety name, have been inspected and approved by a plant inspector, and they are of the size and quality specified in the order.

Set transplants as soon as possible after removing from containers or after pulling. If it is necessary to hold tomato plants for several days before transplanting them, keep them cool (around 55-65 degrees F if possible) and do not allow the roots to dry out prior to transplanting. When setting plants, place them upright and place the roots 3 to 4 inches deep. Setting plants at least as deep as the cotyledons has been shown to enhance plant growth and early fruit production and maturity. Completely cover the root ball with soil to prevent wicking moisture from the soil. Tomatoes growbest if nighttime soil temperatures average higher than 60 degrees F.

At transplanting, apply an appropriate fertilizer starter solution (see fertilizer management section). After transplanting (especially within the first 2 weeks) it is very important that soil moisture be maintained so that plant roots can become well established.

Plant Spacing

Tomatoes can be planted in one of many different arrangements that provide adequate space for plant growth. Often the spacing is based on the type of trellising and equipment that will be used in the field. The within-row and between-row spacings are selected to meet these limitations. The optimal plant population per acre may also be influenced by plant growth habit (compact, spreading), plant size at maturity (small, medium, large), vigor of specific cultivars, climate, soil moisture, nutrient availability, management system and soil productivity.

Generally, for production of determinate varieties on plastic mulch, a minimum of 5 feet between rows is used with an in-row spacing of 18 to 24 inches. Six feet between rows is also a popular interval. To space plants 22 inches apart in rows that are 5 feet apart requires 4,760 plants per acre. With 6-foot centers and 18 inches between plants, 4,840 plants are required per acre. Usually a single row of tomatoes is planted down the center of each plastic mulched bed.

On bare ground, space rows 48 to 72 inches apart with 18 inches to 24 inches between plants in the row. For indeterminate types of tomatoes, which produce larger plants, adjust spacing to decrease the population accordingly.

Varieties

Select varieties on the basis of marketable yield potential, quality, market acceptability, adaptability and disease resistance or tolerance. The selection of a variety(ies) should be made with input from the buyer of the crop several months in advance of planting. Other characteristics to consider include maturity, size, shape, color, firmness, shipping quality and plant habit.

There are a plethora of commercially available tomato varieties, many of which will perform well under Georgia conditions. Varieties will perform differently under various environmental conditions. Yield, though ultimately important, should not be the only selection criteria. Tomatoes produced on plasticmulch with drip irrigation will commonly average more than 1,500 25-pound cartons per acre. Select varieties that have yield potential that equals or surpasses this average.

Plants also need to produce adequate foliage to protect fruit. Basically, a variety must be adaptable to the area, produce a competitive yield and be acceptable to buyers. Disease resistance will be most important with diseases for which there are no other good management options. Varieties produced in Georgia should be resistant to *Fusarium* wilt (Races 1 and 2) and *Verticillium* wilt (Race 1). In recent years, resistance to Tomato Spotted Wilt Virus has become equally as important, since varietal resistance is the most effective control method at this time. Other resistance of significance should include Gray Leaf Spot and Tobacco Mosaic Virus.

All commercially important tomatoes grown in Georgia belong to the species *Lycopersicon esculentum*. Table 1 lists those varieties that have performed well in Georgia or in similar areas of the southeastern United States. Notations in the disease resistance column indicate either resistance or tolerance. Some varieties may not exhibit complete resistance to the disease listed.

Table 1. **Tomato varieties that have exhibited acceptable performance either in variety trials or in grower fields in Georgia.**

Variety	Days to Maturity	Fruit Size	Shape	Disease Resistance
Large Round				
Amelia	78	L, XL	Oblate	F^{123}, ST, TSWV, V, FCR
BHN 444	80	L, XL	Globe	F^{12}, TSWV, V
BHN 640	80	L, XL	Globe	F^{123}, TSWV, V
Biltmore (trial)	80	L	Deep Oblate	F^{12}, ST, ASC, V
Carolina Gold	78	L, XL	Deep Oblate	F^{12}, V
Crista	78	XL, L	Round	F^{123}, TSWV, V
Florida 47 R	75	VL	Deep Oblate	F^{12}, GLS, ASC, V
Florida 91*	72	L	Deep Oblate	F^{12}, GLS, ASC, V
Mountain Crest	75	XL, L	Flat-Globe	F^{12}, V, FCR
Mountain Spring	78	XL	Deep Oblate	F^{12}, St, V, FCR
Sebring	75	XL, L	Deep Oblate	F^{123}, ST, FCR, V
Solar Fire*	75	L	Flat-Round	F^{123}, ST, V
Solar Set*	75	M, L	Flat-Round	F^{12}, ASC, GLS, V
Solimar	78	L	Globe	F^{12}, ASC, GLS, V
Talladega (trial)	78	XL, L	Globe	F^{12}, TSWV, V
Tygress (trial)	78	L	Deep Oblate	F^{12}, V, GLS, TYLC
Cherry				
Cherry Grande	65	Cherry	Globe	F^{1}, ST, ASC, V
Mountain Belle	68	Cherry	Round-Oval	F^{1}, V
Roma/Saladette				
BHN 685	75	Roma	Blocky Globe	F^{123}, TSWV, V
Plum Crimson	75	L, XL	Saladette	F^{123}, V
Plum Daddy	75	Roma	Elongated Roma	F^{1}, V
Puebla	72	M	Elongated Cyl.	F^{12}, ST, ASC, V, BS

F = Fusarium Wilt; ST = Stemphylium; TSWV = Tomato Spotted Wilt Virus; V = Verticillium Wilt; FCR = Fruit Cracking; ASC = Ascomycetes; GLS = Gray Leaf Spot, BS = Bacterial Spot; TYLC = Tomato Yellow Leaf Curl
* hot-set varieties

Staking and Pruning

Most commercial determinate tomatoes are produced using short stake culture for trellising. This type of culture produces fruits that are higher in quality and easier to harvest and enhances spray coverage. In this system, stakes approximately 4 feet long and ¾ to 1 inch square are placed between every one or two plants depending on the tying system that is employed. Stakes are usually driven about 12 inches into the ground. An additional stake can be supplied at the ends of each section to strengthen the trellis.

Stake plants immediately after planting to minimize damage to the root system and to have the trellis ready when needed. Plants are usually tied initially when they are about 12-15 inches tall and should be tied prior to any plants lodging. The first string is usually placed about 10 inches above the ground. Subsequent tyings are placed about 6 inches above the previous one. Determinate varieties may be tied as many as three to four times.

The Florida weave system is one method of tying that is often used. In this system, a stake is placed between every other plant in the row. Twine is then used to tie the plants using a figure eight weave. The twine is wrapped around the stake and is pulled tightly on one side of the first plant and then between the two plants and along the other side of the second plant. At the end of the row or section, the pattern is reversed and, as the twine is wrapped around each stake, the twine is then placed on the other side of each plant going back in the opposite direction along the row. This system uses fewer stakes and encloses the plant with the twine. Subsequent tyings often do not weave between plants but simply go along one side of the plants going one way and the opposite side going the other direction.

Another system of tying involves placing a stake after every plant. The twine is then simply wrapped around each stake and along one side of the plant going along the row and around the other side of the plant coming back in the other direction on the opposite side of the row. Regardless of the system used, the twine should be held with enough tension to adequately support the plants. If the twine is too tight, however, it can impede harvest and damage plants and fruit.

Tomato twine should be resistant to weathering and stretching and should not cut into the plants or fruit. It takes about 30 pounds of synthetic twine per acre for tomatoes. A simple tying tool can be made from conduit or PVC pipe that is 2 to 3 feet long. The twine is passed through the pipe to act as an extension of the worker's arm. This limits the need to stoop over at each stake to wrap the twine. A similar tool can be made from a wooden dowel or narrow wooden strip. With these, a hole is drilled about 1 inch from each end of the piece of wood and the string passed through each hole. This provides the same extension of the hand as the other method.

Determinate tomatoes often still require some level of pruning. Pruning is the removal of suckers (axillary shoots). The degree to which pruning is needed will vary with the variety used but can impact yield and quality significantly. Plants that produce vigorous foliage that are not pruned will produce more, but smaller fruit. Pruning helps increase the size of the fruit. It can also enhance earliness of the crown set, reduce pest pressure and enhance spray coverage. In general, pruning will involve removal of one to all suckers up to the first fork (the sucker just below the first flower cluster).

Growers should experiment with individual varieties to determine the degree of pruning needed. Often the seed supplier can provide information on specific varieties regarding pruning. Some varieties require only the removal of ground suckers (at the cotyledons) or none at all. Overpruning can cause reduced yields and increased sunburn, blossom end rot and catfacing. More vigorous varieties may require the removal of ground suckers plus two additional suckers. Remove suckers when they are small (2 to 4 inches long). Removal of large suckers is more time consuming and can damage the plant. Prune before the first stringing to facilitate the process, since the strings may be in the way. A second pruning may be required to remove suckers that were not large enough to remove easily during the first pruning and to remove ground suckers that may have developed. Prune plants when the foliage is dry to reduce the spread of disease.

Transplant Production

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Tomato production in Georgia is an expensive, labor intensive endeavor developed to produce high quality fresh market fruit. Because of the cost involved and because early market fruit command higher prices, growers exclusively use transplants to produce tomatoes. Tomato transplant production is a relatively easy but highly specialized function of production. Many growers have neither the greenhouse facilities nor the expertise to undertake transplant production; instead, they will rely on greenhouse growers to produce their transplants. For these growers to ensure a quality supply of transplants, they should contract early with their greenhouse grower to secure plants of the variet(ies) they wish to grow.

Growers should expect to plant between 3,600 and 5,800 plants per acre in a staked tomato operation, depending on the plant spacing. Expect to produce about 4,000 transplants per ounce of seed with approximately 3 ounces required to produce 10,000 seedlings. For example, to produce 10 acres of tomatoes with 5,800 plants per acre would require 58,000 transplants and would require about 18 ounces of seed (rounding up to 60,000 plants). Many seed companies no longer sell seed by weight but by count and will supply the germination rate as well. In such a case, the count and germination rate can be used to estimate the amount of seed to plant to produce the desired number of plants. For example, to produce 58,000 seedlings from seed with 90 percent germination would require 64,445 seed (58,000 divided by 0.90).

Tomato seedlings are usually produced in trays or flats that are divided into cells. Tomatoes require a cell size of approximately 1 inch square to produce a high quality, easily handled transplant. These trays or flats are available in a number of different configurations and sizes. They may be purchased as flats and inserts, polystyrene trays or, more recently, as one-piece rigid polyethylene plastic trays. Growers should make sure the trays or flats used can be handled with their transplanting equipment.

Media for production is usually peat based with various additives such as perlite and vermiculite to improve its characteristics. These can be purchasedready mixed or you can formulate your own mix. The individual components of peat moss, perlite, vermiculite, etc., can be purchased. Whether buying the individual components or a ready-made product, it is advisable to use finer textured media when starting seed. Check with your supplier about media texture. Some media are specially made for this purpose. In addition, these media may have fertilizer and wetting agents mixed in. Media with fertilizer is often referred to as *charged*.

Treated and/or coated seed may be used to produce seedlings. Most seed is sold with a fungicide applied to the seed. This will help prevent damping off during the germination process. In addition, various seed coats are available, from polymer to clay coats. These are useful when using automated seeding equipment to aid in seed singulation. Plant tomato seed ⅛ to ¼ inch deep. With an automated seeder, the seed will be placed on the surface and will have to be covered, usually with a thin layer of vermiculite.

After flats have been filled and the seed planted, they are often wrapped with plastic pallet wrap or placed in germination rooms (rooms with temperature and humidity tightly controlled) for 48-72 hours to ensure even moisture and temperature for optimum germination. The optimum germination temperature for tomatoes is 85 degrees F, at which tomato seedlings should emerge in about 5-6 days. See Table 2 for soil temperatures and number of days to germination.

Table 2. Soil temperature and days to germination.

Soil Temperature (ºF)	60	68	77	85	95
Days to Emergence	14	8	6	5	9

If charged media is used, there will be no need for fertilizer for the first 3 to 4 weeks of production. After that, use 150-200 ppm of a suitable water soluble fertilizer once per week (Table 3). With media that has no premixed fertilizer, begin fertilization as soon as the plants emerge. Growers may wish to use as little as 50 ppm of a suitable water soluble fertilizer with every irrigation. Tomatoes will require approximately 5 to 7 weeks to produce a good quality transplant. Cooler temperatures will slow growth, so greenhouse temperatures should be kept above 60 degrees F at night to accelerate growth.

Prior to transplanting, tomatoes should be hardened off. This is the process of reducing water and/or lowering temperature. Do this several days prior to transplanting. A good way to achieve this is to move the plants outside the greenhouse to a protected location (some shade), or open the sides of the greenhouse if possible. Reduce the amount of water the plants receive, but don't allow the plants to wilt. Hardening plants is critically important to ensure survivability. Unhardened plants are much more vulnerable to environmental extremes.

A good quality transplant will be a sturdy, compact plant with a root mass that completely fills the cell. Water plants prior to transplanting. Tomatoes can be transplanted deeper than they grew in the greenhouse container and, in fact, it is desirable to do so. Roots will form on the stem that is below the ground.

Take care when transplanting into black plastic so the plants do not touch the plastic. The plastic can absorb enough heat to injure and kill plants. A drench of about 0.5 pint of a suitable starter solution should be applied to each plant. Examples of suitable solutions include mixing 3 pounds of 11-34-0 or 18-46-0 fertilizer in 50 gallons of water. Most transplanting equipment will have a tank to hold the solution and will automatically dispense the solution to each plant.

Carefully monitor plants for the first few days to a week after transplanting to ensure survival. Note any problems with dry soil, clogged irrigation, plants touching the plastic, etc., and take corrective action.

Table 3. Amount of water soluble fertilizer to mix 100 gallons of fertilizer solution.

Fertilizer Source	**ppm of nitrogen**			
	50	100	150	200
	weight (oz.)			
20-20-20	3.3	6.7	10.0	13.4
15-0-15	4.4	8.9	13.4	17.8

Production Using Plastic Mulch

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The use of plastic mulch in the commercial production of staked tomatoes is almost universal in the southeast. Plastic mulch is used to promote earliness, reduce weed pressure, and to conserve moisture and fertilizer. Most often drip irrigation is used in conjunction with plastic mulch. There are both advantages and disadvantages to producing crops under this system.

Advantages: Plastic mulch promotes earliness by capturing heat, which increases soil temperatures and accelerates growth. Black plastic will prevent the establishment of many in-row weeds. Mulch will reduce fertilizer leaching from tomato beds and will conserve moisture by reducing soil surface evaporation.

Furthermore, where fumigants are used, plastic mulch provides a barrier that increases fumigant efficiency. Plastic mulch also keeps fruit cleaner by reducing soil spatter. When using drip irrigation particularly, disease is often reduced as the foliage stays drier and, again, soil is not splashed onto the plant.

Disadvantages: Specialized equipment is required to lay plastic mulch, which means increased variable costs for custom application or the purchase of this equipment. Yellow and purple nutsedges are not controlled by black plastic mulch, and suitable fumigants/herbicides must be applied if nutsedge is a potential problem. The cost of plastic removal and disposal is an additional expense.

In most instances, plastic mulch culture has increased yields and returns sufficiently to offset these potential disadvantages.

Types of Plastic

One to 1¼ mil black plastic is the cheapest and traditionally has been most often used in spring tomato production. Embossed plastic has a crimped pattern in the plastic that allows the mulch to stretch and contract so it can be laid snug to the bed. This can be important, particularly in multiple cropping operations where, for example, spring tomatoes may be followed by fall cucumbers. The embossed plastic is less likely to bedamaged by wind and other environmental factors, thus increasing the potential for use on multiple crops.

Summer planted tomato crops for fall production cannot tolerate excessively high soil temperatures. They should be planted on white plastic, which reflects some surface heat and does not warm the soil as much. For spring production, however, white is not recommended since maximum soil warming is needed. In lieu of using white plastic, many growers use a dilute white paint sprayed over the bed to lighten the plastic and reflect heat for fall production.

Recently, metalized mulches have become popular. These plastic mulches have a thin film of metal that is applied with a vacuum which produces a reflective effect. Research has shown that these mulches can help reduce the incidence of Tomato Spotted Wilt Virus infection on tomatoes by repelling thrips. However, these mulches do not warm the soil as well as black mulches, resulting in reduced plant growth early in the spring. Often, these plastics are produced with a black strip down the middle with the shoulders metalized. This allows for heat retention to get the earliness effect while producing the reflective effect needed to repel thrips and reduce TSWV. Recent research has also shown that metalized mulches also retain fumigants better and may allow for use of reduced rates.

Virtually Impermeable Films (VIF) are used in some parts of the world to reduce fumigant release into the atmosphere. These films are as yet not routinely available in the U.S., are more expensive and, depending on the fumigant, can increase the preplant interval.

Although biodegradable plastic mulches are presently available, they have not been proven to be beneficial. Since most growers want to get two, three or four crops using the same plastic, biodegradable plastics break down too quickly to allow this. When perfected, these materials have the potential to greatly reduce the cost of plastic removal and disposal. Growers using a biodegradable plastic mulch for the first time should test it on a small area until its effectiveness under their conditions is proven.

Bed Preparation

Bed height and width depend on several factors including soil type, bedding equipment, available plastic, etc. Standard bed heights range from 4 to 8 inches. Bed width is also dictated by equipment and grower preference. Current top widths of beds range from 28 to 36 inches. Ordinarily plastic mulch must be 20 to 24 inches wider than the bed width preferred, so it will cover the sides of the bed and can be tucked under the soil to anchor the plastic. The plastic must fit firmly over the bed to minimize wind movement and facilitate planting. Mulch must be covered at the ends of each bed to prevent wind from getting under the plastic and fumigant from escaping. Any available opening, such as a tear or uncovered tuck, that allows wind entry will cause problems.

Use trickle or drip irrigation with plastic mulch for maximum efficiency. It is still important, however, to have optimum soil moisture during plastic application. The use of overhead irrigation requires punching additional holes in the plastic to facilitate water entry, which compromises the integrity of the plastic and reduces its effectiveness in controlling weeds and minimizing leaching of nutrients.

Land preparation for laying plastic is similar to that described in the prior chapter on culture and varieties. The site should still be deep turned and rototilled. Usually a hipper is used to form a high ridge of soil down the middle of the bed to assure the bed pan is filled with soil. This creates a firm, full bed. The bed pan should leave a bed with a slight crown in the middle that slopes slightly to each side. This prevents water from standing on the plastic or being funneled into the holes and waterlogging the soil. Generally, fumigant is applied as the bed pan passes and plastic is installed just behind the pan. Drip tape is installed at the same time, just in front of the plastic, and should be buried 1 inch below the surface to prevent "snaking" under the plastic and to reduce rodent damage to the tape. Drip tape buried deeper will be difficult to remove and will not wet the upper portion of the root zone. Soil moisture should be good at the time plastic is installed to ensure a good, firm bed.

Fertilizer Management Under Plastic

Apply any needed lime 2 to 3 months ahead of plastic mulch installation. Preplant fertilizer applicationwill vary with bed size and planting scheme. On larger beds (4 feet wide or greater), it is advisable to incorporate all phosphorus and micronutrients into the bed before installing plastic. If drip fertigation is not used, apply all the nitrogen and potassium preplant as well.

If narrower beds are used, preplant application of all the needed fertilizer may cause fertilizer salt toxicity. Sidedressing is required, therefore, by a liquid injection wheel, through drip irrigation, or a banded application outside the tucked portion of the bed.

Most tomatoes are planted where fertigation with drip irrigation is used. In these cases all the phosphorous (P) and micronutrients, and one-third to one-half of the nitrogen (N) and potassium (K) should be incorporated into the bed before the plastic is laid. Apply the remaining N and K through weekly fertigations beginning just after transplant establishment. The rate of application of these fertigations will change with the stage of the crop.

Planting into Plastic Mulch

Tomatoes are transplanted with a tractor mounted implement that uses a water wheel to punch holes in the plastic at the appropriate interval. A person (or persons) riding on seat(s) mounted behind the water wheel(s) places a transplant into the newly formed hole and covers the rootball. An alternate approach used by many producers is use of a water wheel or similar device to punch holes, with a crew of people walking the field and hand setting plants. The plants are then watered with a water wagon following the setting crews.

If a fumigant is used for soil sterilization, it will be necessary to wait the prescribed time period before punching holes into the plastic to ensure good fumigant activity and avoid phytotoxicity. If an appropriate waiting period is not observed, some soil fumigants can destroy tomato transplant roots and cause stunting or plant death.

Other types of transplant methods are available as well. Carousel type planters are sometimes used, which will punch a hole in the plastic and set the plant all in one operation. This equipment requires fewer people to operate since only one person is needed per row. These implements are often slower and usually someone has to walk behind the planter to make sure plants are covered well.

Irrigation

Kerry Harrison
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Irrigation is essential to produce consistent yields of high quality tomatoes in Georgia. Rainfall amounts are often erratic during the growing season, and tomatoes are often grown in sandy soils with low water holding capacity. This combination of factors makes supplemental irrigation necessary for commercial tomato production.

Irrigation studies in the southeast show that irrigation increases annual tomato yields by an average of at least 60 percent over dryland production. Quality of irrigated tomatoes is also much better. Irrigation eliminates disastrous crop losses resulting from severe drought.

Tomatoes are potentially deep rooted, with significant root densities up to 4 feet deep. In Georgia soils, however, the effective rooting depth is generally much less. Actual root depths vary considerably depending upon soil conditions and cultural practices. The effective rooting depth is usually 12 to 18 inches with half of the roots in the top 6 inches. It is important not to allow these roots to dry out or root damage will occur.

Moisture stress in tomatoes causes shedding of flowers and young fruit, sunscalding and dry rot of fruit. The most critical stages for watering are at transplanting, flowering and fruit development.

Several types of irrigation may be used successfully on tomatoes in the southeast. Ultimately, the type chosen will depend on one or more of the following factors:

- Availability of existing equipment
- Field shape and size
- Amount and quality of water available
- Labor requirements
- Fuel requirements
- Cost

Sprinkler Irrigation

These systems include center pivot, linear move, traveling gun, permanent set and portable aluminum pipe with sprinklers. Any of these systems are satisfactory if they are used correctly. There are, however,significant differences in initial cost, fuel cost and labor requirements.

Any sprinkler system used on tomatoes should be able to deliver at least an inch of water every 4 days. In addition, the system should apply the water slowly enough to prevent run-off. In sandy soils, the application rate should be less than 3 inches per hour. In loamy or clay soils, the rate should not exceed 1 inch per hour.

Sprinkler systems with a high application uniformity (center pivot, linear move and permanent set) can be used to apply fertilizer. This increases the efficiency of fertilizer utilization by making it readily available to the plant and reduces leaching.

Drip Irrigation

Drip irrigation has become the standard practice for tomato production. Although it can be used with or without plastic mulch, its use is highly recommended with plastic mulch culture. One of the major advantages of drip irrigation is its water use efficiency. Studies in Florida indicate that drip irrigated vegetables require 40 percent less water than sprinkler irrigated vegetables. Weeds are also less of a problem, since only the rows are watered and the middles remain dry. Some studies have also shown significant yield increases with drip irrigation and plastic mulch when compared with sprinkler irrigated tomatoes. The most dramatic yields have been attained by using drip irrigation and plastic mulch, and supplementing nutrients by injecting fertilizers into the drip system (fertigation).

Drip tubing may be installed on the soil surface or buried up to about 1.5 inches deep. When used in conjunction with plastic mulch, the tubing can be installed at the same time the plastic mulch is laid. Usually one line of tubing is installed on each bed. A field with beds spaced 5 feet center to center will require 8,712 feet of tubing per acre (one tube per bed). The output rate of the tube is specified by the user. For discussion purposes, however, you can determine the per acre water capacity by multiplying the output rate of the tube (per 1000') by 8.712 (i.e., on a 5' bed spacing a 4.5gpm/1000' output rate tube will require 39.2 gpm per acre water capacity).

The tubing is available in various wall thicknesses ranging from 3 mils to 25 mils. Most growers use thin wall tubing (10 mils or less) and replace it every year. Heavier wall tubing can be rolled up at the end of the season and reused; however, take care in removing it from the field and store it in a shelter. Labor costs for removing, storing and reinstalling irrigation tubing are often prohibitive.

Excellent results have been achieved by injecting at least half of the fertilizer through the drip system. This allows plant nutrients to be supplied to the field as needed. This method also eliminates the need for heavy fertilizer applications early in the season, which tend to leach beyond the reach of root systems or cause salt toxicity problems. Only water soluble formulations can be injected through the drip systems. Nitrogen and potassium formulations tend to be more water soluble than phosphorous and, consequently, are more easily injected. These nutrients also tend to leach quicker and need to be supplemented during the growing season. Thoroughly flush drip systems following each fertilizer injection.

Water used in a drip irrigation system should be well filtered to remove any particulate matter that might plug the tubing. Test the water for minerals that could precipitate and cause plugging problems.

Scheduling Irrigation

The combined loss of water by evaporation from the soil and transpiration from plant surfaces is called *evapotranspiration* (ET). Peak ET rates for tomatoes are about 0.2 inch per day. Factors affecting ET are stage of crop growth, temperature, relative humidity, solar radiation, wind velocity and plant spacing. Transplant tomatoes into moist soil and irrigate with 0.3 to 0.5 inch immediately after transplanting to settle the soil around the roots.

Once a root system is established, maintain soil moisture to the 12-inch depth. The sandier soils in south Georgia have an available water holding capacity of about 1 inch per foot of soil depth. You should not deplete more than 50 percent of the available water before irrigating; therefore, when you use 0.5 inch, it should be replaced by irrigation. Soils having a higher clay content may have water holding capacities as high as 2 inches per foot. In these soils you can deplete as much as 1 inch before irrigating. This means net application amounts should be between 0.5 and 1.0 inch per irrigation. The actual amount applied should be 10 to 20 percent higher to account for evaporation losses and wind drift. The irrigation frequency will depend on daily evapotranspiration. In general, for sprinkler irrigated tomatoes during peak water use periods, sandy soils should receive 0.6 inch two or three times a week, and clay soils should receive 1.25 inches about every 5 days.

Irrigation can best be managed by monitoring the amount of moisture in the soil. This can be done with soil moisture blocks. For best results on tomatoes, maintain soil moisture below 30 centibars. Drip irrigation systems need to be operated more frequently than sprinkler systems. Typically, they are operated every day or every other day. Do not saturate the soil with water, especially when using plastic mulch. Plastic mulch will tend to keep the soil from drying out and tomatoes grow poorly in waterlogged soil.

Physiological Problems

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Several physiological problems can affect tomatoes. Most of these are due to specific adverse environmental conditions. Growers can do some things to help minimize their impact, but in many cases not much can be done. In addition, many of these conditions are not well understood, so corrective action is not always possible.

Blossom-End Rot

Blossom-end rot is a calcium deficiency that occurs at the blossom end of the fruit. It is characterized by black, necrotic, sunken tissue at the blossom end. Fruit with necrotic tissue is unsalable and the damage cannot be corrected. Although the tissue is calcium deficient, preplant applications of calcium or postplant applications to correct the disorder often have no effect.

Blossom-end rot develops very early in fruit formation when fruit is smaller than a fingernail, which is a critical time for calcium deposition in newly forming tissue. Calcium is relatively immobile in plants. Once it becomes part of the plant tissue in one location, it cannot be easily moved to new developing tissue. Further, calcium moves in the water stream of the plant's vascular tissue. So during hot ,dry conditions with high transpiration, calcium uptake may be high but may not be moving laterally into forming fruit. This results in deficiency in these developing tissues even though there is sufficient calcium present in the soil and available to the plant. There is evidence indicating that unstaked and unpruned plants are less likely to have this problem, but in Georgia most tomatoes are staked and pruned for ease of harvest and quality of fresh market fruit.

To a certain extent, this problem can be alleviated with even moisture during plant growth. Wide swings from wet to dry conditions as well as overwatering tend to aggravate this problem. Exogenous applications of calcium as foliar sprays have been suggested to alleviate this problem. Any such application would have to occur prior to visible symptoms when fruit are just forming, but there is little evidence this is an effective practice.

Blossom Drop

Although tomatoes are warm season vegetables, they require relatively moderate temperatures to set fruit. Nighttime temperatures above 70 degrees F. will cause blossom drop, which in turn will reduce yields.

This problem is solved by planting at that time of year when night temperatures will be below this threshold during flowering and fruiting. Transplanting dates for south Georgia would be from March 1 to April 30 in the spring and from July 15 to August 15 in the fall. In north Georgia this would be from April 15 to June 15 in the spring and it is not recommended that tomatoes be grown in the fall. In addition to planting date, there are "hot set" tomatoes available. These tomatoes have been bred to set fruit under higher temperatures (see Table 1 on page 7 for varieties). For fall planted tomatoes, hot set types are recommended.

Fruit Cracking

Tomato fruit are prone to cracking under certain circumstances. There are two different types of cracking — radial and concentric — both of which occur at the stem end. Radial cracking is more common and usually occurs during periods of high temperatures (at or above 90 degrees F.) and prolonged rain or wet soil when fruit will rapidly expand and often crack. This is particularly prevalent after a long period of dry weather. This type of cracking is also more prone to occur if fruit are exposed to intense sunlight. Finally, fruit load may also be a factor, with a light load more prone to cracking.

Maintaining even moisture conditions, avoiding excessive pruning, and having a heavy fruit load will help prevent this problem. Variety selection can also help alleviate this problem. Varieties are available that are resistant to cracking. Generally, cracking susceptible varieties will crack when fruit are still in the green stage, whereas resistant varieties often don't show cracking until later, when the fruit is turning color.

Concentric cracking is also caused by rapid growth, but generally occurs when there are alternating periodsof rapid growth followed by slower growth.

This can occur with wet/dry cycles or cycles of high and low temperatures. Generally this type of cracking occurs as fruit near maturation. Even moisture throughout the growing period will help alleviate this problem. Also avoid fertilization spikes that encourage cyclic growth.

Catfacing

Catfacing is characterized by distorted growth at the blossom end of fruit, often with rough calloused ridges. Catfacing generally occurs when fruit are formed during cool or humid weather that favors the corolla adhering to the developing fruit. The adhesion of these flower parts causes the distortion that appears as the fruit matures. Usually catfacing is most evident during the first harvest with fruit that was set during cooler temperatures. Planting later and using varieties resistant to catfacing will help prevent this from occurring.

Zippering may be related to catfacing, only the damage occurs in straight lines from the blossom end to the stem end. The line may have a calloused or corky appearance.

Puffiness

Fruit may appear normal or nearly so but, when cut, the locules appear empty. There is little or no fruit gel or seeds present. This usually occurs when fruit develop under conditions that are too cool or too hot (below 55 degrees F or above 90 degrees F.), which interferes with normal seed set. Tomatoes are self-fertile but require some disturbance of the flower in order for the pollen to be shaken onto the stigma. This can occur from insects or wind, or during the normal handling of plants (staking and pruning). Wet, humid and cloudy weather may interfere with insect pollination and the pollen may not shed as readily. Cool weather will slow the growth of pollen tubes. In addition, excess nitrogen appears to be a factor with this condition.

Little can be done to alleviate this problem other than planting at the proper time of year. Hot set varieties appear to be less susceptible to this problem.

Sunscald

Tomato fruit may develop a papery thin area on the fruit that will appear tan or white in color. This is caused by sunscald, where the area affected is exposed to intense sunlight and heat resulting in a breakdown of the tissue. Sunscald may also appear as hard yellow areas on the fruit that are exposed. Maintaining good foliage cover during fruit development and avoiding excessive pruning will minimize this problem.

Graywall or Blotchy Ripening And Internal Browning

Several different factors may contribute to these conditions. Internal browning may be caused by a virus (tobacco mosaic virus; see the disease section on page 25). Silverleaf whitefly has also been associated with uneven ripeness in tomatoes (see section on insects on page 29).

Graywall and blotchy ripening may occur together and may be caused by a bacteria. The outer wall will appear gray and be partially collapsed. Internally there are necrotic areas within the walls of the fruit. Factors associated with this condition include high nitrogen, low potassium, low temperatures, excessive soil moisture and soil compaction. Addressing these factors may reduce the incidence of this disorder.

Internal White Tissue

Occasionally, a tomato will exhibit white tissue in the crosswalls when cut. This is rarely seen when fruit are harvested at the mature green stage, but it can be a problem with vine ripe fruit. It is unclear what causes this, but adequate potassium fertilizer appears to reduce the problem.

Rain Check

Rain check is the formation of tiny transverse cracks on the fruit. These cracks may heal, forming a rough texture on the fruit; generally these fruit are unmarketable.

As with many of these disorders, it is unclear what causes this, but it is associated with rain events. Heavy rains following dry periods are times when this is most likely to occur. This phenomenon may be related to other types of cracking and may be alleviated with growing conditions that don't encourage wet/dry cycles.

Lime and Fertilizer Management

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Lime and fertilizer management should be tailored to apply optimal amounts of lime and nutrients at the most appropriate time(s) and by the most effective application method(s). Fertilizer management is impacted by cultural methods, tillage practices and cropping sequences. A proper nutrient management program takes into account native soil fertility and residual fertilizer. Therefore, the first step in an appropriate fertilizer management program is to properly take a soil test 3 to 5 months before the crop is to be planted.

Soil pH

Adjusting the soil to the appropriate pH range is the first consideration for any fertilizer management program. The soil pH strongly influences plant growth, the availability of nutrients, and the activities of microorganisms in the soil. It is important to keep soil pH in the proper range in order to produce the best yields of high quality tomatoes. Soil tests results indicate soil pH levels and also provide recommendations for any needed amounts of lime required to raise the pH to the desired range.

The optimum pH range for tomato production is 6.2 to 6.8. Most Georgia soils will become strongly acid (pH 5.0 or less) with time if lime is not applied. Continuous cropping and application of high rates of nitrogen reduce pH at an even faster rate. Lime also adds calcium and, with dolomitic lime, magnesium to the soil.

Calcium has limited mobility in soil, so broadcast and thoroughly incorporate lime to a depth of 6 to 8 inches. This will also neutralize soil acidity in the root zone. To allow adequate time for neutralization of soil acidity (raising the pH), lime should be applied and thoroughly incorporated 2 to 3 months before seeding or transplanting. However, if application cannot be made this early, liming will still be very beneficial if applied and incorporated at least 1 month prior to seeding or transplanting.

The two most common liming materials available in Georgia are calcitic and dolomitic limestone. Dolomiticlimestone also contains 6 to 12 percent magnesium in addition to calcium. Since many soils, and particularly lighter Coastal Plain soils, routinely become deficient in magnesium, dolomitic limestone is usually the preferred liming material.

Fertilizer Management and Application

Recommending a specific fertilizer management program universal for all tomato fields would result in applications that are inefficient and not cost effective. In addition to crop nutrient requirements and soil types, fertilizer recommendations should take into consideration soil pH, residual nutrients and inherent soil fertility. Therefore, fertilizer recommendations based on soil test analyses have the greatest potential for providing tomatoes with adequate but not excessive fertility. Applications limited to required amounts result in optimum growth and yield without wasting fertilizer or encouraging luxury consumption of nutrients, which can negatively impact quality or cause fertilizer burn.

Recommendations based on soil tests and complemented with plant tissue analyses during the season should result in the most efficient lime and fertilizer management program possible. Valid soil sampling procedures must be used to collect the samples submitted for analyses, however. To be beneficial, a soil sample must reliably represent the field or "management unit" from which it is taken. Soil samples that are improperly collected, compiled or labeled are of dubious benefit and may actually be detrimental. If you have questions about soil sampling, please contact your local county extension office for information.

In addition to lime application, preplant applications and in-season supplemental applications of fertilizer will be necessary for good crop growth and yield. In general, preplant applications are made prior to installation of plastic mulch. Research shows that broadcasting over the entire field is usually less effective than banding. An acceptable alternative to field broadcasting and one that is most often used with plastic mulch production is the "modified broadcast" method, wherethe preplant fertilizer containing a portion of the nitrogen and potassium, and any recommended phosphorous and micronutrients, are broadcast in the bed area only.

For example, on a 72-inch wide bed, a swath (24 inches to 48 inches wide) of fertilizer is uniformly applied centered over the bed and incorporated by rototilling. Additional applications are then made through the drip irrigation system. In bareground culture, preplant applications are followed by one to three sidedressed applications. The general crop requirements and application timings for the various nutrients are discussed below.

Starter Fertilizer Solutions

Fertilizer materials dissolved in water and applied to the soil around plant roots at or just after transplanting are called starter solutions. When proper formulations and rates are applied, they can promote rapid root development and early plant growth. Starter solutions for tomatoes should contain a high rate of phosphorus (approximate ratio of 1 Nitrogen:3 Phosphorus:0 Potassium is common) and should be mixed and applied according to the manufacturer's directions. Common starter solutions consist of 3 pounds of a formulated material (such as 10-34-0, which weighs approximately 11 lbs./gallon) mixed in 50 gallons of water. Approximately ½ pint of the starter solution is normally applied per plant.

In addition to supplying phosphorus, which may be inadequately available (especially in cold soils in the early spring), the starter solution supplies water and firms the soil around roots. This helps eliminate air pockets that can cause root drying and subsequent plant or root damage. A starter solution is no substitute for adequate rainfall or irrigation after transplanting, however.

Be careful to mix and apply starter fertilizer according to the manufacturer's recommendations. If the starter solution is too highly concentrated (mixed too strong), it can kill plant roots and result in dead or stunted plants. When mixing and applying from a large tank, mix a fresh solution only after the tank becomes empty. This helps prevent the gradual increase in concentration that will occur if a portion of the previous mix is used for a portion of the water component in subsequent batches. If a dry or crystalline formulation is used, be sure it is thoroughly mixed and agitated in the tank, since settling can result in streaks of highly concentrated application that can stunt or kill plants.

Phosphorus and Potassium Recommendations

Table 4 indicates the pounds of fertilizer nutrients recommended for various soil P and K levels according to University of Georgia soil test ratings of residual phosphorus (P_2O_5) and potassium (K_2O).

All the recommended phosphorus should be incorporated into the bed prior to plastic mulch installation or, for bare ground production, applied during or near transplanting. As previously discussed, approximately ½ pint of a starter solution should be applied to each transplant.

For early growth stimulation in bare ground culture, pop-up fertilizer should be banded 2 to 3 inches to the side of the plants and 2 to 3 inches below the roots. Around 100 to 150 pounds per acre of a pop-up fertilizer promotes earlier growth, particularly in cool/cold soils. A good pop-up fertilizer has approximately a 1 to 3 N to P ratio. It should be relatively high in phosphorus and low in potassium.

One-third to one-half of the potassium should either (1) be incorporated into the bed prior to installing plastic mulch, or (2) be applied in two bands, each located 2 to 3 inches to the side and 2 to 3 inches below the level of plant roots for bare ground production. The remainder of the recommended potassium should be applied through the drip system according to the schedule in Table 5 or, for bare ground culture, in one to three applications as needed. It can be banded in an area on both sides of the row just ahead of the developing root tips. The maximum number of applications is usually more effective on sandy soils.

Nitrogen Recommendations

Typical Coastal Plains soils require a total of 150 to 200 pounds of nitrogen (N) per acre. Extremely sandy soils may need additional N or an increased number of applications. Piedmont, Mountain and Limestone Valley soils usually require only 100 to 150 pounds of N per acre for tomato production.

Nitrogen rates actually needed will vary depending on rainfall, soil type, soil temperature, irrigation, plant population, duration of the harvest season, and method and timing of applications. Excessive N applications can delay maturity, cause rank vine growth at the expense of fruit set, and reduce shipping quality of fruit.

For typical Coastal Plains soils, one-third to one-half of the recommended nitrogen should either (1) be incorporated into the bed prior to plastic installation or, (2) with bare ground culture, applied in two bands, each located 2 to 3 inches to the side and 2 to 3 inches below the level of plant roots. Apply the remaining recommended N through drip irrigation according to the schedule in Table 5. On bare ground, one to three side dressed applications (possibly four to five applications for extended harvest period on very sandy soil) are needed. It can be banded in an area on both sides of the row just ahead of the developing root tips. For heavier Piedmont, Mountain and Limestone Valley soils, one to two applications are usually sufficient.

Approximately 50 percent of the total applied N should be in the nitrate form. High rates of ammoniacal nitrogen may interfere with calcium nutrition and result in an increased incidence of blossom-end rot (BER). Side dressing with calcium nitrate as the nitrogen source often significantly reduces the severity of BER.

Magnesium, Sulfur, Zinc and Boron Recommendations

If the soil test indicates magnesium is low and if lime is recommended, apply dolomitic limestone. If magnesium is low and lime is not recommended, apply 25 pounds of elemental magnesium per acre. Apply a minimum of 10 pounds of sulfur per acre and, if soil test indicates low, apply 1 pound of actual boron per acre and 5 pounds of actual zinc per acre. These nutrients should be supplied in the preplant fertilizer application.

Table 4. Phosphorous and potassium recommendations for tomato production.

	Phosphorous and Potassium Recommendations (lbs/ac)			
	Low	**Medium**	**High**	**Very High**
Phosphorous Ratings				
Recommended P	200	150	100	50
Potassium Ratings				
Recommended K	200	150	100	50

P - Represents pounds of P_2O_5 recommended per acre; K - Represents pounds of K_2O recommended per acre.
Note: If soil testing is done by a lab other than the University of Georgia Soils Testing Laboratory, the levels recommended above may not apply because of potentially different methodology and definition of fertility ranges among labs.

Table 5. An example fertilizer injection schedule for a Coastal Plains soil that is low in potassium. The schedule is for a 14-week crop. Extended harvests will require additional injection applications.

			Crop Stage in Weeks (lbs/A/day)					
Nutrient	**Total (lbs/A)**	**Preplant (lbs/A)**	**1-2**	**3-4**	**5-6**	**7-10**	**11-12**	**13-14**
Nitrogen	225	50	1.0	1.5	2.0	2.5	2.0	1.0
Potassium	225	50	1.0	1.5	2.0	2.5	2.0	1.0

Foliar Application of Fertilizer

The fact that plants can absorb some fertilizer elements through their leaves has been known for some time. Leaves of many vegetable plants, however, are not especially well adapted for absorbing nutrients because of a waxy cuticle. In some instances, plants that seem to benefit from foliar uptake are actually benefitting from nutrient spray that reaches the soil and is taken up by roots.

The effectiveness of applying macronutrients such as nitrogen, phosphorus and potassium to plant leaves is questionable. It is virtually impossible for tomato plants to absorb enough N, P or K through the leaves to fulfill their nutritional requirements; furthermore, it is unlikely that they could absorb sufficient amounts of macronutrients to correct major deficiencies. Although nitrogen may be absorbed within 24 hours after application, up to f4 days are required for potassium uptake, and 7 to 15 days are required for phosphorus to be absorbed from foliar application.

The crucial question is whether or not foliar N, P or K actually increases yield or enhances quality. Although some growers feel that foliar fertilizer should be used to supplement a soil applied fertilizer program, research findings do not support this practice. If proper fertilizer management of soil applied nutrients is used, then additional supplementation by foliar fertilization is not usually required.

Foliar nutrients are often expected to cure a variety of plant problems, many of which may be unrelated to nutrition. They include reducing stress induced blossom drop, aiding in healing frost or hail damaged plants, increasing plant resistance to various stresses and pests, etc. Nutrients are only effective as long as they are supplying a nutritional need, but neither soil-applied nor foliar-applied nutrients are panaceas.

Quite often after frost or hail occurs, tomato growers apply foliar nutrients to give the plants a boost to promote rapid recovery. If a proper fertilizer program is being used before foliage damage, tomato plants don't need additional fertilizer. What they do need is time and the proper environment for the normal recovery processes to occur. In addition, the likelihood of significant nutritional benefits from a foliar application of fertilizer to plants that have lost most of their leaves (or have a large proportion of their leaves severely damaged) is questionable.

Foliar application of sulfur, magnesium, calcium and micronutrients may help alleviate deficiencies. They should be applied, however, only if there is a real need for them and only in quantities recommended for foliar application. Application of excessive amounts can cause fertilizer burn and/or toxicity problems.

Foliar applications of calcium nitrate or calcium chloride (one to three weekly applications beginning at first bloom or at first sign of BER) may reduce the incidence of blossom-end rot (BER), but there is little evidence indicating this is an effective practice. If attempted, the recommended rate is 3 to 4 pounds in 100 gallons of water per acre.

Two to three foliar applications of water soluble boron (approximately 1 to 2 ounces by weight of actual boron per application) at weekly intervals coinciding with flowering has in some instances enhanced fruit set. A commercial formulation that contains both boron and calcium (2 to 3 ounces by weight of calcium per application) may be applied. Follow manufacturer's directions when applying any commercial calcium/boron formulations.

Plant Tissue Analysis and Petiole Sap Analysis

Plant tissue analysis or petiole sap analysis is an excellent tool for measuring the nutrient status of the crop during the season. Particularly with fertigation, it is simple to adjust fertilizer injection rates according to the analysis results. Sufficiency ranges for tissue analysis are in Tables 6 and 7 and are for first flower stage and first ripe fruit stage, respectively, with the sample taken from the most recently mature leaf. Fresh sap can be pressed from the petioles of tomato plants and used to determine nitrogen and potassium nutritional status. Sufficiency ranges for these are listed in Table 8.

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Table 6. Plant tissue analysis ranges for various elements for tomato sampled at the first flower stage with most recently mature leaves.

	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu	Mo
Status	Percent						Parts per Million					
Deficient <	2.8	0.2	2.5	1.0	0.3	0.3	40	30	25	20	5	0.2
Adequate	2.8-4.0	0.2-.04	2.5-4.0	1.0-2.0	0.3-0.5	0.3-0.8	40-100	30-100	25-40	20-40	5-15	0.2-0.6
High >	4	0.4	4	2	0.5	0.8	100	100	40	40	15	0.6

Table 7. Plant tissue analysis ranges for various elements for tomato sampled at the first ripe fruit stage with most recently mature leaves.

	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu	Mo
Status	Percent						Parts per Million					
Deficient <	2.0	0.2	2.0	1.0	0.25	0.3	40	30	20	20	5	0.2
Adequate	2.0-3.5	0.2-0.4	2.0-4.0	1.0-2.0	0.25-0.5	0.6-0.6	40-100	30-100	20-40	20-40	5-10	0.2-0.6
High >	3.5	0.4	4	2	0.5	0.6	100	100	40	40	10	0.6

Table 8. Sufficiency ranges for petiole sap tests for tomato at various stages of crop development.

	Fresh Petiole Sap Concentration	
Crop Development Stage	**NO_3 - N**	**K**
First Flower Buds	1000-1200	3500-4000
First Open Flowers	600-800	3500-4000
Fruits 1-inch Diameter	400-600	3000-3500
Fruits 2-inch Diameter	400-600	3000-3500
First Harvest	300-400	2500-3000
Second Harvest	200-400	2000-2500

Sprayers

Paul E. Sumner
Extension Engineer

The equipment used for applying liquid insecticides, fungicides, herbicides and foliar fertilizers are classified as sprayers. Basically, there are two types of sprayers recommended for spraying tomatoes — hydraulic and air-curtain boom. The key to maximum coverage with insecticide and fungicides is the ability of the air within the plant canopy to be replaced with pesticides.

The **air-curtain booms** (Figure 1, page 23) are designed with an external blower fan system. The blower creates a high velocity of air that will "entrain" or direct the spray solution toward the target. Some sprayers provide a shield in front of or behind the conventional spray pattern, protecting the spray from being blown off-target.

The concept of this approach is to increase the effectiveness of pest-control substances, provide better coverage to the underside of leaves, promote deeper penetration into the crop canopy, make it easier for small droplets to deposit on the target, cover more acres per load, and reduce drift.

Studies conducted by the USDA Agricultural Research Service in Stoneville, Mississippi, have shown that the air-assisted sprayers tended to show improved insect control in the mid to lower canopies. The air stream tended to open the canopy and help spray particles penetrate to a deeper level. Mid- to lower-canopy penetration and coverage is importantwhen working with insecticides and fungicides, but may not be as critical when applying herbicides.

The **hydraulic boom** sprayers (Figure 2, page 23) get their name from the arrangement of the conduit that carries the spray liquid to the nozzles. Booms or long arms on the sprayer extend across a given width to cover a particular swath as the sprayer passes over the field. Each component is important for efficient and effective application.

Most materials applied by a sprayer are a mixture or suspension. Uniform application demands a uniform tank mix. Most boom sprayers have a tank agitator to maintain uniform mixture. The agitation (mixing) may be produced by jet agitators, volume boosters (sometimes referred to as *hydraulic agitators*) and mechanical agitators. These can be purchased separately and put on sprayers. Make sure an agitator is on every sprayer. Some growers make a mistake of not operating the agitator when moving from field to field or when stopping for a few minutes. Always agitate continuously when using pesticides that tend to settle out.

Nozzles

Nozzle tips are the most neglected and abused part of the sprayer. Since clogging can occur when spraying, clean and test nozzle tips and strainers before each application. When applying chemicals, maintain proper ground speed, boom height and operating pressure.

This will ensure proper delivery of the recommended amount of pesticide to the plant canopy.

Herbicides

The type of nozzle used to apply herbicides is one that develops large droplets and has no drift. The nozzles used for broadcast applications include the extended range flat fan, drift reduction flat fan, turbo flat fan, flooding fan, turbo flooding fan, turbo drop flat fan and wide angle cone nozzles. Operating pressures should be 20 to 30 psi for all nozzles except drift reduction and turbo drop flat fans, flooding and wide angle cones. Spray pressure more than 40 psi will create significant spray drift with flat fan nozzles. Operate drift reduction and turbo drop nozzles at 40 psi. Operate flooding fan and wide angle cone nozzles at 15 to 18 psi. These nozzles will achieve uniform application of the chemical if they are uniformly spaced along the boom. Flat fan nozzles should overlap 50 to 60 percent.

Continued on Page 27

Sprayers

Figure 1. Air-assisted boom sprayer.

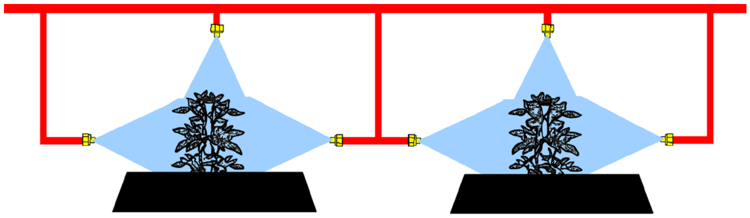

Figure 3. Use one nozzle over the row up to 8 inches, then change to three nozzles for optimum coverage of the tomato plant.

Figure 2. Hydraulic boom sprayer.

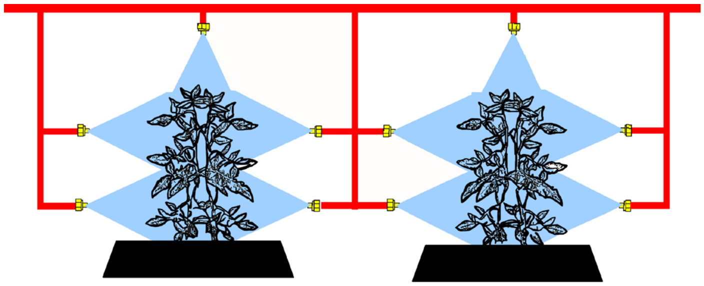

Figure 4. Add more pairs of nozzles as the plants grow taller and thicker.

Diseases

Figure 5. Leaf lesions caused by bacterial spot.

Figure 6. Chlorotic leaves caused by bacterial spot.

Figure 7. Fruit lesions from bacterial spot.

Figure 8. Bacterial wilt causes rapid wilting.

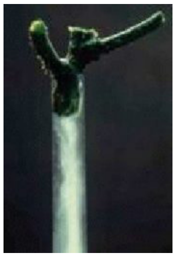

Figure 9. Bacterial streaming from infected plant cut and placed in water.

Figure 10. Plants on left stunted by TSWV.

Figure 11. TSWV ring-spots on foliage.

Figure 12. Dark streaks caused by TSWV.

Figure 13. Chlorotic spots caused by TSWV.

Figure 14. Small plant is severely stunted by TYLCV.

Figure 15. “Mouse-eared” appearance of leaves on plants infected with TYLCV.

Figure 16. Marginal leaf chlorosis associated with TYLCV.

Figure 17. Leaf lesions from early blight.

Figure 18. Complete yellowing and wilting from Fusarium wilt.

Figure 19. Vascular discoloration from Fusarium wilt.

Figure 20. Southern stem blight mold and reproductive structures on stem.

Insect Management

Figure 21. Adult thrips.

Figure 22. Adult winged aphid.

Figure 23. Adult flea beetle.

Figure 24. Hornworm larva.

Figure 25. Cabbage looper larva.

Figure 26. Winding mines in leaf created by leafminers.

Figure 27. Adult spider mites and eggs (highly magnified).

Figure 28. Speckled leaf caused by spider mites.

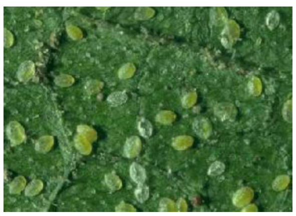

Figure 29. Sweetpotato whitefly nymphs on the underside of a leaf.

Figure 30. Late instar fruit-worm larva.

Figure 31. Early instar fruit-worm larva.

Figure 32. Late instar beet armyworm.

Figure 33. Beet armyworm egg mass hatching.

Figure 34. Yellowstriped army-worm larva.

Figure 35. Southern green stink bug adult.

Figure 36. Southern green stink bug nymph (late instar).

Figure 37. Leaffooted bug adult.

Figure 38. Tomato pinworm larva and damage (calyx of fruit removed).

Harvest, Handling and Sanitation

Figure 39. Field heat retained in packed tomatoes can speed up the breakdown of fruit.

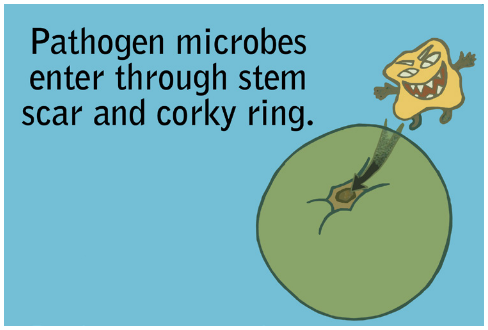

Figure 40. Infiltration of pathogens into a tomato.

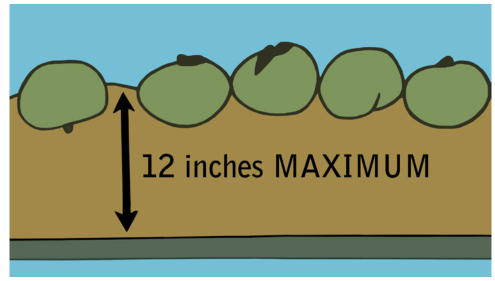

Figure 41. Partial submersion of tomatoes in a dump tank.

Figure 42. Using ORP meter to measure chlorine activity in wash water.

Figure 43. FDA regulations require that portable toilet and hand washing facilities be available within ½ mile of working field crews. [Photo courtesy of Trevor Suslow, UC-Davis]

Figure 44. Testing pH regularly will help maintain the maximum disinfectant activity of chlorine in wash or cooling water.

Figure 45. Commercial tomato sizing rings.

Figure 46. Barcoding facilitates traceback and sanitizing of reusable plastic containers.

Figure 47. Commercial forced air cooling system.

Figure 48. Blotchy coloring, surface pitting and black mold decay are evidence that these tomatoes were stored at too low a temperature.

Marketing

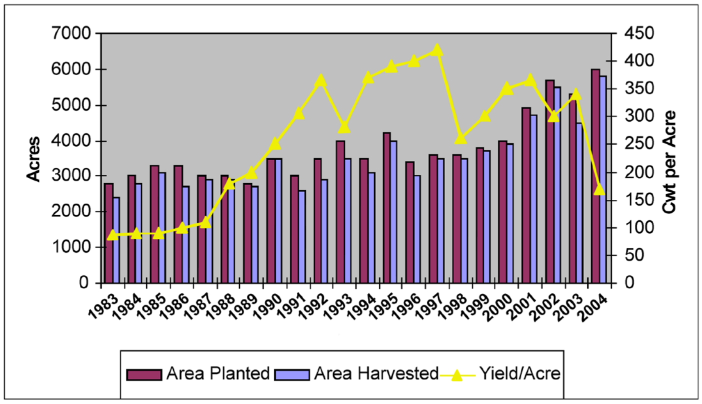

Figure 49. Georgia Tomato Area Planted, Harvested and Yields, 1983-2004. [Source: Georgia Agricultural Statistics Service/USDA, 2002 Census of Agriculture Georgia Profile. Also see http://www.nass.usda.gov/ga/]

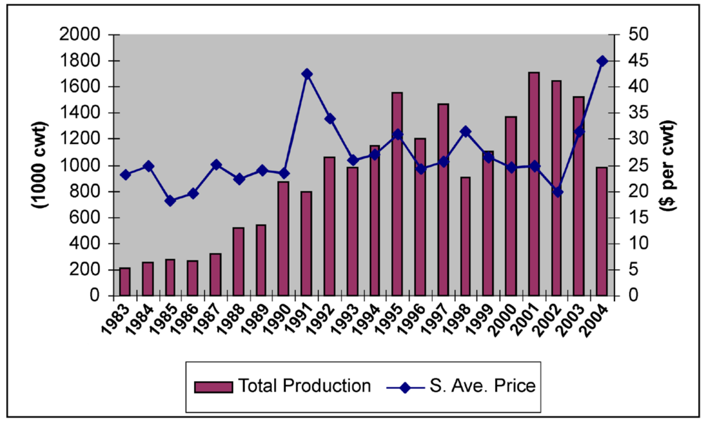

Figure 50. Georgia Tomato Production and Average Seasonal Prices, 1983-2004. [Source: Georgia Agricultural Statistics Service/USDA, 2002 Census of Agriculture Georgia Profile. Also see http://www.nass.usda.gov/ga/]

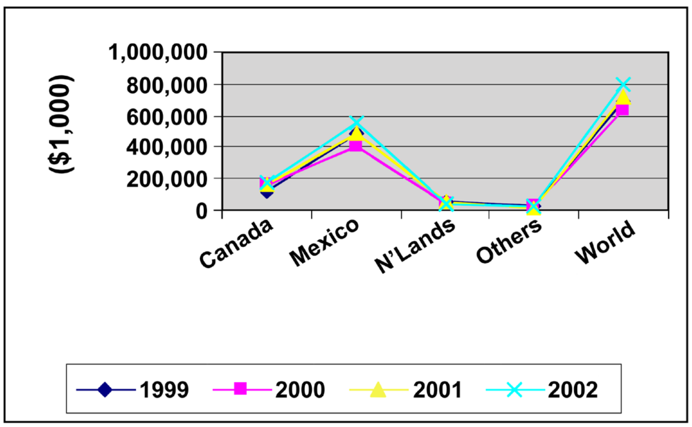

Figure 51. U.S. Import Value of Tomatoes: Selected Countries and the World ($1,000). [Source: ERS/ USDA Vegetables & Melon Outlook/VGS-2003, July 2003.]

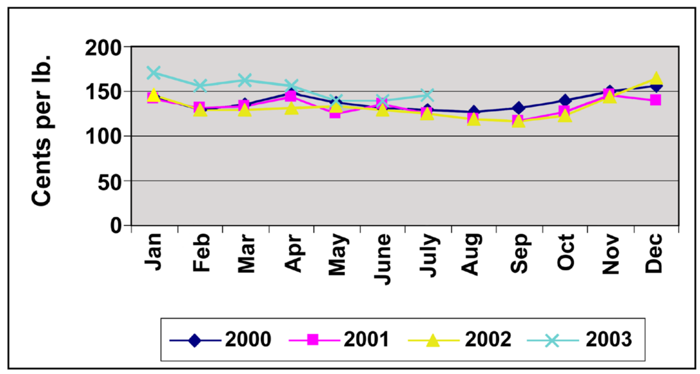

Figure 52. U.S. Average Tomatoes Retail Prices by Month: 2000-2003. [Source: ERS/USDA Vegetables & Melon Outlook/VGS-298, August 21, 2003]

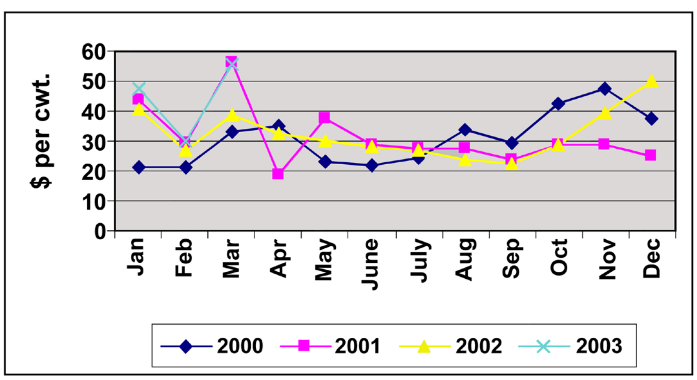

Figure 53. U.S. Monthly Tomatoes F.O.B. Shipping-Point Prices: 00-03. [Source: ERS/USDA Vegetables & Melon Outlook/VGS-296, April 17, 2003]

Continued from Page 22

Insecticides and Fungicides

When applying insecticides and fungicides, use solid or hollow cone type nozzles. The two patterns that are developed by solid or hollow cone nozzles can be produced by different tip configurations. One type tip, disc-n-core, consists of two parts. One part is a core (swirl plate) where the fluid enters and is forced through tangential openings. Then a disc-type hardened stainless steel orifice (opening) is added

Another type of tip that produces the same patterns is of one-piece construction (nozzle body). Liquid is passed through a precision distributor with diagonal slots that produce swirl in a converging chamber. The resulting pattern of both tip configurations is either solid or hollow cone. Even fan and hollow cone nozzles can be used for banding insecticide or fungicides over the row.Nozzle Arrangements

When applying insecticides and fungicides, it is advantageous to completely cover both sides of all leaves with spray. When spraying tomatoes, use one or two nozzles over the top of the row (up to 8 inches wide). Then as the plants start to grow and bush, adapt the nozzle arrangement for the various growth stages of plants (Figures 3 and 4, page 23). Opposing nozzles should be rotated clockwise slightly so that spray cones do not collide. This will guarantee that the spray is applied from all directions into the canopy. As the plant increases in height, add additional nozzles for every 8 to 10 inches of growth. In all spray configurations, the nozzle tips should be 6 to 10 inches from the foliage. Properly selected nozzles should be able to apply 25 to 125 gallons per acre when operating at a pressure of 60 to 200 or higher psi. Usually, more than one size of nozzle will be needed to carry out a season-long spray program.

Calibration

Calibrate sprayers often. Calibration should be conducted every 8 to 10 hours of operation to ensure proper pesticide application. A good calibration procedure to follow is in *Calibration Method for Hydraulic Boom and Band Sprayers and Other Liquid Applicators*, University of Georgia Cooperative Extension Circular 683.

This circular is available through local county extension offices and on the web at: http://pubs.caes.uga.edu/caespubs/pubcd/C683/C683.htm.

Diseases

David B. Langston, Jr.
Extension Plant Pathologist

Plant diseases are one of the most significant limiting factors to tomato production in Georgia. The hot, humid climate coupled with frequent rainfall and mild winters favor the development of many pathogens and the diseases they cause.

Bacterial Diseases

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 (Figure 5, page 23). 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 (Figure 6, page 23). Premature leaf drop is the ultimate result of leaf infection. Fruit lesions appear as small, round, dark brown to black spots (Figure 7, page 23).

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 beinspected for bacterial spot lesions before being sold or planted in the field.

Prevention is the best method for suppressing losses to bacterial spot. Purchase seed 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 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 past 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. Other bacterial-spot suppressive treatments are also available.

Bacterial wilt causes rapid wilting.Bacterial wilt, caused by *Ralstonia solanacearum*, is a devastating bacterial disease of tomatoes world-wide. This bacterium can last in the soil for several years and has been responsible for taking whole fields out of production. Bacterial wilt is recognized by a rapid wilting of the tomato plant, often while the plant is still green (Figure 8, page 23). Wilted plants will eventually die. A quick diagnostic tool is to cut a lower stem of a suspected infected plant and place it in a clear vial or glass of water and watch for the opaque, milky bacterial streaming that comes from the cut area (Figure 9, page 23).

Bacterial wilt is not easily controlled by fumigation or chemical means. There are few commercially available cultivars with resistance to bacterial wilt. The best control tool is to rotate away from infested fields for several years.

Bacterial speck, caused by *Pseudomonas syringae* pv. *tomato* is more of a problem of the cooler growing regions in north Georgia but rarely has been a problem in south Georgia. Leaflet lesions are very small, round and dark brown to black. During favorable weather the lesions can coalesce and kill larger areas of leaf tissue. Bacterial speck causes oval to elongated lesions on stems and petioles. Tomato fruit may have minute specks with a greener area surrounding the speck. Control measures are similar to bacterial spot.

Virus Diseases

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.

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) is one of the most common viruses affecting tomato in the southeastern United States. 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. As with any virus disease, however, early infections tend to cause more yield losses than those occurring later in plant development. TSWV causes plant stunting (Figure 10, page 23), ringspots (Figure 11, page 23) and bronzing on infected plants. Tomato fruit produced on infected plants may be misshapen, have dark streaks (Figure 12, page 23) or have chlorotic spots (Figure 13, page 23). TSWV in Georgia tomato has been suppressed through the use of metalized plastic and other colored mulches as well as resistant varieties.

Cucumber mosaic virus (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 symptoms for CMV are severely stunted, distorted and strapped (faciated) leaves, stems and petioles. Symptoms of CMV often resemble phenoxy herbicide injury. Few options are available for suppressing losses to CMV, but destruction of weed hosts that harbor the virus will aid help suppress disease spread.

Tomato yellow leaf curl virus (TYLCV) is a very serious virus disease that has only recently caused losses in Georgia. This is a virus that is whitefly-transmitted and is only a problem in years when white-fly populations are high. Infected plants appear to be severely stunted and little to no yield can be obtained from these plants (Figure 14, page 23). Plant symptoms appear as severely stunted individual plants with greatly reduced leaves that take on a mouseeared appearance (Figure 15, page 23). Tomato leaflets of infected plants may also have a distinct marginal chlorosis (Figure 16, page 23).

This disease is often brought in on infected transplants and then spread by whiteflies, so transplant inspection is a must. Identifying infected plants soon after transplanting and removing them will help prevent secondary spread. Preventive, systemic insecticide applications may prevent disease spread as well.

Fungal Diseases

Early blight caused by *Alternaria solani* is the most common fungal disease of tomato foliage in Georgia. Leaf symptoms appear as round to oblong, dark brown lesions with distinct concentric rings within the lesion (Figure 17, page 23). Lesions are generally surrounded or associated with a bright yellow chlorosis. Stem lesions are slightly sunken, brown and elongated with very pronounced concentric rings. Fruit may become infected around the calyx, and a velvety spore mass can often be observed on fruit lesions. The disease is introduced by wind or rain-splash and is carried over to subsequent crops on infested debris.

Wet, humid weather favors disease development. In the field, the fungus spores are spread mainly by wind. Unless controlled, it causes severe defoliation. Resistant varieties are available to avoid losses to early blight. Rotation and deep turning are important for reducing initial inoculum. The disease is easily controlled with chemical sprays. Spray programs used for bacterial leaf spot will suppress early blight, but the-Figure 9. Bacterial streaming from infected plant cut and placed in water.addition of chemicals specifically targeted at early blight should be incorporated into the spray program.

Late blight caused by *Phytopthora infestans*. This is probably one of the best known tomato diseases worldwide, but it is a rare in Georgia except for occasional epidemics observed in north Georgia. This disease causes dark, water-soaked, greasy lesions on stems and foliage. A whitish-gray, fuzzy sporulation can be seen on the undersides of leaf lesions and directly on stem lesions during periods of high moisture. A soft rot of fruit can also be observed.

Phytopthora is a fungal-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 its life cycle. The pathogen is carried by wind to non-infested areas, where it remains in the soil and on infested plant debris until favorable weather and a new host crop coincide to create a new epidemic. Warm days and cool nights coupled with adequate moisture favor the spread and infection of the late blight pathogen.

Plant resistance to this disease is available but does not play a major role in disease control. Destroying plant debris and rotating away from fields with a history of the disease is a must. Preventive fungicide sprays are generally relied on heavily where this disease occurs as a yearly problem.

Septoria leaf spot (*Septoria lycopersici*) and **Target spot** (*Corynospora cassiicola*) are foliar fungal diseases of some importance in Georgia but are not generally a problem with the current spray regime that is targeted at early blight and bacterial spot.

Fusarium wilt caused by *Fusarium oxysporum* f.sp. *lycopersici*. Fusarium wilt is a soilborne disease of tomatoes that is generally a problem in specific fields where the pathogen has been introduced. The disease is initially brought into a field on infested seed, plant stakes, transplants or infested soil on equipment.

Symptoms usually appear during hot weather and after fruit set has begun. Symptoms appear as a yellowing and wilting on one side of the plant at first, usually during the hottest part of the day, followed by the eventual complete yellowing and wilting of the plant (Figure 18, page 23). Entire death of the plant is the final result. Vascular discoloration is often observed on stems above the soil line (Figure 19, page 23).

This fungus can stay in the soil in a resting state for several years, and rotation away from these fields for 5-7 years will lessen the severity but will not completely eliminate the disease. Fumigation really only delays disease onset and may lessen the total disease incidence. Preventing the disease from getting into the field is the best control measure, followed by the use of resistant varieties. Several races of this disease occur, however, and resistance must be specific to the race of Fusarium that is in the field in question.

Southern stem blight caused by *Sclerotium rolfsii*. This 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 base. Later in the season, small, round brown bodies appear in the mold (Figure 20, page 23). Infected plants wilt and slowly die. Vascular discoloration can be observed on stem tissues above the lesion.

The severity of the 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.

Nematodes

Root-knot nematodes (*Meloidogyne* spp) can cause serious economic damage to tomatoes. These tiny worms live in the soil and feed on the roots of tomatoes. Not only do they cause physical damage that interferes with the uptake of water and nutrients, but they allow the establishment of other diseases.

Nematode infected plants are generally stunted with pale green to light yellow foliage. Symptoms may be temporarily masked by supplying additional fertilizer and water. Soils infested with root-knot nematodes should be avoided or treated with fumigant or chemical nematicides before tomatoes are planted.

Insect Management

Alton N. Sparks, Jr.
Extension Entomologist

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, 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, outbreaks are difficult to predict, and it is even more difficult to predict if control measures will be required. A knowledge of insect habits, careful pest monitoring and timely use of effective control measures will enable growers to avoid or at least reduce the damage they suffer. Tomato is well suited for insect pest management.

Because a variety of insects may attack tomato, scheduled sprays are frequently considered for insect management. Scouting two to three times per week, however, 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 Pest Management Handbook* to aid in selecting the correct insecticide for control of specific insect pests described in the following text.

Seedling Pests

Cutworms. Young tomato transplants may be cut down just above the soil surface by cutworms. While this damage is readily apparent, the insects are difficult to detect during the day as the larvae typically hide in the ground. Detection of the insects and verification of the pest problem is most easily accomplished when larvae are feeding at night.

The majority of cutworms pass the winter in the soil as full-grown larvae, and cutworm damage can be particularly abundant in fields where grass sod was the previous crop or in previously fallow fields with heavyweeds. Greatest damage is often found in wet areas of fields but can also be concentrated on field margins where cutworms are moving in from adjacent areas.

Cutworms are generally considered a seedling pest, but they may also feed on foliage and fruit of mature plants. Use preventive insecticide treatments on fields with a history of cutworms or on tomato fields following grass sod. Where preventive treatments are not used, use directed sprays for cutworm control when 5 percent of the seedlings have been damaged or destroyed and cutworms are still present. All directed or foliar sprays used for cutworm control should be applied late in the day when cutworms are active.

Other insects attacking the main stem of seedlings. Several occasional pests may cause damage similar to cutworms. White grubs (immature stage of May beetles and June beetles) may cut off plants, but they will typically cut plants slightly below the soil line as compared to cutworms, which will usually cut at or slightly above the soil line.

Vegetable weevils, crickets and grasshoppers may also attack the main stems of seedlings. Generally these pests do not cut off plants except for the smallest transplants. They tend to feed up and down the main stem, removing the softer outer tissue, and can completely girdle the plant. This damage generally causes plant death and, at the least, makes the plant susceptible to lodging and seedling diseases.

Three-cornered alfalfa hopper may also attack seedlings. This pest has piercing-sucking mouth parts and does not remove plant tissue. It will circle small stems while feeding, producing a "girdle" on the stem, which interferes with water and nutrient translocation. This weakened area makes the plant susceptible to lodging.

Thrips. Thrips may be present in tomato fields throughout the growing season, but they are more prevalent in the spring. Prior to plants blooming, tobacco thrips generally dominates the population since this species readily feeds and reproduces on foliage. Flower thrips species populations can increase dramatically once blooming and pollen availability increases. Flower thrips populations may increase prior to the crop blooming if outside sources of pollen are plentiful.Plant injury is caused by both nymphs and adults (Figure 21, page 24) puncturing leaf and floral tissues and then sucking the exuding sap. This causes reddish, gray or silvery speckled areas on the leaves. With severe infestations, these areas can interfere with photosynthesis and result in retarded growth. Heavy infestations during the bloom stage may cause damage to developing fruit through egg laying. This damage appears as dimples with necrotic spots in the center and may be surrounded by a halo of discolored tissue. Occasionally thrips aggregate on fruit well hidden from sprays. This may result in russeting damage from continual feeding during fruit development. While thrips can cause direct damage to foliage and fruit, their role as vectors of tomato spotted wilt (TSWV) is of primary concern in Georgia.

To prevent direct damage, make applications of insecticides when 20 percent of plants show signs of thrips damage, or when 5 or more thrips per bloom are found. Thrips are very small, so close observation is necessary. Thrips may be monitored in a variety of ways including various methods of beating plants to dislodge thrips from foliage into a collection device (Styrofoam cup, white tray, sticky trap). An effective in-field survey method for thrips in blooms is to place several blooms in a vial of alcohol and count the thrips as they die and settle to the bottom.

Where TSWV is of concern, grow virus resistant varieties. For management of TSWV in susceptible varieties, UV-reflective plastic mulch, or metalized mulch, has proven useful in suppression of thrips populations and virus incidence. Insecticides also are frequently used in a preventive manner where TSWV is of concern.

Foliage Feeders

Aphids. 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 (Figure 22, page 24) move from field to field spreading virus diseases, host plant resistance in tomatoes has helped minimize this problem. Large populations of aphids on young plants can cause wilting and stunting but rarely occur. At harvest, infestations can represent a contamination 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. Feeding by these pests causes newly formed leaves to be crinkled and malformed. 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.

Colorado Potato Beetle. Colorado potato beetles occasionally occur in damaging numbers in tomato fields. They lay orange-yellow eggs in groups of a dozen or more on the undersides of leaves; these eggs are often mistaken for lady beetle eggs. Injury to tomatoes is due to actual consumption of foliage and stems by the chewing adults and larvae. Young plants may be completely defoliated.

In tomato-growing areas where spraying for insect control is a regular practice, insecticides have reduced the population so that it is no longer a serious problem. In some areas, however, the control of this insect still demands attention. Colorado potato beetles can occur in large numbers and are generally uniformly distributed over a local area. Because of their short life cycle and high reproductive capacity, treatments are needed as soon as beetle eggs or larvae are found. Because this is a rare pest, determine its presence by scouting.

Flea Beetles. 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 (Figure 23, page 24).

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. Apply insecticides for control of flea beetles 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.

Hornworms. 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 (Figure 24, page 24). Hornworms may feed on green fruit, but they 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. Apply treatments for horn-Figure 22. Adult winged aphid.worm control when one larva is found on 4 percent of the plants examined.

Cabbage Looper. The most common looper in tomatoes in Georgia is the cabbage looper (Figure 25, page 24). Loopers are foliage feeders and damage to fruit is rare. Larvae chew irregular holes in leaves. Leaf damage is of concern only when large numbers of larvae attack small plants or if feeding is extensive enough to open the canopy to expose fruit to sunburn. Mature plants can tolerate multiple larvae per plant without significant loss.

Looper eggs are laid singly on plants and can be confused with tomato fruitworm eggs; however, looper eggs are flatter than fruitworm eggs and have finer ridges radiating from the top of the egg. Looper larvae are easily identified by their habit of arching their backs into a loop as they crawl. Loopers are frequently controlled by insecticide applications applied for other caterpillar pests.

Leafminers. Adult leafminers are tiny, shiny, black flies with yellow markings. Adult female flies lay eggs within the leaves, and white to pale yellow larvae with black mouthparts mine between the upper and lower leaf surface for about 5 to 7 days before dropping to the ground to pupate. As the larvae grows and consumes more leaf tissue, the winding mine increases in diameter. Leafminer infestations usually are first detected as these slender, white, winding trails caused by the larvae (Figure 26, page 24). The leaves are greatly weakened and the mines may serve as points where decay and disease may begin. With severe infestations, heavy leaf loss may lead to sun scald of fruit.

Several parasites attack this pest and can keep leaf-miner 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. Begin treatments for leafminer control when populations reach an average of five mines/leaf with at least 25 percent of the mines containing live larvae.

Spider Mites. Spider mites appear to be developing into a more consistent pest in south 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, page 24). 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 paleblotches (Figure 28, page 24). In heavy infestations, the entire leaf appears light in color and 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.

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.

In general, apply treatments for mite control when mites become numerous and their damage appears excessive. Some of the newer acaricides, however, 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 tomatoes, which are favored hosts of spider mites.

Whiteflies. Adult whiteflies are tiny (about ⅛ inch) insects with white wings, a yellow body and piercing-sucking mouthparts. Adults are found on the underside of leaves, where they feed and lay eggs. While adults can cause direct damage by feeding, typically the nymphs are the more damaging stage. The scale-like nymphs (Figure 29, page 24) also occur on the underside of leaves and all but the first instar are sessile.

Whiteflies, particularly the sweetpotato or silverleaf whitefly, can be a severe pest in tomatoes grown in the fall. Because this pest does not overwinter well in south Georgia, tomatoes grown in the spring typically are harvested before whitefly populations reach damaging levels. The sweetpotato whitefly can cause direct damage in the fall, when populations are large enough to cause defoliation, and can produce enough honeydew and sooty mold to be a contamination problem at harvest. At much lower densities, however, this pest causes irregular ripening of fruit and can transmit severe viral diseases, including tomato yellow leaf curl. Whiteflies typically are not a problem in tomatoes grown in the spring. Preventive treatments with systemic soil-applied insecticides are generally necessary for tomatoes grown in the fall, and may require additional foliar treatments.

Fruit Feeders

Tomato Fruitworm (corn earworm). Among the most serious pests of tomatoes is the tomato fruitworm or corn earworm, particularly in the summer and fall. The larvae vary greatly in color from a light green to brown or nearly black and are lighter on the underside (Figure 30, page 24). 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 (Figure 31, page 24).

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. If fruiting structures are not available, the larvae can feed on foliage. The larva are rather restless and shift from one fruit to another so a single caterpillar may spoil several fruit without eating the equivalent of a single fruit. This movement does benefit control efforts, as the caterpillars are exposed to insecticide applications as they move among fruit. Several generations of tomato fruitworm may develop each year. Apply treatments for tomato fruitworm control when 1 percent of fruit are infested with larvae or if eggs are easily found.

Beet Armyworms. Beet armyworm (Figure 32, page 24) 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. This pest is now a fairly consistent pest in the summer and fall, however.

Beet armyworms feed on both the foliage and fruit of tomato plants. Eggs are laid in masses on the undersides of foliage. Young larvae remain near the site of hatching (Figure 33, page 24), feeding in groups that cause characteristic foliar damage referred to has "hits." After feeding on foliage for a few days, medium sized larvae (3rd 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.

Other Armyworms. Both Southern armyworm and Yellowstriped armyworm are commonly encountered defoliators of tomatoes. Their behavior is similar to thebeet armyworm, with eggs laid in masses, early instars feeding gregariously on foliage, and later instars feeding on foliage or fruit. The Southern armyworm is more prevalent than the Yellowstriped armyworm, but both are occasional pests. Larvae of both species have two lines of dark triangular marks on their backs and a longitudinal white to yellow line along each side (Figure 34, page 24). Yellowstriped armyworm seldom reach population densities that require treatment, but can be difficult to control. Large outbreaks of southern armyworm can occur, but this pest is easily controlled with insecticides. Insecticides targeted at other caterpillar pests likely prevent more frequent damage by southern armyworm.

Tarnished Plant Bugs. Tarnished plant bugs are sucking bugs 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.

Stink Bugs and Leaffooted Bugs. Several species of stink bugs can damage tomatoes. Stink bug adults are generally medium sized shield-shaped bugs with broad "shoulders" and a bluntly rounded abdomen (Figure 35, page 24). They also have a triangular shaped shield on their backs. The most common species in tomatoes are either a uniform green color (southern green stink bug) or tan to brown with light colored undersides (various species of brown stink bugs). Stink bug nymphs are more oval shaped (Figure 36, page 24) and vary greatly in color. Eggs are somewhat barrel-shaped and are deposited on end in tightly packed clusters. 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 (Figure 37, page 24).

Stink bugs and leaffooted bugs have needle-like mouthparts with which they puncture plant tissue and remove sap. The greatest damage results from feeding on fruiting structures. Severity of the damage to fruit varies greatly with the developmental stage of the fruit. Damage early in fruit development can lead to severe deformities and abscission, while damage near harvest may result in small dark spots at the feeding site. These insects may also introduce bacteria and yeast as they feed, or may simply provide a site of entry for disease organisms, resulting in fruit decay. Stink bugs have become more of a problem in Georgia in recent years.

Tomato Pinworm. Tomato pinworms are small moths with a somewhat speckled appearance. Damage is caused by the caterpillar, which appears smooth-skinned with a purplish appearance in older larvae (Figure 38, page 24). Larvae usually begin feeding in leaf mines before moving to fruit but may enter fruit soon after hatching. In leaves, larvae mine for the first two in-stars, then form leaf folds in which the last two instars are completed. The most important damage occurs when larvae enter fruit. Larvae may enter fruit of any maturity. Larvae generally bore into fruit under the calyx, and the entry holes are difficult to detect. Once larvae have been feeding for a while, brown granular frass can often be seen at the edge of the calyx. Larvae may feed shallowly beneath the skin of the fruit near the stem or may bore into the core of the fruit. The feeding creates narrow blackened tunnels and exposes fruit to decay. It is difficult to sort out infested fruit, and larvae present at harvest may create a contamination problem. Adults can be monitored with pheromone traps, and pheromones have been used for mating disruption.

In Georgia, this is not a consistent pest; cultural controls, scouting and judicial use of pesticides is recommended. Problems with pinworm frequently arise from use of infested transplants; use of locally produced “clean” transplants is recommended to avoid transplanting pest problems with the crop. Close scouting of the crop for leafmines and frass around the calyx should detect populations before they reach damaging levels. In most cases in Georgia, this pest is likely controlled by insecticide applications targeting other lepidopterous species.

Weed Control

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

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

One of the most effective tools for suppressing weeds in tomatoes 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

Weeds can be controlled effectively through cultural practices that result in rapid tomato canopy establishment thus providing an undesirable environment for weed growth. Cultural practices may include the following: (1) plant seeds or transplants free of weeds; (2) plant healthy and vigorously growing plants; (3) good seedbed preparation; (4) proper fertilization and watering; (5) follow recommended row spacing; and (6) manage diseases and insects.

Site selection also 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 the use of alternative crops and control methods. Additionally, to prevent the spread of weeds from field to field during harvest, clean equipment and personnel when moving from heavily infested areas. This precaution can be of significant consequence in preventing or minimizing the introduction of new weed 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 tomatoes are produced on mulch, limiting the practicality of most mechanical control methods. Of course, hoeing and hand pulling of weeds are quite common.

For those growers producing tomatoes on bare ground, mechanical control practices such as cultivation and primary tillage are very beneficial for managing weeds.

Mulching

The use of polyethylene mulch increases yield and earliness of vegetables. Mulches act as a barrier to the growth of many 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, so 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 to find a suitable alternative to methyl bromide.

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.

Developing a Herbicide Program

Before selecting herbicides, growers should know what weeds are present or are expected to appear, the soil characteristic (such as texture and organic matter content), the capabilities and limitations of the various herbicides, and how best to apply each herbicide.

Weed Mapping: The first step in a weed management program is to identify the problem; this task is best accomplished by weed mapping. Develop surveys each fall to provide a written record of the species present and their population levels.

Proper weed identification is necessary since weed species respond differently to various herbicides. For assistance in identifying weeds, contact your local county extension office.

In-Season Monitoring: Monitor fields periodically to identify the need for postemergence herbicides. Even after herbicides are applied, continue monitoring to evaluate the success of the weed management program and to determine the need for additional control measures.

Herbicides: Properly selected herbicides are effective tools for weed control. Herbicides may be classified several ways, depending on how they are applied and their mode of action in or on the plant. Generally, herbicides are either soil-applied or foliage applied. They may be selective or non-selective, and they may be either contact or translocated through the plant. For example, paraquat (Gramoxone) is a foliage applied, contact, non-selective herbicide, while metolachlor (Dual) usually is described as a soil-applied translocated, selective herbicide.

Foliage-applied herbicides may be applied to leaves, stems and shoots of plants. Herbicides that kill only those parts of plants which the spray touches are contact herbicides. Those herbicides taken into the plant and moved throughout the plant are translocated herbicides. Paraquat (Gramoxone) is a contact herbicide, while glyphosate (Roundup) or sethoxydim (Poast) are translocated herbicides.

For foliage-applied herbicides to be effective, they must enter the plant. Good coverage is critical, and these products often require the addition of some type of adjuvant. Soil-applied herbicides are either applied to the surface of the soil or incorporated into the soil. Lack of moisture or rainfall following application of soil-applied herbicides often results in poor weed control.

Many herbicides applied in Georgia offer residual weed control, which is beneficial in the crop where the herbicide was applied. Before applying any herbicide in a crop, however, review the herbicide label and obtain the needed information on rotation restrictions. Many herbicides applied in peanut, cotton, tobacco and other vegetable crops can cause significant crop injury to tomato planted the following year.

For herbicide recommendations, contact your local extension office or view the most recent *Georgia Pest Management Handbook*.

Stale Seedbed: Herbicide options in the tomato crop are limited. The use of a stale seedbed approach prior to planting tomato on bareground or prior to transplanting tomato into mulch can be extremely 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. Be extremely careful when applying herbicides over the top of mulch prior to planting because some herbicides cannot be successfully removed from mulch and may cause severe crop injury once the crop is planted. Both glyphosate and paraquat, however, can be applied over mulch as long as a rain-fall or irrigation event of at least 0.5 inch occurs after applying these herbicides but before planting.

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Harvest, Handling and Sanitation

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Field Maturity

Fresh tomatoes are the number one crop in terms of farm gate value among all the vegetables grown and harvested in Georgia. Tomatoes should only be harvested when they reach the *mature-green* stage. If tomatoes are harvested any earlier, the fruit will fail to ripen normally. Since the mature-green state is difficult to judge externally, growers will often take a representative sample of fruit from their fields and cut it open for internal examination. A typical mature-green tomato will have a jelly-like matrix in all locules, and seeds will be sufficiently developed so as not to be cut when the fruit is sliced with a sharp knife.

While a few large commercial tomato operations harvest mature-green tomatoes that will be ripened later with ethylene gas, most Georgia growers wait until about 10 percent of their field reaches the "breaker" (pinking at the blossom end) stage of maturity before harvesting. Tomato quality at harvest is primarily based on uniform size and freedom from growth or handling defects. Appearance is a very important quality factor. Tomatoes should have a waxy gloss; small blossom-end and stem-end scars that are smooth; presence of a brown corky tissue at the stem scar; uniform color and minimum size for the variety; and an absenceof growth cracks, catfacing, zippering, sunscald, insert injury, hail damage, mechanical injury or bruising.

Size is not typically a factor of grade quality, but it may strongly influence commercial buyers' expectations. Georgia growers strive to harvest only large and extra-large tomatoes.

Harvesting

Fresh market tomatoes are harvested by hand in Georgia. The harvesting operation varies somewhat among growers. Mature-green harvested tomatoes are placed into polyethylene picking buckets that are carried to a flat-bed trailer where the fruit is dumped into plastic bulk bins. Each bin holds between 800 and 1,200 pounds of fresh fruit, and the trailer is positioned in the field so pickers only have to walk a minimal distance to reach a bin. Once all bins are loaded, they are transported to a centralized packinghouse where the fruit is washed, sized and packed out. Some growers avoid use of bulk bins because of potential damage to the fruit and field pack tomatoes into boxes. Some growers also combine the two approaches, with field packing of "pinks" (tomatoes that have begun changing color) and bulk harvesting of mature green tomatoes.

Good harvesting management is needed to pick high quality tomatoes. Care must be taken when harvesting "breaker" stage fruit because the riper the tomato, the more susceptible it is to bruising. Harvest crews should carefully place fruits into picking containers instead of dropping them. Research has demonstrated that a drop of more than 6 inches onto a hard surface can cause internal bruising that is not evident until after the tomato is cut open.

Bruising is characterized by water-soaked cellular breakdown of the cross-wall and locular (seed cavity) area. External bruising will be caused if pickers hurl or dump tomatoes too vigorously from the picking bucket into unpadded bulk bins. Bins should never be over-loaded because excessive tomato weight will cause bruise damage due to compression. Harvested tomatoes must be shaded to minimize heat-up while waiting for pallet bin dumping at the packinghouse. Research hasshown that bulk bin tomatoes held in the hot sun for just one hour can be as much as 25 degrees F warmer than fruit held in the shade. Field heat can speed up breakdown after packing (Figure 39, page 25).

Pickers should do preliminary grading to remove decayed fruit from the plants as they harvest the field. This will prevent cross-over disease contamination to otherwise healthy, sound fruit. Wet tomatoes should never be harvested, because surface moisture increases field heat accumulations in the load and enhances disease development.

All picking buckets should be cleaned and sanitized at the end of each harvest day to prevent the potential accumulation of disease organisms from infecting sound fruit picked the next production day. Rinse buckets with water to remove soil and field debris, then wash them in a sanitizing solution consisting of 5 oz. of household bleach (5.25 percent sodium hypochlorite) mixed in 5 gallons of water.

Postharvest Handling

The importance of care in handling tomatoes between the time of harvest and shipping to market cannot be overemphasized, since about half of the cost of tomato production is in the grading, cooling and packing of the product. Bulk bins of harvested tomatoes are taken from the field to the packing house, where they are mechanically unloaded in a water dump tank or concrete pit. Water jets convey the fruit by flume onto an inclined dewatering roller belt with soft bristle brushes that remove field debris. The fruit is then dried, pre-graded, color sorted and sized before being jumble-packed into 25-pound fiberboard cartons.

Georgia tomatoes typically are not waxed before shipping.

Mechanical damage (i.e., cuts, punctures, bruises, scars, scuff marks and discolored areas) accounts for more defects at the shipping point and in the market than all other defects combined. Of these, bruises are the most common and serious, comprising about half of all mechanical damage. Bruised tomatoes may be flattened or indented and soft; the locules either are dry or, if gelatinous tissue is present, it may be thick and stringy from continuous pressure or watery from severe impacts.

When tomatoes are physically injured during handling, disease organisms can easily invade the flesh, setting up decay. As shown in Table 9, decay due to bruising was the greatest contributor to tomato loss in marketing channels (Ceponis and Butterfield, 1979).

Tomatoes are scuffed and scarred when they rub against rough surfaces, such as bin boxes, pack-out cartons, dirty sorting belts, or even against each other, particularly when dirty. Tomatoes below about 60 degrees F scuff more easily than warm fruit. Scuffing and scarring are followed by pitting and browning, because the injured tissue dries out.

Tomatoes may be bruised any time between field and kitchen by being (1) thrown into picking box or bin; (2) pressed out of shape in a bin loaded too deeply; (3) dumped too vigorously from box or bin onto sorting belt, or dropped too far from sorting belt to shipping container; (4) squashed during stacking, loading or in transit; (5) handled roughly during sorting in the ripening room or during prepacking; (6) dumped into bulk retail display; or (7) squeezed in the hand of the customer or between harder items in the grocery bag.

External bruising mainly occurs before the fruit is packed, which allows the removal of most of the damaged fruit at origin. Internal bruising, however, occurs mainly during or after packing. The riper the fruit, the more readily it bruises. Degree of bruising under given conditions is not related to size, weight or mass of fruit in any one cultivar, however, although the latter do differ in their susceptibility to bruising.

Mechanical injury can be prevented, or at least reduced, only by careful analysis of each step during handling and by devising ways to minimize throwing, dropping or squeezing the fruit. Where drops are unavoidable, padding with 1-inch thick foam rubber substantially reduces injury. Avoid drops of 6 inches or more, whether the fruits hit a solid object or each other. Dumping fruit into water instead of directly onto a belt can help reduce bruising.

Scuffing and scarring can be minimized by keeping boxes, bins and belts clean and by packing fruit firmly but not too tightly. A loose pack allows fruits to rotate and rub against each other in transit, which leads to scuffing injury.

Table 9. Wastage of fresh tomatoes in Greater New York retail stores and in consumer samples (1974-1977).

Location of loss and type of packaging	Causes of loss (% by weight)			
	Bruise decay	Physical injuries	Physiological disorders	Total
Retail				
Prepackaged	4.2ab*	1.5a	0.6a	6.3a
Loose	3.8b	2.0a	0.9a	6.7a
Consumer				
Prepackaged	6.5a	1.1a	0.3a	7.9a
Loose	3.8a	0.7a	0.2a	4.7b

* Numbers followed by the same letter are not significantly different at 5% probability level.

Dump Tank Management

Recent attention by regulators, buyers and the industry has focused on the issue of infiltration of potential food-borne pathogens, such as *Salmonella*, through the stem scar or harvest wounds on fresh-market tomatoes or other fruits and vegetables during submersion in water dump or flotation tanks and flumes. This concern has been prompted primarily by two outbreaks of *Salmonella* in 1990 and 1993 linked to the consumption of fresh tomatoes from a single South Carolina packinghouse. More recently, Salmonella was identified as the pathogenic agent responsible for large multi-state food-borne disease outbreaks atretail and food service outlets in 2002 and 2004, respectively.

The same strategy for prevention of infiltration of plant pathogens leading to postharvest disease and decay can be employed to inhibit the internalization of food-borne disease pathogens. Research has shown that dump tank and/or flume water should be heated above the fruit pulp temperature to prevent air spaces of the fruit tissue from contracting. This constriction causes a vacuum, which draws pathogenic microorganisms in the water through the stem scar and into the internal seed cavity, where they are protected from the action of sanitizers (Figure 40, page 25).

Investigations at packing houses have led to the recommendation that postharvest immersion water should be maintained at temperatures of 10 degrees F (6.6 degrees C) above the highest tomato pulp to prevent water and microorganism uptake. Personnel involved with the dumping operation should not guess at the temperatures; use a calibrated thermometer to check both the fruit pulp temperature and water temperature. Although commercial practices vary, a common set point to maintain for water temperature is 104 degrees F (40 degrees C). Also, avoid the necessity and cost of having to heat water by providing shade to incoming bins of tomatoes in the pre-grade staging area.

Pathogen infiltration can also occur by the pressure of tomatoes being submerged too deeply for too long in wash tanks or flumes (Figure 41, page 25). As a general recommendation, tomatoes should not be submerged in wash water more than 12 inches per layer of fruit for longer than 1 minute.

Although chlorination of dump tank and flume waters does not disinfect contaminated tomatoes or those that have infiltrated pathogens through the stem scar, it does help to keep the water sanitized by reducing the number of organisms capable of inoculating healthy fruit.In dump tank water, chlorine exists in both the available and unavailable forms. Only free (available) chlorine is effective as a water sanitizer. However, the amount of free chlorine in the water decreases as volume of leaves, stems, soil, and other organic matter increase in the dump tank. Water pH also must be controlled — ideally between 6.0 and 7.5 in pH — to help keep the free chlorine (hypochlorous acid) in its available form. Research has demonstrated that the free chlorine concentration should be held between 100 and 150 ppm in tomato dump tank and wash waters.

A number of chlorine test kits on the market can be used to measure free (available) chlorine, but none can differentiate between *hypochlorous acid* and hypochlorite ions, both considered in the available form, in the water. Test kits measure both of these forms of chlorine as a concentration of available form. Only the hypochlorous acid, however, is actively sanitizing the water.

So what you really want to measure is only the available and active form of chlorine (hypochlorous acid) sanitizing the water, not the total concentration of chlorine (hypochlorous acid + hypochlorite ions) that is present in the water. A newly developed method to perform this task currently is in use in tomato packing operations. It is called the *Oxidation Reduction Potential (ORP)* system.

How does it work? First, a given dose of chlorine is added to water, some of which produces hypochlorous acid (HOCl). This substance is what is called a *strong oxidizing agent*. What does it do? It causes a chemical reaction called *oxidation* to occur. Oxidation is defined as the transfer of electrons from one substance to another. So HOCl oxidizes human pathogen microbes present in the water, causing them to lose electronsfrom their membranes. This in turn interrupts their metabolic functions, causing their death. Since there is a physical transfer of electrons between substances, a very weak voltage arises, called the *electrical potential*, and this can be quantified with a voltmeter.

The ORP produced by the oxidizing action of HOCl is measured in millivolts (mV) which are displayed using an ORP meter as shown in Figure 42, page 25. The stronger the ORP signal (hypochlorous acid activity), the higher is the number displayed on the meter and the faster the death rate of pathogens. Based on research at the University of California-Davis, the lowest target ORP value to achieve pathogen kill is a minimum of 650 mV. Most importantly, since ORP measures sanitizer activity versus concentration, this value gives you a more accurate, direct measure of how well the human pathogens in your wash water are being killed.

Sanitation

Maintaining good sanitation throughout harvesting and handling tomatoes is extremely important. Human pathogens (those causing food-borne illness) can be transmitted by direct contact from infected employees or animals, or through contaminated equipment and water. Once a tomato is infected, pathogens are difficult or impossible to remove without some form of heat treatment (i.e., cooking, pasteurization). Of course, fresh tomatoes are normally consumed raw. Employees are the number one source of human pathogens, so training field and packing house workers in proper hygiene techniques is critical.Portable toilets equipped with handwash stations must be available, well stocked and used by all harvest crew members (Figure 43, page 25). Field containers (picking buckets, bins) and harvest aids (knives, gloves) must be cleaned and sanitized on a daily basis. Likewise, training, monitoring and enforcement of employee hygiene practices, such as proper hand washing after using the toilet, among packing shed employees must be documented to reduce the risk of human pathogen contamination to fresh produce.

For many years packing sheds were not considered food handling businesses and, aside from sweeping floors to remove waste material and blowing debris off equipment with an air hose, sanitation was minimal to non-existent. Just one source of human pathogen introduction, however, at any point, can potentially contaminate all tomatoes passing through the line.

The packing shed sanitation program should include the following:

- a Master Sanitation Schedule for cleaning all areas that do not come into contact with produce (i.e., drains, overhead structures, coolers, etc.) on a regular basis;
- written specific standard operating procedures (SOPs) for cleaning and sanitizing all product contact equipment and monitor to be sure the procedures are followed;
- implementation of a pest control and animal exclusion program.

All water used for washing fresh tomatoes in the field (field-packed) or at the packing shed, as well as Figure 44, page 25. Testing pH regularly will help maintain the maximum disinfectant activity of chlorine in wash or cooling water.water for hydrocooling, should be sanitized. The most commonly used sanitizer is some form of chlorine. While research has shown that chlorinated water cannot sterilize fresh produce, the rationale for adding chlorine is to keep the number of human pathogens from concentrating in the water and cross-contaminating every piece of product that passes through it. Maintaining consistent and proper levels of chlorine in wash/cooling water is critical.

Chlorination can be accomplished by several methods: using a gas injection system, adding bleach (sodium hypochlorite), or dissolving calcium hypochlorite tablets. Monitor chlorination levels in the water frequently during operation with a free-chlorine test kit or ORP meter.

Since pH also has a drastic effect on chlorine's ability to disinfect, maintain the pH of wash/cooling water between 6.0 and 7.5 to reduce the amount of chlorine needed to maintain the recommended available (free) chlorine levels (Figure 44, page 25). Excessive use of chlorine, though, can cause "gassing off" (objectionable chlorine odor), can irritate workers' skin, is corrosive to equipment, and increases sanitation costs.

Both chlorine levels and pH measurements must be documented on a quality control form in order to comply with third party audits.

Grading and Packing

Federal grade standards for field-grown tomatoes include U. S. No. 1, U. S. No. 2, U.S. Combination and U.S. No. 3. Most buyers will accept only the equivalent of U. S. No. 1 grade or higher. Tolerances for U. S. No. 1 grade state that tomatoes should have no more than 15 percent total defects (maturity, color, shape), including 10 percent serious damage (scarring, bruising, sunburn, discoloration) and 5 percent decay (blossom-end rot) in any lot of tomatoes examined. Some buyers expect higher quality than these limits.

Georgia tomatoes are graded and packed at the breaker stage of maturity, based on size. Federal color classification requirements define "breakers" as when **there is a definite break in color from green to tannish-yellow, pink or red on not more than 10 percent of the external tomato surface.**

Tomatoes must be graded to achieve uniform shape, color and size. Tomatoes are sized by passing them over a series of perforated belts with holes corresponding to the maximum allowable diameter for the particular size (Table 10; Figure 45, page 25). Georgia growers typically pack only 5 x 6, 6 x 6, and 6 x 7 numeric sizes into jumble-packed fiberboard cartons to a net weight of 25 pounds.

Table 10. USDA size classifications for field harvested tomatoes.

Classification	Minimum Diameter[1]	Maximum Diameter[2]	Carton Size/Arrangement[3]
Small	2-4/32 in. (5.4 cm)	2-9/32 in. (5.79 cm)	7 x 7
Medium	2-8/32 in. (5.72 cm)	2-17/32 in. (6.43 cm)	6 x 7
Large	2-16/32 in. (6.35 cm)	2-25/32 in. (7.06 cm)	6 x 6
Extra Large	2-24/32 in. (7.00 cm)	———	5 x 6

[1] Will not pass through a round opening of the designated diameter when tomato is placed with the greatest transverse diameter across the opening.
[2] Will pass through a round opening of the designated diameter in any position.
[3] Designates number of rows of tomatoes in top layer.

In recent years major retailers such as WalMart, Kroger, etc., have requested growers to pack their produce in reusable plastic containers (RPCs) because containers offer more durability and versatility, can be properly sanitized, and contain bar codes for easy traceback purposes (Figure 46, page 25).

Containers must provide good ventilation, with at least 5 percent of any container side being open so as not to restrict air movement through the container. Avoid packing in second-hand or used containers, which are unacceptable to buyers. Shipping containers must not be under- or over-filled since this will result in short weights and bruise damage to the tomatoes upon stacking. Use eye appealing, reinforced containers giving the name and address of the packer and having the size or weight of the product clearly marked on the package.

Cooling and Shipping

Since the tomato is a tropical fruit, it is adversely affected by exposure to refrigeration temperatures (less than 50 degrees F) during storage. While several cooling methods can be used, "forced air" cooling is recommended. Tomato cartons and RPCs are placed in parallel rows in front of exhaust fans in specially designed refrigerated rooms. A canvas covering is spread over the top containers, draping to the floor as shown in Figure 47, page 25. When the exhaust fans are turned on, a negative air pressure is produced, which in turn pulls the cold air through the containers and is then lifted up toward the refrigerated units for recooling. This circular process allows faster cooling of the product. Once tomatoes are cooled to the appropriate storage temperature, a solenoid switch turns the fans off and the room becomes a storage cooler. Forced air cooling is more advantageous than room cooling because field heat is removed more rapidly, permitting longer shelf-life of the product.

Forced-air coolers are slightly more expensive to build than conventional room coolers because of the fans and extra refrigeration capacity needed. However, proper utilization of forced-air coolers significantly enhances quality and shelf life. Once pre-cooled, colored and ripe tomatoes must be held between 50-55 degrees F and 95 percent relative humidity for a 7-10 day shelf life. Pre-cooling tomatoes before loading into transit trailers is critical. Truck coolers are not designed to remove field heat from tomatoes. They have only enough refrigeration capacity to maintain temperature once tomatoes are cooled. Tomatoes loaded in a transit trailer at 90 degrees F will likely arrive at the market at 90 degrees F. Tomatoes will be soft and overripe and buyers will not accept them.

Tomatoes are subject to *chilling injury* when held at temperatures below 50 degrees F if held longer than 2 weeks, or at 45 degrees F if held longer than 6-8 days. The consequences of chilling injury are failure to develop full color and flavor, blotchy, irregular color development, surface pitting, increased decay (especially black mold caused by *Alternaria* spp.), and browning of seeds (internal) (Figure 48, page 25). Tomatoes are also susceptible to water loss through the stem scar. Shriveling becomes evident with as little as three percent loss in weight if held at less than 85 percent relative humidity.

Tomatoes are moderate to heavy ethylene producers. Ethylene is a natural ripening gas produced by certain fruits and vegetables that can cause physiological and pathological disorders in ethylene-sensitive commodities. Shipping "mixed loads" of tomatoes with other sensitive commodities such as cucumbers, peppers, lettuce, and other leafy greens can cause quality problems (i.e., loss of chlorophyll, accelerated decay) in these commodities and should be avoided.

Resources

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Marketing

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Marketing tomatoes or any horticultural product is more than just selling. Marketing includes planning, production, harvesting, packaging, transportation, distribution, warehousing and pricing. To be successful, marketing must be responsive to consumers' demands. Simplistically, it must be customer oriented.

To add to the multifaceted problems, marketing skills are required and prior determination or knowledge of one's targeted market is a necessary condition. Is it direct marketing, marketing to retail outlets, specialty food stores or wholesalers? Do you need any promotion? Is any specific harvest time required? All these and more questions need to be addressed. Do consumers demand quality, freshness, "reasonable" prices or all of the above?

Georgia Area Planted and Harvested and Yields

Tomatoes are an important horticultural crop for Georgia in particular and the United States at large. According to the Georgia Farm Gate and Georgia Agricultural Statistics Service reports, respectively, this crop ranked 13th and 18th in the 2003 and 2004 Georgia Agricultural Commodity Rankings, respectively. Furthermore, Georgia is the 7th largest fresh tomato producing state nationwide. Georgia tomato production has been rising since 1983, when reported total planted area was 2,800 acres compared to 6,000 acres in 2004. This reflects a 214 percent increase in planted area. In 1993, 1995, 2000 and 2001, areas planted were equal to or more than 4,000 acres. From 2002 to 2004, this figure surpassed 5,000 acres. Year 2004 reported the highest area planted (Figure 49, page 26).

Harvested area has also been rising at the same rate as planted area. In 1983, although 2,800 acres were planted, only 2,400 acres were harvested, equivalent to 86 percent. This harvested amount has increased to 5,800 acres in 2004; that is, about a 242 percent increase compared to 1983. Basically, harvested area is following the same trend as planted area except in 1990, when the recorded harvested and planted area were the same — 3,500 acres (Figure 49).

The most unpredictable trend is tomato yield. According to Georgia Agricultural Statistics Service, yields were pretty constant from 1983 to 1987. Thereafter, yield escalated exponentially from 110 cwt per acre in 1987 to 365 cwt per acre in 1992 (Figure 49).

Although the yield took a nose dive to 280 cwt per acre in 1993, the increasing trend continued until 1996 when yields stood at 420 cwt per acre, the best ever recorded. Even though an increasing trend was recorded from 1998 to 2003, the worst yield of 170 cwt per acre was recorded in 2004. This drastic drop in yield was a result of several hurricanes (Frances, Ivan) and tropical storms that destroyed most of the vegetable farms in southern Georgia (Fonsah, 2005).

Production and Average Seasonal Prices

Georgia tomato production has risen from 203,000 cwt in 1983 to over a peak of 1.7 million cwt in 2001. Other relatively good production years were 1994, 2002 and 2003. The drastic drop in production in 2004 was a result of several hurricanes (Ivan, Frances, Charley, etc.), and tropical storms that caused serious damage on most of the Georgia farms. On the other hand, although there has been a great improvement, average seasonal prices per cwt has been a rollercoaster. In 2004, the price of $45 per cwt was the peak due to the extreme shortage in supply caused by several hurricanes and tropical storms. The relative peak was in 1995 and 2003 when the average seasonal price per cwt were $31 and $31.50 respectively (Figure 50).

Export Trend

Due to the North American Free Trade Agreement, NAFTA, trade among the United States, Canada and Mexico has improved significantly. Presently, Canada is our number one trading partner for fruits and vegetables.

In 2002, tomato export value to Canada was worth $111.7 million, equivalent to 83 percent of total U.S. tomato export value; $11.6 million was recorded for export to Mexico, equivalent to 8.6 percent. Other countries that purchased a negligible quantity oftomatoes from time to time from the United States were the United Kingdom, The Netherlands and Japan (Lucier and Plummer, 2003).

Import Trend

Although the NAFTA agreement has benefitted trade ties between the United States, Canada and Mexico, Mexico has benefitted more by continually expanding its tomato sales to the United States by 14 percent from 2001-2002. The United States imported tomatoes from Mexico worth $490 million, $412 million, $485 million and $552 million in years 1999, 2000, 2001 and 2002, respectively (Figure 51, page 26). It should be noted here that Mexico also has a comparative advantage in terms of weather, cheap labor and other conditions. Also, most of the tomato suppliers are U.S. companies based in Mexico to take advantage of the cheap labor and favorable weather conditions (Lucier and Plummer, 2003).

Mexico was our leading tomato supplier, generating about 69 percent of total import value or $552 million in 2002. Canada ranked second. A negligible quantity supplied came from the Netherlands (Figure 51).

Pricing

Supply and demand determine the general price level. Seasonal average prices per cwt have been fluctuating. In 1990, the seasonal average price per cwt was $27.40 whereas in 2002 the price had jumped to $31.40 per cwt. The peak price was recorded in 1998 at $35.20 per cwt. The U.S. average retail price for the first quarter of 2003 was highest compared with 2000, 2001 and 2002, respectively. Thereafter, the downward trend was consistent with previous years but 2003 was still the best year in terms of average price obtained per pound of tomatoes (Figure 52, page 26).

Tomato prices vary greatly within a season and among years. Most of the price variation within season is caused by weather effects on production. Price variations among years are caused by changes in acreage and weather. Little of the price variation is caused by demand changes. Demand changes are slight from year to year. For recent prices, see University of Georgia Extension Agricultural Economics website: www.agecon.uga.edu.

Although the dollar per cwt price was the lowest in January 2000, a significant increase compared to 2001 and 2002 was seen in the fall crop. In December 2002, the best price of about $50 per cwt was recorded. Overall, there were variations from month to month and from year to year. This variation has to do with the quantity produced and imported (Figure 53, page 26).

Consumers determine the demand by deciding what and how much they will buy, so marketing efforts must be consumer oriented. Consumers normally reflect their wants in the product and product characteristics they buy. Characteristics of tomato quality include shape, thickness, firmness and uniform glossy color. Variety and age determine color. Large tomatoes normally bring premium prices, regardless of color. The competing states' production levels determine the supply.

Wholesalers' and Distributors' Purchase Decision for Fresh Produce

A 2002 University of Georgia marketing survey asked wholesalers and distributors to rank their purchase decision for fresh produce.

The result is summarized in Table 11. It is not surprising that quality is the most important factor in the wholesalers' and distributors' purchasing decision. It was interesting, however, that quality and price were ranked higher than reliability. Unfortunately, the origin of fresh produce was ranked last.

Table 11. Average ranking of specific factors in wholesalers'/distributors' purchase decision for fresh produce — Ranked most to least important (n = 8).

Factor	Average Ranking
Quality	1.13
Price	2.00
Reliability	3.63
Quantity	4.13
Convenience	5.00
Transportation	5.25
Origin	6.88

Source: Wolfe, K., and E.G. Fonsah. 2002. "Wholesalers and Distributors Outlook for Fruit and Vegetables Produced in Georgia." *GFVGA News* Vol. 7, No. 4, Fall.

Wholesalers/distributors consider quality, price and reliability to be the most important factors in making a purchase. Being grown in Georgia will not help Georgia growers if their produce cannot compete on quality, price and reliability. These three factors are the minimal requirements needed to enter this market and can be thought of as a baseline from which products grown in Georgia must be differentiated.

Georgia's reputation for providing quality tomatoes in the quantity demanded has improved. Competition from other areas in the southeast requires that this reputation be maintained and improved. As production continues to expand, some growers will not be able to compete. Production skills alone will not ensure survival. Marketing will increase in importance.

Conclusion

Marketing tomatoes, or any product, is more than selling. Marketing includes production, distribution, and pricing. To be successful, marketing must be responsive to consumers' demands. Consumers demand quality, freshness and "reasonable" prices. The U.S. production of fresh tomatoes has been continually on the rise since 1978 when 156.1 million pounds were produced. By year 2002, production had increased more than three times to 534.9 million pounds.

Due to NAFTA, trade among the United States, Canada and Mexico has improved significantly. Presently, Canada is our number one trading partner for fruits and vegetables. The United States importedtomatoes from Mexico worth $490 million, $412 million, $485 million and $552 million in years 1999, 2000, 2001 and 2002, respectively.

Supply and demand determine the general price level. Seasonal average prices per cwt have been fluctuating. In 1990, the seasonal average price per cwt was $27.40 whereas in 2002 the price had jumped to $31.40 per cwt. Tomato prices vary greatly within a season and among years. Most of the price variation within a season is caused by weather effects on production. Price variations among years are caused by changes in acreage and weather. Consumers determine the demand by deciding what and how much they will buy. Thus, marketing efforts must be consumer oriented. Consumers normally reflect their wants in the product and product characteristics they buy.

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Production Costs

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Tomato growers can use enterprise budgets to estimate production and break-even costs. Budgets include cost estimates for those inputs necessary to achieve the specified yields over a period of years. Since production practices vary among growers, each grower needs to adapt budget estimates to reflect his or her individual situation.

Detailed printed and computerized budgets are available in most county extension offices and at the University of Georgia, Department of Agricultural and Applied Economics Website: www.agecon.uga.edu.

Types of Costs

Total costs of producing any crop include both variable and fixed costs. The variable or operating costs vary with the adopted cultural practices. Common variable cost components include seed, fertilizer, chemicals, fuel, and labor.

Variable costs are further broken down into pre-harvest (Table 12) and harvesting and marketing operations (Table 13) in the hypothetical budget. This provides you an opportunity to analyze the costs at different stages of the production process.

Fixed costs include items such as equipment ownership (depreciation, interest, insurance, and taxes), management, and general overhead costs (Table 14, page 50). Most of these costs are incurred even if little production takes place and these costs should be considered when planning production costs.

Land cost may either be a variable or a fixed cost. Because it varies significantly from county to county, from region to region, and whether it is irrigated or non-irrigated, it is not included in this hypothetical budget. Even if you own the land, there is a cost. Land is a fixed cost in this budget even though no cost has been recorded. A fixed cost per hour of use shows ownership costs for tractors and equipment (depreciation, interest, taxes, insurance and shelter). Overhead and management are 15 percent of all pre-harvest variable expenses. This amount pays for management and farm costs that cannot be allocated to any one specific enterprise. Overhead items include utilities, pick-up trucks, farm shop and equipment, and fees.

Cost/Unit of Production

The cost categories are broken down in cost per unit (Table 15). The pre-harvest variable costs and the fixed costs decline with increasing yields.

Budget Uses

In addition to estimating the total costs and break-even costs for producing tomatoes, there are other uses of the budget. Estimates of the cash costs (out-of-pocket expenses) provide information on how much money needs to be borrowed. The cash cost estimates are helpful in preparing cash flow statements. In the instance of share leases, the cost estimates by item can be used to more accurately determine a fair share arrangement by the landlord and tenant.

Risk Rated Net Returns

Since yields and prices vary from year to year, an attempt is made to estimate the riskiness of producing tomatoes. The Extension Agricultural Economics Department uses five different yields and prices to calculate risk (Table 16). The median values are those prices and yields a particular tomato grower would anticipate to exceed half the time.

Half the time, the grower would anticipate not reaching below these prices and yields. Optimistic values are those prices and yields tomato growers would expect to reach or exceed one-year-in-six. The pessimistic values are poor prices and yields that would be expected one-year-in-six. The best and worst values are those extreme levels that would occur once a lifetime (1 in 49).

The risk rated section (Table 17) shows a 62 percent chance of covering all costs. About 50 percent of the time, the budgeted grower would expect to net $956 or more. Two-thirds of the time, he/she would expect to net less than $1,464. One year out of six he would expect to make more than $1,464 per acre or to lose more than $3,430.

Summary

Successful tomato production and management is always challenging and like any agricultural commodity, it is difficult. However, it remains an economically feasible production enterprise for many Georgia vegetable growers. Enterprise budgets can be used to aid producers in production and marketing decisions. For additional or more detailed information, please contact your local extension office.

Table 12. Hypothetical variable or operating costs of producing tomatoes.

Item	Unit	Quantity	Price	Amt/Acre	Total
Variable Costs					
Plants	Thou	5.00	183.75	918.75	919
Lime & gypsum	Acre	1.00	45.00	45.00	45
Fertilizer (base & side dressing)	Ton	1.00	250.00	250.00	250
Plastic[1]	Roll	2.80	98.00	274.40	274
Fumigation	Acre	1.00	520.00	520.00	520
Insecticide[2]	Appl	20.00	21.20	424.00	424
Fungicide	Appl	4.0	38.50	154.00	154
Herbicide	Acre	3.00	10.00	30.00	30
Stakes & string	Acre	1.00	125.00	125.00	125
Labor, mach operation	Hr	5.00	5.50	27.50	28
Labor, transplant	Hr	100.00	5.00	500.00	500
Cleanup (plastic & stakes)	Acre	1.00	150.00	150.00	150
Machinery	Acre	1.00	25.76	25.76	26
Irrigation	Acre	1.00	202.71	202.71	203
Land rent	Acre	1.00	0.00	0.00	0
Interest on operation capital	$	3,647.12	0.09	164.12	164
			Pre-harvest variable costs	**3,811.24**	**3,811**

*Fertilizer amount and application rates should be based on soil test recommendations.
[1]Metalized plastic for fall planting costs $210 per roll or $378 for 1.8 rolls per acre.
[2]Fall planting includes injectable insecticides and fertigation.

Table 13. Hypothetical harvesting and marketing costs of producing tomatoes.

Harvest and Marketing Costs				
Picking and hauling	Ctn.	2,000	1.25	2,500.00
Grading and packing	Ctn.	2,000	0.85	1,700.00
Container	Ctn.	2,000	0.70	1,400.00
Marketing	Ctn.	2,000	0.70	1,400.00
Total Harvest and Marketing				**7,000.00**
Total Variables, Harvesting and Marketing Costs/Acre				**10,811.24**

Table 14. Hypothetical fixed costs of producing fresh tomatoes.

Annual Dept. Payment				
Machinery	Acre	1.00	84.90	84.90
Irrigation[3]	Acre	1.00	67.89	67.89
Land	Acre	1.00	0.00	0.00
Overhead and Management	$	3,811.24	0.15	571.69
Total Fixed Outlays				**724.47**
			Total Budgeted Cost per Acre	**11,535.71**

[3]See irrigation budget on the University of Georgia Department of Agricultural and Applied Extension Economics Web site: www.agecon.uga.edu.

Table 15. Hypothetical costs per carton of producing tomatoes.

Costs per Carton	
Pre-harvest variable cost per carton	1.96
Harvest and marketing cost per carton	3.60
Fixed outlays per carton	0.37
Total budgeted cost per carton	5.94

Table 16. Risk rated return for tomatoes yield and prices.

	Best	Opt	Median	Pess	Worst
Yield (cartons)	2400	2200	2000	1600	1400
Price per carton	10.00	8.00	6.50	5.00	4.00

Table 17. Tomato production risk rated returns over total costs net return levels (top row); the chances of obtaining this level or more (middle row); the chances of obtaining this level or less (bottom row).

	Best	Optimistic		Expected		Pessimistic	Worst
Returns ($)	5,645	4,082	2,519	956	-506	-1,968	-3,430
Chances	7%	16%	30%	49%	49%	49%	49%
Chances				51%	32%	16%	6%
		Chances for Profit	**62%**			**Base Budgeted Net Revenue**	**1,464**

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