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Commercial Production of Staked Tomatoes in the Southeast

(including Alabama, Georgia, Louisiana, Mississippi, North Carolina, and South Carolina)

EDITOR

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The exceptional quality of tomatoes (*Solanum lycopersicum, syn. Lycopersicon lycopersicum*) produced in the Southeast is recognized throughout the United States. This reputation was gained by growing good-tasting varieties on trellises, and later, short-staked systems to keep the fruit off the ground and allow good air movement around the plants. Although farmers in other parts of the country now grow staked tomatoes, this region maintains the advantages of having the right soils, climate, and moisture to produce the highest quality tomatoes.

Producing staked tomatoes can provide substantial income. Average production in the Southeast exceeds 15 to 20 tons per acre at lower elevations and 20 to 30 tons per acre in elevations from 1,500 to 2,500 feet. Some growers produce as much as 30 to 45 tons per acre. The production of staked tomatoes is highly specialized and can be risky. It is labor intensive, requires a high initial investment, and demands high-level management, but financial gains can also be quite high. This method of production should be undertaken only by someone willing and able to assume the financial risks and who is committed to the high level of management required to be successful.

GETTING STARTED

Preparations for growing staked tomatoes should begin the year before the first crop will be grown. Factors to consider are tomato varieties, site selection, soil type, soil fertility (the present status and any needed adjustments), crop rotation, and the history of the field (including past incidence of disease).

Tomato Cultivars

Two types of tomatoes are commonly grown. Most commercial varieties are *determinate*. These "bushy" types have a defined period of flowering and fruit development causing the vine to quit growing at a certain height. In comparison, most heirloom varieties and greenhouse tomatoes are *indeterminate*, meaning they produce flowers and fruit throughout the life of the plant and the vine keeps growing until frost or something else kills it. Most commercial varieties are also hybrids, meaning that they are produced from two genetically different parents. Seeds saved from the fruit of a hybrid tomato will produce a mixture of plants resembling the original parents and the hybrid. This is usually not desirable.

Variety selection is one of the most important management decisions. Many breeding programs worldwide involve the development of new tomato cultivars. The most successful cultivars in a production area are generally ones that have been developed and tested under the growing conditions of that particular area. A number of characteristics are important to consider when selecting varieties for cultivation: yield, disease resistance, horticultural quality, adaptability, and market acceptability. Growers should be aware of any diseases or conditions that might adversely affect tomatoes in their region.

For example, growers in an area with a history of tomato spotted wilt virus (TSWV) are encouraged to use resistant varieties (Table 1).

Florida 47 and Mountain Fresh are currently among the leading varieties for the large-fruited industry at higher elevations and are used for late-season production at lower elevations. Popular early season varieties include Mountain Spring and Mountain Crest. Most current varieties are determinate and have resistance to several fruit disorders as well as to race 1 of Verticillium wilt and races 1 and 2 of Fusarium wilt (Table 1). Some cultivars also have resistance to one or more of the following diseases: Fusarium wilt race 3, TSWV, early blight, late blight, and nematodes (Table 1). These varieties have been bred to produce large, firm, uniform fruit with good shipping qualities and excellent market acceptance.

Mountain Belle is a favorite cherry tomato variety, with round, firm fruit and averaging 1¼ inches in diameter. Two popular plum tomato varieties are Plum Crimson and Plum Dandy. Grape type tomatoes are now well established in the industry and consist primarily of the variety Santa. The new variety, Smarty, is an improved grape tomato with long shelf life. Unlike all the other types of tomatoes described here, grape tomato plants are indeterminate and vigorous,

Mountain Fresh Plus	round	X		X	X	X		X			X	ANS
Mountain Spring	round	X		X	X	X					X	AGLMNS
Phoenix	round	X		X	X	X					X	N
Quincy	round				X	X				X	X	AGLM
Red defender	round	X		X	X	X				X	X	AGLMNS
Redline	round	X			X	X	X			X	X	AGLMNS
Scarlet red	round	X		X	X	X					X	AGLMNS
Solar set[#]	round	X			X	X					X	GLMS
Sun Chaser	round			X	X	X					X	L
Sun Leaper	round			X	X	X					X	AGLNS
Sunbeam	round	X		X	X	X					X	NS
Sunrise	round	X		X	X	X					X	M
Talladega	round	X		X	X	X				X		AGLS
Cherry Grande	cherry	X		X	X	X					X	AGLMNS
Marcelino	cherry											N
Mountain Belle	cherry			X	X						X	AGNS
Sun Gold	cherry											AMN
Brixmore	grape							X	X		X	N
Elfin	grape											GNS
Jolly Elf	grape					X						AGMNS
Mini Charm	grape				X	X			X		X	M
Navidad	grape					X						AGMNS
Rosa	grape											AN
Santa Claus	grape											AGNS
Saint Nick	grape											AGMN
Smarty	grape											ANS
Snapy	grape											AN
BHN 410	roma		X		X	X					X	AGNS
Mariana	roma	X	X	X	X	X		X			X	N
Picus	roma	X		X	X					X	X	N
Plum Crimson	roma	X		X	X	X	X				X	AGN
Plum Dandy	roma	X		X	X						X	GN
Plum Regal	roma	X			X	X				X		N
Spectrum	roma											GNS
Sunoma	roma	X	X	X	X	X		X	X		X	N

An ‘X’ indicates the variety is considered ‘resistant’ to that particular disease.

Causal agents of each disease listed above: Alternaria stem canker = *Alternaria alternata* f.sp. *lycopersici*; Bacterial speck = *Pseudomonas syringae* pv. *tomato*; Gray leaf spot = *Stemphylium solani;* Fusarium wilt = *Fusarium oxysporum* f.sp. *lycopersici*; Root knot nematodes = *Meloidogyne incognita, M. javanica, M. hapla*; Verticillium wilt = *Verticillium dahliae* race 1 (no known commercial resistance to race 2).
*Recommended states: Alabama (A); Georgia (G); Louisiana (L); Mississippi (M); North Carolina (N); South Carolina (S).

[#]Hot-set varieties.

Table 1. Commercial Tomato Varieties, their Resistance to Specific Diseases, and Recommended Location for Cultivation

Variety	Type	Alternaria stem canker	Bacterial speck	Gray leaf spot	Fusarium wilt race 1	Fusarium wilt race 2	Fusarium wilt race 3	Root knot nematodes	Tobacco mosaic virus	Tomato spotted wilt virus	Verticillium wilt race 1	Recommended location (state)*
Amelia	round	X		X	X	X	X	X		X	X	AGLMNS
Bella Rosa	round	X		X	X	X		X		X	X	AGL
BHN 444	round	X		X	X	X				X	X	AGN
BHN 602	round	X		X	X	X	X			X	X	AGLN
BHN 640	round	X		X	X	X	X			X	X	AGLN
Biltmore	round	X		X	X	X					X	N
Carolina Gold	round	X		X	X	X					X	AGNS
Crista	round	X		X	X	X	X	X		X	X	AGLMNS
Fletcher	round	X		X	X	X		X		X	X	N
Florida 47	round	X		X	X	X					X	AGLNS
Florida 91#	round	X		X	X	X					X	GLMS
Floralina	round	X		X	X	X	X				X	ANS
Mountain Crest	round	X		X	X	X					X	AGLNS
Mountain Glory	round	X		X	X	X				X	X	N

requiring up to a 7-foot-high trellis for best management.

New tomato varieties become available to growers frequently. Growers should stay abreast of university trials in their region and evaluate new varieties themselves by growing a few plants on a trial basis for the first year before planting a large acreage. Production of promising varieties can then be gradually increased over the following 2 to 3 years, at which time specific cultural requirements will have been determined and market acceptability evaluated.

Heirloom tomatoes are becoming popular for local sales. Hundreds of heirloom tomato varieties are available, although there are clearly regional favorites. In this area, for example, most consumers are familiar with the varieties Brandywine, Cherokee Purple, and Mr. Stripey. Heirloom tomatoes are open-pollinated varieties that have been passed on from generation to generation. Seeds saved from heirloom tomatoes will produce similar plants from year to year, although there will be more plant-to-plant variation in comparison to most hybrids. Proper seed saving methods must be used to prevent cross pollination and transmission of disease through the seeds. Care should be taken in selecting an heirloom tomato variety because many have little or no disease resistance and may have undesirable characteristics, such as the tendency to crack, catface, or burst.

Site and Soils

Select the site the year before planting to allow time to test the soil and add necessary lime and fertilizer amendments in the fall. Choose a site where no tomatoes or any other solanaceous crop (peppers, eggplants, Irish potatoes,) have been planted for at least 3 years. Also avoid fields that have a history of soil-borne diseases that may affect tomatoes, such as southern bacterial wilt, Verticillium wilt, and southern stem blight. Avoid fields that flood or drain poorly. There should be ready access to water because the field will need to be irrigated. Locate the site with an eye to good air movement to minimize disease problems and lower the probability of damage from late spring and early fall frosts.

The most desirable soils for tomatoes are deep, medium-textured sandy loam or loamy, fertile, well-drained with high organic matter. Organic matter content can be increased by growing green manure crops or by adding compost, or composted or aged manure. Any cover crop should be turned under at least 3 weeks before spring planting.

Rotation

Crop rotation is one of the most economical and effective practices to help reduce or eliminate several of the important tomato diseases. It is especially useful for reducing bacterial diseases, nematodes, and certain wilts and foliar diseases. The rotation period should be *at least* 3 years. Fescue, corn, and small grains are good rotation crops. Tomatoes can also be rotated with other vegetable crops, including cucumbers, sweet corn, and squash. Rotating with other related solanaceous crops, such as pepper, eggplant, or Irish potato, is not advised.

Soil Analysis

Nutrient needs for tomatoes are fairly specific. A grower must know the availability of plant nutrients in the soil to supply appropriate amounts for tomatoes. Guesswork will cost money because you will most likely apply more fertilizer than needed or not apply enough. Have your soil properly sampled and tested long before you prepare the field, preferably in the previous fall. Use the soil test results as a guide for adding lime and fertilizer. Also, have a nematode assay run on a portion of the soil sample to determine whether a nematicide is needed. County Extension agents can supply information on proper soil sampling and can help interpret the results. Guides for sampling agricultural fields can be found online: http://www.ncagr.gov/agronomi/pdffiles/basics.pdf and http://www.ncagr.gov/agronomi/pdffiles/samcrop.pdf

Soil-borne Diseases

Certain nematode and wilt diseases can cause serious damage to a tomato crop. It is important to know whether the threat of disease exists on a proposed site and minimize the potential for damage. For more information, see the DISEASES section (page 22).

Tomato production begins months before the grower plants tomatoes. Cover cropping, choosing a production system, and making sure equipment is available for irrigation and pest management will be key factors in production success, along with fertilization and pest management. The sections that follow describe these factors and the tasks required in tomato production, from transplanting through staking, pruning, and harvesting.

COVER CROPPING

Cover crops are an essential component of tomato production. Many farm plans developed by the U.S. Department of Agriculture Natural Resources Conservation Service have a cover crop component. In addition to providing ground cover during the winter, cover crops also provide green manure for plow down, mulch for no-till, forage for livestock, or grain and straw if allowed to mature. Additional information on cover crops is available online: http://www.soil.ncsu.edu/publications/Soilfacts/AGW-439-58/AGW_439_58.pdf

Winter Cover Cropping

Planting a winter cover crop is necessary for minimizing soil erosion and for maintaining organic matter in the soil. Below is a planting date schedule (Table 2) and brief descriptions of common winter cover crops used in the Southeast.

Common Winter Cover Crops

Rye is a versatile small grain that grows well in the fall (even late fall). Rye, too, is the first small

Table 2. Cover crop planting dates for the southeastern United States

Region	Rye, Triticale	Wheat, Barley	Crimson Clover, Hairy Vetch, Austrian Winter pea
Coastal Plain	Oct. to Nov.	Oct. to Nov.–E	Sept. to Oct.
Piedmont	Sept.–L to Nov.–E	Sept.–L to Nov.–E	Sept. to Oct.–E
Mountain	Sept.–L. to Oct.	Sept. to Oct.	Sept. to Oct.–E
Sept.=September, Oct.=October, Nov.=November, E=Early L=Late			

grain to start growing in late winter or early spring. This makes rye the top choice for tomato growers who have little time in the fall to sow a cover before winter. Rye provides the most biomass to turn under in early spring. It also provides forage for grazing animals and straw if harvested before mature seeds are formed or after seed harvest.

Triticale is now available to tomato growers as an alternative small grain for winter cover cropping. Triticale was developed by combining rye and wheat genetics. This small grain has good winter hardiness and excellent biomass in early spring (similar to rye), but is shorter than rye (more like wheat). Triticale seed may be hard to find some years, and its price may be higher than other small grains. Triticale, however, can provide superior biomass to plow under for the following summer crop.

Barley provides a sufficient source of biomass to be managed in the spring. It does not grow as tall as regular rye, but will tiller and may produce as much straw, forage, or plow down as rye. Even though barley eventually produces the equivalent biomass of rye, it does so later in the spring. Also, the possibility of winterkill is greater with barley. You should plan on planting barley in September or early October for its greatest survival.

Wheat as a cover crop works well and provides an additional option of grain harvest. Wheat also should be planted in September or October and produces biomass similar to that of barley. It, too, can be grazed before turning under. Wheat can be harvested for grain, and it will provide straw as well. Many fall tomato plantings with conservation tillage will use wheat residue as a surface mulch.

Oats offer many options for the tomato grower. Planting fall oats in September or October in most of this region will produce a cover crop and good late-spring biomass. Oats can be grazed, made into hay, or harvested for grain and straw. Planting spring oats in August can provide good winterkilled mulch in some cooler areas of the Southeast. Spring oats, however, have survived some of our milder winters. You may need to kill spring oats with herbicides in some years if you do not plow them under.

Ryegrass has great potential as a green manure and as a forage or hay material, but grower beware! It can become a difficult weed on some farms. Ryegrass tends to grow rather slowly in the fall; therefore, it provides only moderate winter erosion protection if planted in late fall. Ryegrass will produce an abundant supply of biomass by late spring. Grazing and spring hay from ryegrass can be excellent, and its fine, extensive root system makes it a great source for plow down. Because of the resiliency of ryegrass, however, you should avoid using it in sites where a garden or organic tomatoes are to be established. This source of cover does not provide much biomass if plowed early in the spring.

Legumes. Many legumes are available for winter cover cropping. Hairy vetch has a viny growth habit and high nitrogen content, and it grows slowly during the winter. Austrian winter pea also has a viny growth habit and high nitrogen content. It grows slowly during the winter, but it can frost heave. Crimson clover has an upright growing habit, grows slowly during winter, and has moderate nitrogen content. All of these legume winter cover crops need to be planted by late September or early October. Frost heaving can cause the seedlings to dry out during the winter. Plants are susceptible to heaving when they are small, before their roots are established. All legume seed costs will be double or triple what the cost per acre would be for small grains, but legumes that are not plowed down until late April or early May will enrich the soil with far more nitrogen.

Mixing Grass and Legumes

Combining grass and legumes may prove better than planting either alone. Grasses protect soil during the winter and also produce great forage or plow-down organic matter. Legumes do not grow well during the winter, but they grow abundantly in late spring and produce high-protein forage and lots of nitrogen as plow down for the following crop. Crimson clover is the best legume to grow with a grass. Crimson clover's height matches well with triticale, barley, wheat, and oats, but it may be shaded by rye, resulting in less growth than desired. Hairy vetch has been sown with grass cover crops for many years, and the grass and vetch combination is used as a hay or plow down.

Plow Down

Many growers plow down winter cover crops in late winter or early spring. Try to resist this temptation until the cover crops have gained sufficient biomass. Plowing early defeats the main purpose of growing cover crops—to supply organic matter—and does not allow legume cover crops to develop. If you need to plow early, use a grass cover crop (such as rye) that produces good fall growth and provides maximum biomass.

Seeding Rate

Seeding rates are 1 to 1½ bushels per acre for rye, triticale, barley, and wheat and 2 bushels per acre for oats. Broadcast crimson clover at 20 to 25 pounds per acre, hairy vetch at 20 to 30 pounds per acre, and Austrian winter peas at 25 to 35 pounds per acre. Drilling legumes can reduce the rates of seed needed by 5 pounds per acre. If you plant in late fall, use the higher rates for good seed establishment and soil protection.

Summer Cover Crops

Summer cover crops, such as sudangrass or sudex (sorghum-sudan grass cross—don't allow to exceed 3 feet before mowing), seeded at 20 to 40 pounds per acre, are good green manure crops. Sunhemp and pearl millet also produce a good green manure crop and suppress nematodes. These crops can be planted as early as field corn is planted and as late as mid-August. Summer crops should be clipped, mowed, or disked to prevent seed development that could lead to weed problems. Iron Clay southernpea, soybeans, and lablab are three legumes planted during the summer. Summer cover crops can be disked and planted to wheat or rye in September or allowed to winterkill and tilled in the spring. Many soils that are minimally productive due to poor physical properties can be restored and will produce good crops with a good resting-crop program. This practice also helps reduce the buildup of many diseases and insects that attack vegetable crops. Small grains, sudangrass, sudex, timothy, orchardgrass, and ryegrass are good soil-resting crops.

Biofumigant Crops

Biofumigant crops are groups of plants that produce naturally occurring fumigants (glucosinolates), which reduce the negative effects of soil-borne diseases, nematodes and weeds. These crops increase soil tilth and can act as a nutrient sink. Oilseed radish and mustard mixtures (Caliente 119) have been used successfully to control some or all of these pests. A mix of these cover crops can reduce nematode levels and add organic matter to the soil. Throughout much of the region, these crops can be seeded in the fall and overwintered or seeded in early spring. Seeding rates range from 15 to 20 pounds per acre and will vary with location and seed size. These crops respond to 50 to 100 pounds N fertilizer per acre at planting to stimulate fall growth. They grow rapidly under warm soil conditions and can be plowed down in 6 weeks. Spring planting is recommended only for areas where the average last spring frost is May 1 or later.

PRODUCTION SYSTEMS

Conservation Tillage

Conservation tillage has been used for many row crops for more than 40 years. Vegetable farmers are now beginning to use some form of conservation tillage in their production. Tomatoes can be grown in a conservation tillage system because adequate information is available on weed control, tillage equipment, and cover residue to help a farmer transition to some form of tillage reduction. Conservation tillage methods range from mulch tillage (some residue on the surface, with a high level of tillage in the soil) to no-till (maximum amount of residue and no tillage). No-till and strip-till are most often used in the Southeast. If a tomato farmer is new to conservation tillage, weed control will probably be the biggest challenge to overcome. An appropriate weed control strategy should be planned out in advance and may be based on herbicides, mechanical methods, or both.

Strip-tillage

Strip-till creates a tilled surface zone similar to cultivated soil, leaving cover residue between the rows. The tilled zone is typically 8 to 12 inches wide. For 5-foot row spacing, approximately 4 feet of residue will remain, and 80 percent of the soil surface will be covered. Surface tillage requires some form of rotavator, or an implement that chisels and disks the surface (one implement is a Bushhog Ro-till). This form of conservation tillage allows some degree of tillage for incorporating fertilizer or pesticides in the strip-tilled area and for traditional transplanters to easily transplant tomato plants. Some strip-till implements use a subsoil shank and disk coulters to create this strip. When this type of implement is used, soil tillage pans can be fractured to allow better root penetration into the subsoil. Herbicides are commonly used to control weeds within the tilled strip.

No-till

No-till tomatoes have also been successfully grown in this region. Crop residues consisting of last year's row crops (corn or soybean stalks) or winter cover residues are an important component in no-till plantings. Winter cover residues can be killed by either chemical or mechanical management. Living vegetation (fescue or white or red clover) between tomato rows has been successful but requires considerable labor management. No-till production requires a transplanter that has been modified with a cutting coulter to first slice residue or vegetation before planting, and a press wheel with additional weights to firm soil against the tomato plant. This machine has worked well with tobacco and crucifer crops.

Management Changes

Using conservation tillage for tomato production can be successful, but the grower must understand the changes that have occurred in the planting operation. Crop residue between the rows creates a cooler soil temperature than that of soil under black plastic or bare ground. This means slower early growth of the tomato plant in the spring, when soils are cooler than soils under black plastic and bare soil. Tomato vine growth in conservation tilled systems usually will produce as much biomass as tomatoes grown under black plastic, but more growth occurs later in the growing season. Tomatoes grown as a second crop for the season will not have this soil temperature difference and actually produce under very favorable conditions in the fall.

Bare Ground Production

Although most growers in the Southeast use plastic mulch with drip irrigation, a few still grow staked tomatoes on a bare ground production system with overhead irrigation. A bare ground system may be less expensive to establish, but irrigation and weed control costs over the course of the season usually exceed the cost of a plasticulture system. Growers should compare the total costs of producing tomatoes under both systems, including disposables (drip-tape, plastic mulch, and herbicides) and nondisposables (aluminum pipe and sprinklers). If soils must be fumigated, bare ground production is not recommended.

Plastic Mulch and Drip Irrigation System

Yield, fruit size, and fruit quality of spring planted tomatoes are increased by using black plastic mulch with drip irrigation. For late season crops, or when the air temperature exceeds 85°F, use white-on-black plastic mulch, or paint black plastic with a 5:1 (v/v) mixture of exterior, flat white latex paint and water. Form raised dome-shaped beds to prevent water and chemicals from pooling around the stem or accumulating in the plant holes. Lay 4-foot-wide black plastic mulch tightly over the beds. Tractor-mounted equipment is available to build the beds, lay the drip-tape, and spread the plastic mulch in one pass. In areas with a history of TSWV, reflective mulch is recommended to minimize the damage from the disease. Light reflected from the aluminum in the mulch discourages the TSWV insect vectors (thrips) from feeding on the plants. Recent research has shown that metalized mulches also better retain fumigants—and may reduce their application rates.

Virtually impermeable films (VIF) are used in some parts of the U.S. to reduce fumigant rates and release into the atmosphere. These films are gaining popularity but are not yet considered standard practice, are more expensive, and, depending on the fumigant, may increase the preplant interval.

EQUIPMENT

Irrigation

Tomato plants need uniform soil moisture during the entire season to produce the greatest amount of high-quality fruit. There are only a few ways to control excess water. Excessive surface water from heavy rains can be drained from the field by orienting rows properly and by providing drainage ditches. Subsurface drainage can be provided by tilling low, wet areas and subsoiling below the rows where drainage is known to be poor. If soil moisture is deficient, rainfall can be supplemented with a properly designed irrigation system.

Types of Irrigation Systems

Sprinkler irrigation systems range from small portable units of either plastic or aluminum pipe to large mechanically moved systems, such as the cable-tow or hose-pull traveler. Small sprinklers with a portable or solid-set system and a sprinkler spacing not exceeding 60 percent of sprinkler diameter will provide uniform moisture distribution and will use less energy than stationary or mechanically moved gun sprinklers.

Frost and freeze protection and crop cooling require solid-set systems. The entire area must be irrigated at the same time. For climate control, the system should be designed for an application rate of 0.12 to 0.15 inch per hour using a single nozzle sprinkler. The system is effective against radiation frost but will have limited effectiveness against wind-borne freeze. The system should be started when the air temperature at plant height drops to 34°F. It should be operated continuously until the air temperature outside the area rises above 32°F and ice begins to loosen from the plant tissue.

After the danger of frosts and freezes has passed and the system is to be used for moisture control, a second nozzle should be added to the sprinkler head to increase the water application rate. The lateral line pipe must be large enough to handle the greater flow rates without excessive friction loss.

Drip or trickle irrigation offers water and energy conservation and better soil moisture distribution, requires limited water resources, reduces weed and disease problems, and applies fertilizer through the system, while increasing yield. In addition, wind has no effect on water distribution, and cultural and harvesting activities can be carried out while the irrigation system is operating. It does require very clean water (a high degree of filtration) and a high level of management. Drip irrigation systems are subject to animal, insect, and mechanical damage and may involve higher annual equipment costs than some types of sprinkler irrigation systems. Drip irrigation can increase tomato yields when used with plastic mulch, proper filtration, and good management.

Several companies supply line-source drip tubing with orifice spacings from 8 to 36 inches. The discharge rate per 100 feet of tubing depends on the size and spacing of the orifices and on line pressure. Most systems are designed to operate at pressures from 7 to 10 pounds per square inch (psi). These systems should be used in fields with level in-row slopes or only a slight downhill slope from the header pipe. Row length must also be limited to insure reasonably uniform water distribution. Reuse of most drip tubing is impractical because of handling and water delivery problems. Lay-flat hose, a low-pressure type of hose that flattens when water is not being pumped, is often used for header or supply lines for several seasons. On sloping terrain it may be necessary to install pressure regulators in the main line and header pipe to obtain the proper pressure on each row lateral.

Irrigation System Design

Some basic principles must be followed in designing irrigation systems. To ensure uniform water application, friction loss in the lateral line (the sprinkler line or drip tubing) should not exceed 20 percent of the recommended sprinkler or drip tube operating pressure. The distance between sprinklers should not exceed 60 percent of the rated sprinkler diameter. Main and supply lines and header pipes must be large enough to deliver water to all laterals and sprinkler heads at the required operating pressure. The pump capacity needed will be determined by the rated flow from operating sprinklers or drip lines. When determining the necessary pump pressure, you must account for sprinkler or drip line pressure, friction losses in main and lateral lines, and elevation differences.

Contact a reputable irrigation dealer or consultant for help in designing a system that will use water and energy efficiently. Remember that the initial purchase price is only part of the total cost of owning the system. The operating cost over the life of the system can be several times the initial purchase price.

Operating an Irrigation System

Irrigation scheduling should be based on soil moisture level, which can be determined with tensiometers or electrical resistance blocks. Tensiometers measure moisture tension and work best in light-textured (sandy) soils. Electrical resistance blocks depend on electric current flow between electrodes in a ceramic block buried in the soil. They work better in soils with heavier textures. You may need to seek technical advice on the calibration and use of tensiometers and resistance blocks in scheduling irrigation.

Sprinkler irrigation must be coordinated with pesticide spray and harvesting schedules. Irrigate after harvesting or other cultural operations to minimize field traffic while the soil and foliage are wet. Sprinkler irrigation should be done at midday if possible so that the foliage will have a chance to dry before nightfall. Keeping plants continuously wet in early morning or late evening favors disease development.

The rate and frequency of water application will depend largely on soil type, stage of growth, and weather conditions. Light (sandy) soils have a higher water absorption rate but less water-holding capacity than heavy (clay) soils. Therefore, higher application rates (more gallons per minute) may be safely applied on the lighter soils, but more frequent applications may be needed than with heavier soils. As plants become larger, they use more water. Also, during hot, breezy, low-humidity weather, plants use more water and more water evaporates from the soil surface. Under these conditions, you will have to irrigate more often to maintain optimum soil moisture level. During the fruiting season, water use may be as high as 1.5 inches per week or 0.2 to 0.25 inches per day, depending on weather conditions.

The amount of water to apply (the number of inches per acre) during any application depends on system efficiency as well as plant need. Sprinkler irrigation is only about 75 percent efficient, so the amount of water applied must be 25 percent greater than the plants' actual water need. Making two small applications per week is better than applying the total amount at once. Drip irrigation, which is less dependent on crop management operations, can be applied daily, if needed, to maintain the moisture at optimum level. Drip irrigation systems require less water than overhead systems to maintain optimum soil moisture level.

Sprayers

A good sprayer (of the mist blower or high-volume type) is necessary for adequate control of diseases and insects. The essential components of a high-volume sprayer are a piston or diaphragm pump to deliver a pressure of 200 to 400 psi, proper nozzles to break up and distribute the spray, and a means of agitating the spray material in the tank. Use solid or hollow cone type nozzles when applying insecticides and fungicides. All sprayer parts must be designed to operate under high pressure.

When spraying tomatoes, use one or two nozzles over the top of the row (up to 8 inches wide). As the plants start to grow and bush, adapt the nozzle arrangement for the different growth stages. Opposing nozzles should be rotated clockwise slightly so that spray cones do not collide. Rotation will guarantee that the spray is applied from all directions into the canopy. As the plant height increases, 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. Usually, more than one size of nozzle will be needed to carry out a season-long spray program. Since clogging can occur when spraying, clean and test nozzle tips and strainers before each application.

The heart of the sprayer is the pump. With the smaller piston pumps that deliver 400 psi and approximately 9 to 10 gallons per minute, size the nozzles and agitator so that full pressure can be maintained. The pump's limited volume requires slow tractor speeds (1 to 1.5 miles per hour) at engine speeds that will deliver 540 rpm at the power takeoff. If the tractor is not equipped with a slow-speed transmission, two passes over the field may be necessary to achieve proper spray coverage.

Diaphragm pumps provide high pressure and a wider range of spray volumes than piston pumps, making it possible to use larger nozzles and higher tractor speeds without reducing pressure or application rate. For larger plantings (5 acres or more), a larger capacity, trailer-type sprayer with a four-piston or diaphragm pump capable of delivering 20 to 25 gallons per minute and covering four or five rows at a pass is highly recommended.

Sprayers should be calibrated often, usually every 8 to 10 hours of operation, to ensure proper pesticide application.

FUMIGATION

Fumigants are pressurized gases or liquids that change into gases and diffuse through the soil to kill pests. Soil fumigants have been used for more than 50 years to obtain high levels of plant productivity by controlling soil-borne diseases, soil insects, nematodes, and weeds. In general, fumigants are restricted-use chemicals and should be handled carefully by a certified applicator.

The major soil fumigation program used by most tomato growers has been methyl bromide mixed with chloropicrin. As a broad-spectrum fumigant, methyl bromide has produced consistently excellent results; however, methyl bromide use is slowly but persistently decreasing due to an ongoing phase-out and critical-use exemption process that began in 2001. It is also becoming quite expensive. Although this phase-out has triggered an increase in research on alternative fumigants, results generally indicate that no single alternative fumigant can match the consistent broad-spectrum control provided by methyl bromide. Therefore, it is important to know the current and potential pest problems for each farm and field. The chemical alternatives that are currently available all have their strengths and weaknesses. Which product or combination of products will work best for your farm? Determine why you fumigate, and then target the limiting factor. Switching chemicals will not be as simple as taking the methyl bromide tank off and replacing it with product 'X'. Chances are there will be changes necessary for your application rig, personal protective equipment, possible buffer zone changes, and changes in your plant-back times.

As part of a current EPA program to ensure that all pesticides meet current health and safety standards, a re-registration process for currently registered soil fumigants and for a few new fumigant compounds (iodomethane and dimethyl disulfide) is in progress. In most registrations, the EPA has implemented buffer zones that are scalable based upon fumigant rate and number of acres applied. Growers should read the labels and understand the limitations before purchasing these products.

Virtually impermeable films (VIF) continue to be another factor emerging as an important part of fumigation. Fumigants do not easily move through these tarps, so the chemical stays in contact with the soil in the bed for a longer period of time. This has allowed reduced application rates of fumigants with equivalent pathogen and weed control. Be aware, you should expect to pay more for VIF.

FERTILIZATION

These recommendations are based on field studies and research in the southeastern U.S. Growers are advised to use plant analysis to monitor and adjust applications. Nitrogen, potassium, and boron are the key elements in producing quality tomatoes. A soil analysis report will indicate the kind and amount of lime and fertilizer needed for the tomato crop. The recommended materials should be applied as follows.

Lime and Phosphorus

Lime and phosphorus are best applied in the fall. When land is being prepared for seeding the winter cover crop, the amount of lime needed to achieve a pH of 6.0 to 6.8 and any phosphate fertilizers, as indicated by the soil tests, should be applied and thoroughly incorporated into the plow layer. The best mixing is achieved by spreading half of the lime and phosphate before plowing and half after plowing but before disking.

The cover crop should be turned under at least 3 weeks before spring planting. Any recommended phosphate or lime not applied in the fall should be applied at this time.

Nitrogen

Nitrogen (N) requirements are influenced by soil type, crop history, variety, and use of fumigation, drip-irrigation, and plastic mulch. Most of the newer determinate varieties respond negatively to excess N and require careful N management. Too much N can cause heavy vegetative growth, delay maturity, and reduce fruit quality. Avoid using urea on fumigated soils.

N fertilization becomes easier to manage when using drip irrigation. Drip irrigation gives the grower many options because N can be applied gradually at a low rate. If plant analysis reveals a need for additional N, it can be applied directly through the system with quick results. Be sure to use soluble fertilizers and inject them upstream from the filter. Suitable soluble fertilizers are calcium nitrate, ammonium nitrate, potassium nitrate, 15-0-14, and greenhouse-grade soluble fertilizers. Mix the fertilizer in a clean tank (preferably plastic) a day before you plan to inject it. Always use warm water to help dissolve the material. If you inject fertilizer, be sure to skim off the top scum and never use the residue on the bottom of the tank. Continuous feeding of fertilizer can increase yields.

Good results have been attained with 40 to 70 pounds of N per acre broadcast as a pre-plant application (Table 3). Sample each site for residual soil N, and reduce pre-plant N to 40 pounds per acre if residual soil nitrogen is available. Soils with little estimated residual N, such as soils with little organic matter, may need 60 to 70 pounds per acre.

Pre-plant N typically is depleted about the time the lower fruit reaches the size of a dime, which is about 30 days after planting. Begin plant tissue analysis at this time to monitor for N as well as other nutrients. A general rule of thumb for quality fruit is to apply 3 to 4 pounds of N per acre per week through the drip. Additional N will be necessary about 2 weeks before the first harvest when the lower fruit is about the size of a dollar coin. At that time, increase the rate to 6 to 7 pounds of N per acre per week and continue this rate throughout the peak picking season. Growers should continue to monitor N and other nutrients weekly with plant analysis. The rate of N can be reduced to 3 to 4 pounds per acre per week after the peak, through the end of the season. In general, the total rate of N applied per season should be in the range of 90 to 130 pounds per acre depending on the site, and N should always be monitored with plant analysis.

In a bare ground system, a total season rate of 90 to 150 pounds N per acre total is recommended for loam and clay soils, and 150 to 200 pounds N per acre total for sandy and sandy loams. Split applications into one pre-plant and two side-dressed applications for the lighter textured soils, or one pre-plant and at least one side-dressed application for the heavier soils.

Phosphorus

Adequate phosphorus is important during early plant growth. The amount of phosphorus applied in the pre-plant application should be adequate for the entire season. Field studies showed no response from drip-applied phosphorus, so the practice is not recommended.

Potassium

Soil analysis will determine index levels of potassium, although potassium recommendations based solely on soil samples have proven inadequate on many sites that use drip irrigation. Therefore, plant analysis should begin when the lower fruit size is about the size of a dime and be continued weekly through harvest. The potassium concentration early in the season ideally should be above 4 percent. If the concentration is low, begin applying potash at the rate of 10 to 12 pounds per acre per week and continue until first harvest (Table 3). Continue to monitor with plant analysis weekly. If application has not begun by 2 weeks before first harvest, begin applying 10 to 12 pounds per acre per week of potash and continue until first harvest. Apply 20 to 25 pounds per acre per week of potash after first harvest and continue throughout the peak. Potassium concentration during harvest should be held between 2.5 and 3.0 percent. After the peak, reduce the rate to 10 to 12 pounds per acre per week until final harvest.

Boron

Tomatoes require more boron than many other vegetables. Boron deficiency may cause brittle stems, dieback of growing tips, and open-loculed fruit. Adequate boron also helps increase potassium uptake. To prevent boron deficiency, broadcast 1 to 2 pounds actual boron per acre, before or at planting time. Another option is to apply soluble boron as a foliar spray or through the drip-irrigation system. Apply ¼ pound boron in 100 gallons of water per acre. Fully charge the drip-irrigation system before injecting the boron to prevent plant damage. Use plant analysis to monitor boron concentration throughout the remainder of the season. Boron concentrations should be in the range of 60 to 100 ppm throughout harvest. Be careful when applying boron, as it can be phytotoxic. Young transplants are particularly sensitive to boron; adding boron to the transplant water may result in injury or transplant death. A rate of up to 0.5 pounds per acre of Solubor™ through the drip system or during foliar application with dilute sprays has worked well in field studies.

Calcium

Calcium is necessary to prevent blossom end rot disorder. Calcium concentrations should be sufficient where agricultural limestone has been applied and the plant bed is adequately supplied with water. In general, applying limestone to increase soil pH to the desired target, coupled with careful water management, should adequately supply calcium.

Monitoring Plant Nutrient Status

Use regular plant tissue analyses to monitor plant nutrient status. Begin plant tissue analysis about the time the lower fruits reach the size of a dime, or about 30 days after transplanting. If plants are deficient in one or more elements, apply additional fertilizer through the drip irrigation system or as a foliar spray, or side-dress on bare ground. Sufficiency ranges for tissue analysis are in Table 4 for the first-ripe-fruit stage.

Table 3. Nitrogen and potassium fertilization schedule for determinate and indeterminate tomato varieties grown in a plasticulture or strip-till system with drip irrigation on a per acre basis

TIME OF APPLICATION	NITROGEN	POTASSIUM
Preplant	Apply 40 to 70 lbs	Only apply if deficient
One week after first fruit set (about 30 days after planting)*	Apply 3 to 4 lbs per week**	Apply 10 to 12 lbs per week***
About two weeks before harvest	Apply 6 to 7 lbs per week	Apply 20 to 25 lbs per week
Halfway through harvest (after peak)	Apply 3 to 4 lbs per week until the crop is done	Apply 10 to 12 lbs per week until crop is done
Approximate Season Total	90 to 130 lbs	170 to 205 lbs

*Tissue analysis should start at fruit set and continue weekly thereafter to monitor nutrient status and allow adjustments.

**The sandier the soil, the more frequently water and fertilizer should be applied. If these conditions apply, divide the weekly recommended amount into two or three applications. For example, 3.5 lbs per week could be 1.75 lbs twice a week.

***Always apply potassium and nitrogen in a 3:1 ratio; 13-0-44 fertilizer will supply this.

Table 4. Plant tissue analysis ranges for various elements for tomato sampled at the first-ripe-fruit stage using most recently mature leaves

STATUS	N	P	K	Ca	Mg	S
	PERCENT					
Deficient	2.0	0.2	2.0	1.0	0.25	0.3
Adequate	2.0 – 3.5	0.2 – 0.4	2.0 – 4.0	1.0 – 2.0	0.25 – 0.5	0.3 – 0.6
High	3.5	0.4	4.0	2.0	0.5	0.6
STATUS	Fe	Mn	Zn	B	Cu	Mo
	PARTS PER MILLION					
Deficient	40	30	20	20	5	0.2
Adequate	40 – 100	30 – 100	20 – 40	20 – 40	5 – 10	0.2 – 0.6
High	100	100	40	80	10	0.6

N—nitrogen
P—phosphorus
K—potassium
Ca—calcium
Mg—magnesium
S—sulfur
Fe—iron
Mn—manganese
Zn—zinc
B—boron
Cu—copper
Mo—molybdenum

TRANSPLANTS

Source of Tomato Plants

Good-quality transplants that are free of disease and insect pests are crucial to profitable tomato production. Only home-grown or certified plants (those that have been inspected by the state department of agriculture and are certified to be free of disease and insect pests) should be set.

Transplants may be grown locally in outdoor beds and set as bare root or "slick-root" plants, or they may be produced in various types of growing structures in containerized trays. Slick-root plants usually are less expensive, but they are more susceptible to weather and pest hazards and vary more in size and quality. They are also subject to greater transplant shock and should not be set through black plastic. Producing container plants, on the other hand, requires greater management skill and more specialized growing facilities.

Although there are some definite advantages to growing your own tomato transplants, much of the staked acreage in the Southeast is set with commercially grown, containerized transplants produced in Florida and Georgia. Most states have plant certification laws and inspection systems aimed at assuring disease-free plants of good quality. For example, the North Carolina Vegetable Plant Law requires that only certified plants be sold in the state. A plant inspection system helps enforce the law. Growers and those who supply plants to growers should know the reputation of the plant producer and accept shipped-in plants only if:

- They carry the producer's certification and variety name.
- They have been inspected and approved by a state plant inspector.
- They are of the size and quality specified in the order.

Growers should contract early with their greenhouse producers to secure plants of the varieties they want to grow and for the time they need them. Growers should expect to plant between 3,600 and 5,800 plants per acre in a staked tomato operation, depending on plant spacing.

Transplant Production

Expect to produce about 4,000 transplants per ounce of seed. Approximately 3 ounces is 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 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. 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 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 can be handled with their transplanting equipment.

Production media is usually peat based with various additives such as perlite and vermiculite added to improve its characteristics. Media can be purchased ready-mixed, or you can buy the components and formulate your own mix. Either way, use finely textured media for starting seeds. Check with your supplier about media texture. Some media are specially made for this purpose. In addition, these media may contain fertilizer and wetting agents. Media with fertilizer is often referred to as "charged".

Most seed is sold with a fungicide coating to help prevent damping off during germination. In addition, various seed coats are available, from polymer to clay coats. Coated seeds help automated seeding equipment sort and distribute a single seed. Plant tomato seeds ⅛ to ¼ inch deep. Automated seeders place the seed on the surface, so it will have to be covered, usually with a thin layer of vermiculite.

After flats have been filled and the seeds planted, flats are often wrapped with plastic pallet wrap or placed in germination rooms (rooms with temperature and humidity tightly controlled) for 48 to 72 hours to ensure even moisture and temperature for optimum germination. The optimum germination temperature for tomatoes is 85˚F. At this temperature, tomato seedlings should emerge in about 5 to 6 days.

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 to 200 ppm of a suitable water-soluble fertilizer once a week. Begin fertilizing noncharged media as soon as the plants emerge. Growers may also apply a suitable water-soluble fertilizer, in low concentrations (50 ppm), with every irrigation. It will take approximately 5 to 7 weeks to produce good quality transplants. Cooler temperatures will slow growth, so keep greenhouse temperatures above 60˚F at night to accelerate growth.

Prior to transplanting, tomatoes should be hardened off, the process of reducing water and lowering temperature. Harden seedlings several days before transplanting by moving the plants outside the greenhouse to a protected location (with some shade), or by opening the sides of the greenhouse if possible. Withholding water is the best method of hardening plants. Reduce the amount of water the plants receive, but don't allow them to wilt. Do not harden transplants by withholding fertilizer or exposing them to temperatures below 60°F to 65°F during the day and 50°F to 60°F at night. 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.

Seed Treatment

To minimize bacterial canker, bacterial spot, and bacterial speck, seed can be treated. Refer to the DISEASES section titled "Control of Foliar and Stem Bacterial Diseases" for seed treatment protocol (p. 26).

TRANSPLANTING

Moving plants from a plant bed or greenhouse to the open field can cause serious shock if the plants are not properly hardened and handled. In severe cases, the first flower cluster may abort, resulting in delayed harvest and reduced yields. Table 5 provides recommended transplanting dates for each region. To minimize stress, follow these precautions:

- Transplant in late afternoon or on an overcast day to reduce wilting.
- Use a transplant solution containing a starter fertilizer.
- Irrigate the field immediately after transplanting.
- Only containerized plants should be set through black plastic mulch; bare-root plants will wilt and come in contact with the plastic, which will badly damage or kill them if the day is sunny.

Starter fertilizer solutions for tomatoes should contain a high rate of phosphorus. Approximate

Table 5. Tomato (fresh market) planting dates

State, Area	Spring	Fall
AL, north	4/15–6/15	NR*
AL, south	3/1–4/30	7/15–8/30
GA, north	4/15–6/15	NR
GA, south	3/1–4/30	7/15–8/30
LA, north	3/15–6/30	7/1–8/10
LA, south	3/1–6/30	7/15–8/15
MS, north	4/20–6/30	NR
MS, south	3/1–3/15	NR
NC, east	4/15–5/10	8/1–8/15
NC, west	5/15–7/15	NR
SC, east	3/15–4/30	7/1–7/15
SC, west	5/1–6/30	NR

*NR = Not recommended.

ratio of 1 Nitrogen:3 Phosphorus:0 Potassium is common. Be careful to mix and apply the fertilizer according to the manufacturer's recommendations. If the solution is too concentrated, it can kill plant roots and result in dead or stunted plants.

Plant Spacing

Set plants in rows wide enough to accommodate equipment and laborers and to permit good air circulation. The minimum practical row width is 4½ to 5 feet. Staked plants should be spaced 18 to 24 inches apart in the row. Spacing plants 20 inches apart in 5-foot rows requires 5,227 plants per acre. For trellised production, space plants 8 to 10 inches apart in the row for a single-stem system and 18 to 30 inches apart for a two-stem system.

STAKING AND TRELLISING

Short-Stake, String-and-Weave System for Determinate Varieties

Most hybrid tomato varieties are determinate, meaning the vines grow to a certain length and end in a terminal fruit cluster. As a result, all the fruit the plant is going to produce ripens over a short period of time, usually about 8 weeks. Determinate varieties are often grown in a staked production system. The purpose of staking and stringing tomato plants is to hold the foliage and fruit off the ground, which improves fruit quality, allows for more uniform spray coverage, and makes harvesting easier.

The most common system uses wooden stakes, 1 inch square by 4 to 4.5 feet long, driven 10 to 12 inches into the soil midway in the space after every other plant (approximately 2,600 stakes per acre; Figure 1). Use 5- to 7- foot stakes for highly vigorous determinate varieties, most indeterminate grape tomatoes, and some indeterminate heirloom tomatoes. A stake placed between every other plant is adequate to support most determinate varieties. Placing an additional stake at an angle, tied to the end stake of each section, will strengthen the trellis system.

Stakes can be driven by hand with a homemade tool or with a commercially available power-driven stake driving tool. A simple, homemade, hand-operated driving tool can be made from a 36-inch length of 2½-inch galvanized pipe with a cap screwed or welded on one end.

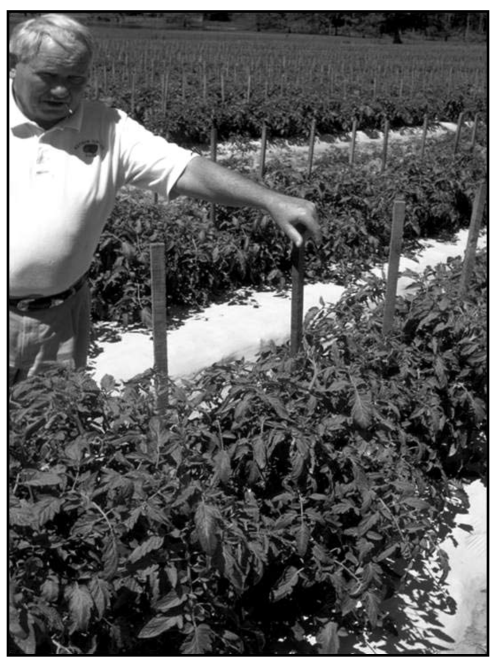

Figure 1. *A wooden stake placed between every other plant is adequate to support most determinate varieties.*

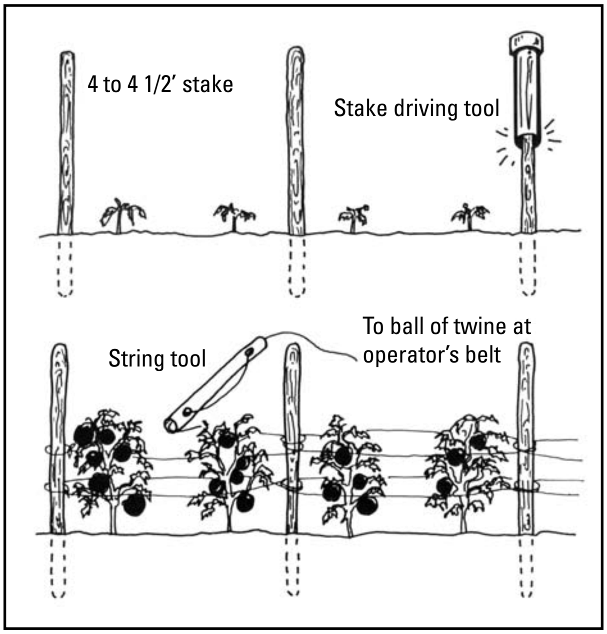

Figure 2. The stringing tool extends the worker's reach and helps to keep the twine tight.

Figure 3. The first string should be about 8 to 10 inches above the soil.

Figure 4. The stringing tool is used to pass the string along one side of the row, looping it around each stake.

Figure 5. Three to four stringings are optimal, each about 6 to 10 inches higher than the preceding one.

The stringing tool serves as an extension of the worker's arm (the length cut to the worker's preference) and helps to keep the string tight.

Proper stringing consists of tying twine to an end stake, passing the string along one side of the plants, and then looping the twine around each stake until the end of a row or section (100 foot sections with alleys may help harvesting) is reached. The same process is continued on the other side of the row. The string tension must be tight enough to hold the plants upright. **Note:** if strings are *too tight*, they can make harvesting fruit more difficult and can scar fruit.

The first string should be about 8 to 10 inches above the soil and should be strung when the plants are 12 to 15 inches high, before they fall over (Figure 3). The initial pruning (described on p. 21) should immediately precede the first stringing. Use the stringing tool to pass the string along one side of the row, looping it around each stake (Figure 4). It is important to keep the string very tight! Proceed to the end of the row section (usually 100 feet) and return on the opposite side, passing the string along the other side of the plants, again looping each stake. Add subsequent strings as the plants grow. Three to four stringings are optimal, each about 6 to 10 inches higher than the preceding one (Figure 5). String plants when the foliage is dry to prevent the spread of diseases. Growers have successfully used variations of this plant support system.

Trellising for Indeterminate Varieties

Most heirloom tomatoes are indeterminate, meaning the vines keep growing and setting fruit until they are killed by disease or frost. They must be grown on a tall, strong trellis. A trellis can be constructed of 3-inch diameter, or larger, posts set 10 to 15 feet apart within the row. Use 7- to 8-foot-long posts, leaving 6 to 7 feet above ground. Run a stout wire (about 12 gauge) across the tops of the posts and secure it with staples. Pieces of twine, long enough to reach the ground, should be tied to the top wire above each plant. The twine can be anchored with a loop to each plant or to a bottom line of twine that is strung about 6 inches off the ground and secured to the posts. Some growers use the standard string-and-weave staked culture system for indeterminate tomatoes, but they use 6-foot stakes instead of the normal 4-foot stakes.

PRUNING

Pruning of the suckers, or auxiliary shoots on the main stem, helps maintain the desired balance between vine growth and fruit production. Pruning only a little or not at all results in extensive vine growth and a heavy load of small fruit. Moderate pruning results in a smaller vine and larger fruit that mature earlier. For a determinate variety grown in a staked system, a good balance between foliage and fruit is usually obtained by removing all suckers up to the one immediately below the first flower cluster. This results in a fork just below the first fruit cluster. With strongly determinate varieties, leave two suckers below the first fruit cluster. If the season of the year slows growth, leave additional suckers to provide adequate fruit cover. A single pruning will usually be adequate, although a later pruning may be needed to remove suckers growing from below ground at the base of the plant.

When suckers reach 1.5 to 2 inches, they should be removed. If suckers aren't removed until they are 4 or more inches long, there may be inadequate foliage to cover the fruit and prevent sunscald, stressing the plant and making it more susceptible to disease. Leaves often curl under these conditions, and yield is reduced. In fact, studies have shown that if suckers exceed 4 inches when they are removed, yield can be reduced dramatically. Do not prune plants when they are wet to avoid spread of diseases. Prune before the first stringing because the string can slow the pruning process. Pruning is variety and fertility dependent. If the plants outgrow the stakes, they may need to be topped. A machete or butcher knife works well for this.

Pruning and training are season-long processes for indeterminate varieties grown on high trellises. Most varieties are pruned to a single stem. All suckers are removed, leaving only the main stem to grow straight up the string. Some growers prefer a two-stem system, letting the main stem and the first sucker grow. These are usually trained into a "V" pattern. The stem(s) must be trained to the strings by wrapping the stems gently around the twine. Special clips can be purchased to secure the plants to the twine, but they are not necessary. Plants should be pruned and trained weekly.

PEST MANAGEMENT

The management and control of pests, including diseases, insects, and weeds, is essential to the successful production of staked tomatoes. Numerous pesticides (fungicides, herbicides, insecticides, and nematicides) are labeled for controlling tomato pests. Because pesticide recommendations are subject to change, they are not included in this publication. For the most current alternative and chemical control recommendations of the tomato pests discussed in the following sections, consult the tomato tables listed in the *Southeastern Vegetable Crop Guidelines* online: http://www.sripmc.org/docs/SoutheasternVegetableGuide.pdf

Integrated pest management (IPM) is an information-based pest management system that relies on knowledge about pest populations to select appropriate management tactics (biological, cultural, and chemical) and maintain pest populations below damaging levels in a sustainable manner. IPM should be a cost-effective approach to pest control. With an IPM approach, a variety of control methods are combined, and treatments are applied only as necessary to prevent economic loss—in other words, when the cost of treatment is less than the cost of the damage expected by the pest. IPM is based on the premise that pest problems differ from season to season and among geographic regions, and even between individual fields or areas within fields.

Some of the most important tomato IPM tactics include: (1) selection of a well-drained field site, (2) cultivation of tomato cultivars with the best disease resistance available, (3) rotation away from solanaceous crops for at least 3 years, and (4) improvement of soil quality. IPM is a systematic approach to crop pest management. It involves careful planning, continual field observation, and detailed record-keeping. Soil sampling, black light insect traps, and field scouting procedures are all important strategies in IPM. If you are interested in adopting some or all of the recommended IPM practices for tomatoes, be sure to consult your county Extension agent.

Controlling tomato diseases and insects is much easier when done *preventively*. The high probability that early blight and bacterial disease will occur every year early in the season makes it necessary to spray fungicides routinely on a 5- to 7-day schedule. Growers should scout fields weekly for disease and insects and apply appropriate pest management practices. The online version of this publication at http://ipm.ncsu.edu/ includes an appendix of photographs to help growers identify diseases, insects, and physiological disorders. Select the “Production Guides” link.

Diseases

Diseases can significantly limit tomato production in the Southeast. For example, foliar diseases can reduce yields 20 to 40 percent. Other diseases, such as bacterial spot, speck and canker, root knot nematodes, and Verticillium wilt, can lead to further yield reductions. Diseases must be managed if you want to attain maximum profits. This section describes the most common tomato diseases in the Southeast and provides general guidelines for their control.

Nematodes

Several species of nematodes, particularly root-knot nematodes, can severely damage tomato plants and reduce yield. Root knot nematodes usually cause distinctive swellings, called *galls*, on affected roots (Appendix, Fig. A-1). To determine whether problematic nematodes are present, send soil samples to the laboratory in your state. Materials for collecting and mailing the samples are available at county Extension offices or laboratories in most states.

Alabama:
Plant Diagnostic Lab, ALFA Agricultural Services and Research Building, 961 South Donahue Dr., Auburn University, Auburn, AL 36849-5624.
Phone: 334-844-5506; Fax: 334-844-4072.
http://www.aces.edu/dept/plantdiagnosticlab/

Georgia:
Plant Pathology Nematode Laboratory,
2350 College Station Rd., University of Georgia,
Athens, GA 30602. Phone: 706-542-9144;
Fax: 706-542-5957.
http://plantpath.caes.uga.edu/extension/clinic.html

Louisiana:
Nematode Advisory Service, Department of
Plant Pathology and Crop Physiology,
302 Life Science Building-LSU, Baton Rouge, LA 70803.
Phone: 225-578-2186; Fax: 225-578-1415.

Mississippi:
MSU-ES Nematode Lab, 190 Bost North, Rm. 9,
Mississippi State, MS 39762-9655;
Phone 662-325-2146 or 662-325-8336;
Fax: 662-325-8336.
www.extensionplantclinics.msstate.edu

North Carolina:
Nematode Advisory Section, NCDA&CS Agronomic Division, 1040 mail service center, Raleigh, NC 27699.
Phone: 919-733-2655.
http://www.agr.state.nc.us/agronomi/nemhome.htm

South Carolina:
Plant Problem Clinic and Nematode Assay Lab,
511 Westinghouse Rd., Pendleton, SC 29670.
Phone: 864-656-2677. www.clemson.edu/plantclinic

A typical report will indicate if plant pathogenic nematodes are present and what action is needed. Follow label instructions carefully when applying nematicides. The field should be well prepared (plowed and disked) before application, and all plant material should be thoroughly decomposed. Be very careful to use transplants that are free of nematodes, or control efforts will be ineffective.

Wilt Diseases

Organisms that cause wilt diseases in tomatoes usually persist in the soil for a long time. In fields where wilts have been a problem, you must take special steps to control them. Five important wilt diseases occur in varying degrees in the Southeast: Fusarium, bacterial wilt, Verticillium, southern blight (also known as southern stem rot), and walnut wilt.

Fusarium wilt appears first as a yellowing of the lower leaves (Appendix, Fig.A-2). As the disease progresses, the yellowing gradually moves up the plant. Leaflets on a given branch may be affected on one side only. The vascular system of the plant develops a brown discoloration, and eventually the entire plant may wilt and die. Three forms, or races, of this fungus exist, called race 1, 2, or 3. Fusarium wilt is rarely seen, however, due to the development of resistant varieties. In recent years, *Fusarium oxysporum* f.sp. *lycopersici* race 3 has been identified in the region. Several new varieties are resistant to this race (Table 1).

Bacterial wilt (also called Granville wilt or southern bacterial wilt) is caused by the bacterium *Ralstonia solanacearum*. Wilting first appears on the youngest leaves of plants during hot daytime temperatures. The infected plants may recover, temporarily, in the evening, when temperatures are cooler. A few days later, a sudden and permanent wilt occurs (Appendix, Fig. A-3). This bacterium also infects other crops, such as tobacco, potato, eggplant, and pepper, and causes a fairly rapid wilt in tomato. The vascular system and pith become discolored, and slimy bacterial ooze often exudes from cut surfaces. This bacterium has been known to overwinter at elevations of 2,000 feet or less. At lower elevations, this disease is prevalent. No consistently effective control measures are available. Deep application (more than 10 inches) of several fumigants have delayed expression of the disease but does not totally eliminate the pathogen. Fields with a history of bacterial wilt should be avoided for tomato production, and farmers should rotate with nonsusceptible crops.

Verticillium wilt is widespread in the mountains but rarely occurs in other growing areas. In a survey of tomato fields in western North Carolina, more than 50 percent were found to have some levels of Verticillium wilt. In addition, a second strain (race 2) of *Verticillium dahliae* has been identified in the mountains. This strain causes wilt in the varieties resistant to race 1, as no source of resistance to race 2 is commercially available. The disease begins with a yellowing of lower leaves, and discoloration gradually progresses up the plant (Appendix, Fig. A-4). V-shaped lesions on leaves often appear, and fruit can be damaged by loss of protective foliage. Vascular discoloration of the lower stem is evident when cut longitudinally. Infected plants are rarely killed, as compared with Fusarium wilt, and the vascular discoloration is less. Verticillium-infected plants are stunted, and yields may be reduced from 20 to 50 percent. The fungus can persist in the soil for many years in the absence of a susceptible host. For this reason, the disease is difficult to control by rotation. Pepper, eggplant, potato, and tobacco are all hosts and should not be used as rotation crops. Soil fumigation is the most effective control method, but it is not 100 percent effective. Some growers have reduced Verticillium wilt in fields by deep-shanking fumigants (chloropicrin) using an applicator with a chisel plow.

Southern blight (also known as southern stem rot) is a major problem in lower elevations. This disease is troublesome in the piedmont but rarely occurs in the mountains. It is caused by the soil-borne fungus *Sclerotium rolfsii*, which affects many other crops, including tobacco, soybeans, pepper, sweet potato, okra, and eggplant. This fungus attacks the stem of the plant near the soil line and produces a white, moldy growth (Appendix, Fig. A-5). After a few weeks, small white to tan circular structures called *sclerotia* form on this fuzzy white growth and can overwinter in infested fields. Problem fields should be avoided, and rotation with grain crops is recommended. Soil treatment with recommended chemicals may be effective. Preparing the land with a moldboard plow set to bury trash 6 to 10 inches deep during land preparation also gives effective control.

Walnut wilt is characterized by rapid wilting of plants in a localized pattern, usually in areas near the border of the field (Appendix, Fig. A-6). The disease is caused by a toxin produced by roots of black walnut and butternut trees. The toxin may remain in the soil and continue to cause the disease for several years after walnut or butternut trees are removed.

Wilt Control Strategies. Wilt diseases of tomatoes are best controlled by: (1) growing resistant varieties when available, (2) rotating tomatoes with other nonhost crops, (3) fumigating the soil, and (4) planting tomatoes at least 50 feet from walnut or butternut trees or their stumps. When practical, infected plant material should be removed or destroyed after each harvest. Grafting tomatoes onto disease-resistant rootstocks has become a widespread practice for control of soil-borne bacterial and fungal diseases in greenhouse production, but the practice is not yet considered economically viable in field production.

Most of the commercial varieties are resistant to race 1 of both Fusarium and Verticillium wilt. Since Verticillium race 2 is widespread in the mountains, however, you should become familiar with this disease and take steps to reduce its effects. If land is infested with Verticillium race 2, use a multipurpose soil fumigant or, if possible, plant the crop on land that has not been in tomatoes or other susceptible crops for at least 5 years.

Fumigants that are effective against Verticillium, as well as other wilt disease organisms, may be broadcast or applied in the row. For fumigant treatments to be effective: (1) the land should be prepared 3 to 4 weeks before treatment to allow for full decomposition of plant debris; (2) the soil at the time of treatment should be in seedbed condition with adequate moisture, neither too wet nor too dry; and (3) the soil temperature should be above 50°F. In fields where Verticillium is present, use both a Verticillium-resistant variety and soil fumigation to control this disease.

Foliar Diseases Caused by Fungi

Five significant foliar diseases caused by fungi infect tomatoes in the Southeast.

Early blight, caused by the fungus *Alternaria solani*, is one of the most serious foliar diseases in the Southeast, but the disease is universally troublesome most other places where tomatoes are grown. It occurs during both relatively dry and wet periods early in the growing season. It appears first as small, dark brown to black spots on the leaves or stems (Appendix, Fig. A-7). Leaf spots may enlarge, producing leathery-looking lesions with black concentric rings. These lesions can lead to blighting and loss of entire leaves. Spots on the stem may enlarge and eventually girdle it, causing what is known as collar rot. Fruit may also be spotted by this disease.

Gray leaf spot, caused by *Stemphylium* species, is characterized by small grayish-brown leaf lesions that appear glazed and often crack and tear across the lesion. Severe infection causes the leaves to turn yellow, wither, and eventually die. During warm, humid conditions in the Southeast, this disease can be highly destructive. Most commercial varieties are now resistant to this disease, however, and therefore it is not often observed.

Gray mold, caused by the fungus *Botrytis cinerea*, is an important foliar and fruit disease in the mountains, especially when conditions are cool and wet after midseason and during post-harvest shipping. The disease is characterized by a dark brown to gray fungal growth on blighted petioles and leaves (Appendix, Fig. A-8). Infected fruits become soft and watery; the flesh turns light gray and sometimes shows a thick, dark gray, velvet-like fungal growth. Wider plant spacing, which allows for good air circulation and improved spray coverage, will help control gray mold.

Late blight, caused by the fungus-like organism *Phytophthora infestans*, is usually severe in the mountains and in late plantings in the piedmont. The disease can be highly destructive and cause complete plant loss if not controlled once observed. The causal fungus is favored by cool, wet weather and can attack all above-ground parts of the plant. Leaf symptoms are characterized by greenish-black, water-soaked lesions with a white, downy fungal growth on the underside of the lesions (Appendix, Fig. A-9). Infected foliage will eventually shrivel and die. Rotted fruits are firm with a brown leathery appearance.

Septoria leaf spot, caused by the fungus *Septoria lycopersici*, can be as destructive as early blight. It is common in coastal and piedmont tomato fields but not in the mountains. Small (about ⅛ inch in diameter) water-soaked, circular spots develop on the oldest leaves first (Appendix, Fig. A-10). These lesions typically have dark margins with gray centers and contain numerous small black structures. Severe infection results in premature leaf drop, eventually causing sunscald on fruit.

Control of Foliar Fungal Diseases. To control the above diseases, (1) use disease-free transplants either by following the recommendations for pest control in the plant bed or by purchasing certified plants, (2) plant potatoes as far away from the tomato field as possible, (3) control weeds and volunteers in production areas, (4) spray plants in the field regularly with protective fungicides (see http://www.sripmc.org/docs/SoutheasternVegetableGuide.pdf), and (5) use a high-pressure sprayer (200 to 500 psi, 100 gpa) or mist blower for thorough spray coverage of all plant parts. Begin spraying 1 or 2 days after transplanting. Continue to spray every 7 days and after heavy rains that may have washed off the previous application. Diluted sprays (1×) applied with standard boom sprayers are recommended. Use 2× concentrations in backpack mist blowers. Table 6 shows the volume of spray needed per acre for effective disease control.

Table 6. Suggested amounts of fungicide spray to use for control of foliar diseases

Type of Sprayer	Concentration	Rate (gallons of spray per acre)		
		Early	Midseason	Late
Boom type, hydraulic	1×	50	100	150
Air blast (mist blower)	2×	25	50	75

Foliar and Stem Diseases Caused by Bacteria

Three significant foliar and stem diseases caused by bacteria affect tomatoes in the Southeast.

Bacterial canker is caused by the bacterium *Clavibacter michiganensis*, subspecies *michiganensis*, and is transmitted by tomato seed and infected transplants. The bacterium can overwinter in woody tomato stem tissue left in the field, but it will not survive in fleshy tomato tissue that has been plowed and buried in the fall. The bacterium can also overwinter on trellis posts or stakes, wire, field boxes, and other equipment. Once canker is in a field, bacteria are spread by splashing rain, machinery, or people working when the foliage is wet.

There are two distinct phases of canker, each with its own set of symptoms: the systemic or vascular phase and the foliar or blight phase. Systemic infection causes the vascular tissue to become discolored and pithy, which leads to wilting of leaves and general stunting. However, the foliar or blight phase is more common and consists of numerous small, tan spots on leaves, petioles, and pedicels (Appendix, Fig. A-11); brown-black discoloration along edges of leaflets; and typical "birds-eye" fruit spotting. There are no current commercial varieties with resistance to bacterial canker.

Bacterial spot. In the past few years, bacterial spot has become an economically significant disease in the Southeast, where it has been identified throughout most production areas. Bacterial spot causes frequent and severe yield and quality losses in fresh-market tomato production due to defoliation and spotting of fruit. In Florida, the disease is endemic and is caused primarily by *Xanthomonas euvesicatoria* and *Xanthomonas perforans*.

Throughout the Southeast, a new strain of bacterial spot called race T4 has been responsible for much of the leaf blighting in the past few years. Symptoms of this disease are often confused with bacterial speck, as leaf symptoms of both bacterial diseases are quite similar. Typical lesions on tomato leaflets are small, water-soaked, greasy spots about ⅛ inch in diameter. Spots can lack a yellow halo in the early stages of infection, but they usually develop halos over time. Stems, petioles, peduncles, pedicels, and sepals can also develop spots. Spots may grow together, killing large areas or entire leaves, and cause defoliation.

Bacterial spot can usually be differentiated from bacterial speck by symptoms on immature fruit. Bacterial spot fruit lesions are small, water-soaked spots that become slightly raised and enlarged until they reach ¼-inch in diameter (Appendix, Fig. A-12). The centers of these spots later become irregular, light brown, and slightly sunken and have a rough, scabby surface. In early stages of infection, a white halo may surround each lesion, at which time it resembles the fruit spot of bacterial canker.

Growers apply copper and mancozeb at least twice weekly in an attempt to control this disease, although control is difficult when environmental conditions are optimal for disease development (75ºF to 85ºF and moist). Control is also complicated in part by copper and streptomycin-tolerant strains, as well as lack of host resistance. Some studies indicate that the cultivar Mountain Fresh appears to have the best tolerance to this disease.

Bacterial speck. During the past two decades, bacterial speck has also become an economically significant disease in the Southeast. The pathogen *Pseudomonas syringae* pv. *tomato* has the ability to move quickly through the field during moist conditions and cooler temperatures (optimum temperature is 65ºF to 75ºF). Typical speck lesions on tomato leaflets are similar to bacterial spot lesions mentioned above, although bacterial spot lesions tend to look greasy, whereas those of speck do not (Appendix, Fig. A-13). Both diseases affect flowers. Lesions on stems and petioles cannot be distinguished. Speck and spot are more clearly differentiated by fruit symptoms. Bacterial speck appears on immature fruit as a black, slightly sunken stippling, eventually causing lesions less than 1/16 inch in diameter. Bacterial speck control is limited due to copper and streptomycin resistance, persistence in debris for long periods of time, and lack of host resistance.

Control of Foliar and Stem Bacterial Diseases. All three bacterial diseases can be devastating. To minimize their occurrence and spread, follow these practices:

- Treat seed for bacteria using hot water (at 133ºF for 25 minutes), hydrochloric acid (1.9 percent for 5 hours), or sodium hypochlorite (1.05 percent for 40 minutes). The third treatment is the easiest if you are growing your own transplants. Wrap the seed in a clean cheesecloth bag and suspend the bag for 40 minutes in a solution of 1 part household bleach (such as Clorox) and 4 parts water, stirring often. Drain and spread the seed on the cheesecloth to dry (no rinsing). Rub the seeds lightly as they dry to prevent them from sticking together. Dust with 1 teaspoon of Thiram 65WP per pound of seed.
- Plant the seed in sterilized soil. Plant beds should not be located where tomatoes were grown within the past 3 years.
- Spray seedlings weekly with an approved antibiotic (streptomycin) combined with routine fungicide sprays. See *Southeastern Vegetable Crop Guidelines*: http://www.sripmc.org/docs/SoutheasternVegetableGuide.pdf
- Buy transplants only from a disease-free source, and make sure that they are certified. Never introduce bacterial-infected seedlings into your field.
- Use good sanitation practices throughout your operation. Flats, pots, sashes, stakes, posts, wire, seedbed frames, and other pieces of equipment should all be disinfected with methyl bromide (2 pounds per 100 cubic feet)

or with a solution of 10 percent bleach (1 part bleach to 9 parts water), especially if bacterial canker has been a problem on your farm.

- Never use irrigation water that has been in contact with tomato plant refuse or that receives runoff from a contaminated field.
- Avoid working in contaminated fields when the plants are wet. For example, avoid working early in the morning, during fog, or immediately after a rain. These bacteria are easily spread by hand contact with plants during pruning and tying.
- Minimize infection and the spread of disease by removing suckers when small.
- Wash hands and tying sticks in a 10 percent bleach solution after handling diseased plants and before handling healthy plants.
- Work infested areas of a field last.
- Spray contaminated fields with a recommended copper fungicide every 5 to 7 days. The regular spray program for control of foliar disease should also be continued.
- Fall plow or burn plant refuse at the end of the cropping season. These bacteria can overwinter in infested plant debris but will be destroyed by burning or by the decomposition of plant material that has been plowed under.

Fruit Rots

Several fruit rots can begin either in the field or in transit after harvesting and packing. A good field spray program will generally prevent field fruit rot problems. Postharvest fruit rots and decay can be minimized by proper harvesting and handling (avoid bruising) and by sanitation in the packing house. Water in wash tanks should be heated to 5°F warmer than the tomatoes. Change it daily and maintain the correct level of approved disinfectants. Never pack wet fruit into boxes.

Viruses

Certain viruses, particularly the tomato spotted wilt virus (TSWV), tomato strain of tobacco mosaic virus (TMV or ToMV), tobacco etch virus (TEV), and tomato yellow leaf curl virus (TYLCV), can be troublesome in this region. Symptoms of these viruses are similar and difficult to distinguish in the field. All of these viruses cause stunting, reduce yields, and give a mottled and distorted appearance to affected leaves. In addition, some strains of these viruses can cause fruit distortion.

TSWV. TSWV outbreaks have increased in this decade on many crops in the Southeast. Recent incidences of 20 to 60 percent have caused major tomato losses in this region. Symptoms of the disease typically include cupping and rolling of the upper leaves, which usually turn purple or brown along the veins (Appendix, Fig. A-14). An internal spotting or browning of leaf tissue (spotted wilt) occurs frequently but is not always evident. Once infected with the virus, growing tips of the plant are usually severely affected with systemic browning and severely stunted growth (Fig. A-15).

This virus infects many crops, including pepper, peanut, tobacco, lettuce, potato, chrysanthemum, and numerous weeds. Weed hosts identified as potential TSWV carriers include spiny Amaranthus, lambs quarters (*Chenopodium* sp.), *Galinsoga* sp., morning glory (*Ipomoea* sp.), wild lettuce (*Lactuca* sp.), pasture buttercup (*Ranunculus* sp.), black nightshade and other *Solanum* sp., purslane (*Portulaca* sp.), and sowthistle (*Sonchus* sp.). Primary infection occurs when the TSW virus overwinters on broadleaf weeds and is then spread by thrips. Controlling winter annuals is a good way to reduce the incidence of this virus. TSWV can be reduced by:

- Choosing resistant varieties (Amelia, Crista, BHN-640);
- Controlling weeds both in and around tomato fields;
- Avoiding excessive nitrogen rates; and
- Using reflective mulch, where possible.

TMV and ToMV. TMV has been detected in all growing regions of the Southeast, including the mountains, piedmont, and coastal plain. The tomato strain of TMV can be seed borne or carried in on infected transplants, but is not carried on tobacco products. It can also overwinter in undecomposed roots from a previous crop. Once introduced into a field, TMV can be transmitted from infected plants to healthy plants by workers. The incidence of TMV can be reduced by:

- Using seed treated with sodium hypochlorite (see the canker seed treatment described earlier) or trisodium phosphate;
- Hand rinsing periodically in 20 percent milk (whole, dried, or skim) when handling plants;
- Using crop rotation (at least a 2-year cycle) to ensure the destruction of TMV in old tomato roots;
- Using resistant varieties, although only a limited number of TMV resistant varieties are commonly used in this region.

TEV. Leaflets of plants infected with TEV may show crinkling, distortion, and reduction in size (Appendix, Fig. A-16). TEV behaves differently from TMV. It overwinters in weeds and perennial plants at the edges of the field and is transmitted to tomatoes from these sources by insects, principally aphids. TEV cannot be transmitted from plant to plant by handling. Using insecticides to control aphids does not control the spread of the virus because the aphids generally transmit it before they are killed by an insecticide spray. Some control can be achieved by keeping areas adjacent to the field weed-free.

TYLCV. Although initially found in the Mediterranean, TYLCV is now a problem in the southern United States. The virus typically spreads from infected solanaceous weeds by larvae of the sweetpotato whitefly. Increased populations of this insect vector are associated with this virus. TYLCV cannot be transmitted from plant to plant by handling. Control measures typically involve limiting the whitefly population.

Insects

Staked tomatoes are a high-value crop with little tolerance for insect damage. Consequently, management programs for direct pests (insects that feed on the fruit) must control insects before they cause damage. In contrast, population densities of indirect pests (insects feeding on the leaves or roots) can be allowed to become established before control measures are needed, and low populations may be tolerated without control. More than 14 species of insects and mites can infest tomatoes in the Southeast. Only a few, however, are considered key pests (such as tomato fruitworm, stink bugs, thrips, whiteflies, and mites) that consistently infest tomato crops from year to year. Others are more sporadic. Nonetheless, certain sporadic pests can cause serious damage and be difficult to control when they do appear.

Integrated Pest Management

Integrated pest management (IPM) considers pest biology and populations to select appropriate biological, cultural, and chemical tactics that will keep pest populations below damaging levels in a sustainable manner. Because of the economics of tomato production and the low tolerance for pest damage, chemical control has been and will continue to be the primary tool used to control insects in tomatoes. However, biological and cultural controls can sometimes be used to avoid or reduce the potential for infestation by certain insects. Host plant resistance to diseases transmitted by insects can greatly affect tolerance for the insect involved, basically shifting the emphasis of control from disease transmission (very low tolerance for the insect) to reduction of direct feeding injury (much higher tolerance for many of our disease vectors). See the descriptions below for biological or cultural control options available for specific pests.

IPM involves regularly scouting fields for potential pest damage and then determining which insecticidal controls are needed and appropriate. Even where insecticides are used preventively, scouting evaluates the efficacy of the control program. Scouting has become particularly important in recent years with the introduction of new insecticides that have a narrower spectrum of pest activity than older, more broad-spectrum insecticides. Although these new insecticides are generally more effective and environmentally friendly than older products, they often control only one or two different insects, and some are only effective against a specific life stage of the pest. Hence, the insecticide-selection decision must be based on knowledge of the specific pest(s) present in the field, and in some instances, the life stage of the pest (small versus large larvae).

Insecticide Resistance Management

Many tomato insect and mite pests have a high potential for developing pesticide resistance.

The potential for resistance development varies considerably among pests, with those that have a high reproductive rate and limited host range and mobility being most likely to develop resistance. Insecticide resistance management incorporates pest management practices and pesticide-use strategies that avoid or delay the development of resistant pest populations, with the ultimate goal being to prolong the effective life of a pesticide(s). Sound resistance management tactics are important because of the high cost of resistance (from loss of yield and pest control costs) and the limited number of pesticides that are registered for use on tomatoes.

Tomato pests that have developed resistance to one or more pesticides include two-spotted spider mites, whiteflies, leafminers, and Colorado potato beetles, although the latter is of concern primarily in the coastal plain of North Carolina. The beet armyworm is also notorious for resistance development; however, this has been less of a problem in recent years, since the registration of diverse new lepidopteran-specific insecticides. A key concept for resistance management is that resistant insects are already present in the population, but they are normally a low percentage. Repeated application of insecticides with a similar mode of action allows the resistant individuals to increase their numbers (you kill most of the susceptible pests, and the resistant ones survive and reproduce) until the insecticide no longer provides satisfactory control. Employ the following resistance management tactics to minimize the development potential of resistant pest populations.

- Avoid unnecessary applications by establishing scouting programs and threshold levels to determine when pesticide applications are needed.
- Apply the correct dose of pesticide. A low percentage of a pest population is predisposed to resistance development, and applying a pesticide below labeled rates enhances the potential for survival of these individuals.
- Rotate pesticide applications with different modes of action. Continuous exposure of a pest population to pesticides with the same or similar mode of action accelerates resistance development. If a pest is present and requires control over multiple generations within the same season, pesticides with different modes of action should be used against different generations. For those pests that migrate from adjacent fields—either different crops or early plantings of the same crop—employ this pesticide rotation scheme across crops.

Insect Pest Biology and Control Strategies

Management strategies targeting insect pests are based on an understanding of a pest's biology and life history. Knowledge about a pest's development, overwintering strategies, feeding habits, and movement patterns all help to determine effective control strategies. This section provides a brief description of the key insect and mite pests of tomatoes, along with information about treatment threshold levels and nonchemical control options.

Tomato fruitworm, *Helicoverpa zea*. Also called the corn earworm and cotton bollworm, the tomato fruitworm is the most common direct pest of field-grown tomatoes in the Southeast (Appendix, Fig. A-17). North Carolina is on the northernmost edge of the overwintering range of this insect, and the occurrence and abundance of overwintering pupae varies among different areas. Nevertheless, immigrating populations from nearby areas ensure annual infestations in all production regions. Although moths emerging from the overwintering generation often infest early planted tomatoes, populations on tomato are generally highest in July and August and are generated from earlier infestations in nearby corn; silk-stage corn is a preferred host. Moths deposit eggs on tomato foliage (Fig. A-18). Upon hatching, larvae will initially feed on foliage for a short time before boring into fruit (Fig. A-19). Control tactics aim to kill larvae as they hatch from eggs and before they bore into fruit. The closely related tobacco budworm, *Heliothis virescens*, sometimes infests tomatoes, and control strategies for this insect are the same as those for fruitworms.

A diversity of natural enemies can impact fruitworm populations on tomatoes, including egg parasites (*Trichogramma* spp. and *Telenomus helithidis*), larval parasites (*Campletis sonorensis* and *Cotesia marginiventris*), and predators (*Orius* *insidiosus* and *O. tristicolor*). Because of the low tolerance for damage to tomatoes, however, the combined action of these natural enemies does not prevent economic loss. Therefore, insecticides should be applied at frequent intervals (7 to 10 days) when moths are laying eggs on post-bloom tomatoes. Prior to bloom, low populations of these pests can generally be tolerated as defoliation is usually minor. Moth activity can be monitored with pheromone traps.

Stink bugs, *Euschistus servus, Acrosternum hilare, Nezara viridula*. The brown (*E. servus*), green stink bug (*A. hilare*), and southern green stink bug, (*N. viridula*) are common tomato pests, although the severity of damage varies considerably among fields. All three species overwinter as adults in weeds and debris surrounding fields and migrate into tomato fields throughout the season. Tomato fields planted adjacent to soybeans are highly susceptible to stink bug infestations, because soybean is a preferred host of these insects. Adults and immatures feed on developing fruit with their piercing mouthparts (Appendix, Fig. A-20), causing discolored blemishes that render fruit unmarketable (Fig. A-21). Stink bugs are very difficult to detect in tomatoes because they are easily startled and seek shelter when disturbed. Chemical control is currently the only effective option for managing these pests.

Thrips, *Franklinellia fusca, F. occidentalis and F. tritici*. Depending on the species and growth stage of plants, thrips can feed on both tomato foliage and flowers. Direct damage to fruit is caused by thrips ovipositing or feeding in small, developing fruit before stamens have been shed. Damage is expressed as small dimples in mature fruit that are sometimes surrounded by a halo (Appendix, Fig. A-22). The impact of this damage depends on the population density and market conditions. Thrips are also important as vectors of tomato spotted wilt virus (TSWV). The tobacco thrips (*F. fusca*, Fig. A-23) and western flower thrips (*F. occidentalis*, Fig. A-24) can both transmit TSWV, while western flower thrips and flower thrips (*F. tritici*) are most important as direct pests. Thrips and other pests with sucking mouthparts also contribute to gold fleck disorder.

Chemical control is required to prevent direct damage to fruit. Thrips can be sampled from flowers by placing a white index card under a cluster of flowers and tapping the cluster with a finger. An average of one thrips per flower has worked well as a threshold level. Thrips densities vary considerably among fields, but flower-infesting thrips are most abundant in June and July in the Carolinas and April and May in Georgia.

The potential for thrips transmission of TSWV to tomatoes (and other crops) varies among locations, and can even vary among adjacent fields. Both TSWV and thrips vectors overwinter in certain winter annual and perennial weeds, and the virus is transmitted to tomato crops when thrips disperse from these overwintering sites in the spring. Tomatoes planted later in the season in North Carolina are generally at a lower risk for infection. Important weed hosts of TSWV and thrips vectors include buttercup, chickweed, dandelion, henbit, plantain, and spiny sowthistle. The majority of TSWV infections are the result of primary spread (thrips transmitting the virus from surrounding weeds directly to tomatoes). Insecticidal control of thrips does not prevent virus infections in fields, but soil-applied systemic insecticides or an aggressive insecticide control program during the first 3 to 4 weeks after transplanting can reduce the incidence of infections. Reflective mulches also reduce TSWV spread to tomatoes. TSWV resistant varieties should be used in areas with a history of virus problems, changing the emphasis of thrips control from reducing virus transmission to reducing direct damage, which increases the tolerance for thrips. Tomato transplants should not be grown in the same greenhouse as any ornamental bedding plants.

Spider mites, *Tetranychus urticae, T. cinnabarinus*. Spider mites are a common problem for field-grown tomatoes, and the consistency and severity of infestations has increased in recent years. Twospotted spider mite (TSSM), *T. urticae*, is most common, but the carmine mite (*T. cinnabarinus*) can also reach damaging levels. Spider mites overwinter on weeds surrounding fields and certain winter crops, such as strawberries, and migrate to tomatoes when overwintering hosts die back or are destroyed in the spring. Mites indirectly damage tomatoes by feeding on foliage, reducing the rate of photosynthesis and thus reducing overall yields ((Appendix, Fig. A-25). Feeding on fruit also causes gold fleck disorder. Populations build to high densities under hot and dry conditions, and are also aggravated by certain pesticides applied for insect control, particularly pyrethroids and some neonicotinoids.

TSSM has developed resistance to numerous miticides, and use of resistance management strategies is critical to preserving the efficacy of those now effective. Fields should be sampled frequently to (1) detect infestations at a density when miticides work well and (2) avoid unnecessary applications. Mites can be sampled by observing 10 leaflets (terminal leaflet on a leaf from the upper third of the plant) from five locations per field. When mites reach an average of two mites per leaflet, a miticide should be applied. Infestations often progress from the edge of fields near weed hosts to the center, so sampling should be biased toward field borders. If more than one application of a miticide per season is needed in a tomato field (including adjacent fields of the same or different crops), use products with different modes of action. Regular use of low rates of horticultural oils (0.5 to 1 percent) can help suppress mite populations.

Whiteflies, *Trialeurodes vaporariorum, Bemisia argentifoli*. The greenhouse whitefly (*T. vaporariorum*) and silverleaf whitefly (*B. argentifolii*) are both important pests throughout the Southeast, particularly on greenhouse-grown tomatoes and fall-grown tomatoes in south Georgia. Damage results from adults and nymphs feeding on leaves, which can reduce the rate of photosynthesis and stunt growth ((Appendix, Fig. A-26). The most important damage from the greenhouse whitefly is sooty mold growth on whitefly honeydew, which accumulates on fruit and leaves. The silverleaf whitefly presents sooty mold problems and causes irregular ripening of fruit at even low population densities. Large whitefly populations are also a nuisance to workers. In more northern areas (North Carolina), field infestations of whiteflies often originate from transplants infested in greenhouses. Many serious viruses can be vectored by whiteflies and are a primary concern in Florida where the pest and viral diseases occur year-round. When managing whiteflies as vectors of viral disease, tolerances for whitefly populations are greatly lowered.

Once whiteflies become established on a crop, they can be very difficult to control. Preventive control can be achieved with soil-applied systemic insecticides at or shortly after planting. Make the initial application of foliar applied insecticides when populations are low.

Armyworms, *Spodoptera* spp. Armyworms are sporadic pests of tomatoes in northern areas of the Southeast (North and South Carolina); but when infestations occur, they can cause extensive damage and be difficult to control. Three species affect tomatoes, including the southern armyworm, *S. eridania*; yellowstriped armyworm, *S. ornithogalli*; and beet armyworm, *S. exigua* (Appendix, Fig. A-27). The beet armyworm is the most difficult to control because of its high reproductive capacity and resistance to many common insecticides. Larvae of all three species feed on foliage and fruit, but only the fruit feeding significantly damages the crop.

Controlling weeds in and adjacent to tomato fields can help minimize infestations, because weeds often serve as oviposition hosts for armyworms. But weed control alone will not eliminate the potential for infestations. Chemicals are usually necessary to control armyworm infestations. Many insecticides with excellent activity against armyworms have been registered on tomatoes in recent years; however, most of these products are more effective against small armyworm larvae than large larvae.

Aphids, *Macrosiphum euphoribae, Myzus persicae*. The potato aphid (*M. euphoribae,* Appendix, Fig. A-28) and green peach aphid (*M. persicae,* Fig. A-29) both infest tomatoes, although the potato aphid is more common. Winged aphids infest tomatoes from weed habitats. Although the aphids are usually kept at low densities by insecticides applied for other insects, in the absence of insecticides they are common pests. When aphid populations reach high densities, their feeding stunts leaves and increases plant susceptibility to early blight. Leaf stunting and blight reduce the leaf area, which can lower yields and cause more weather-related physiological fruit disorders (sunscald and weather check). Aphids also attract an array of generalist predators, some of which (leaf-footed bugs) may feed on and damage fruit.

Natural populations of generalist predators can sometimes control potato aphid infestations on tomatoes grown with minimal broad-spectrum insecticides. Common predators include lady beetles, syrphid flies, lacewing larvae, and predatory midges. Potato aphid infestations are often delayed and reduced when tomatoes are grown on black plastic. This practice alone, however, does not eliminate the need for supplemental control. In the absence of effective biological or cultural control, insecticides should be applied when a maximum of 50 percent of plants are infested with aphids. Sampling should consist of recording the presence or absence of aphids on an upper leaf on 10 consecutive plants in four or five locations in a field.

Flea beetles, *Epitrix cucumeris, Epitrix hirtipennis, Aystena blanda*. Flea beetles are a common but rarely injurious pest of tomatoes. Infestations are most common within 3 weeks after transplanting, when adult beetles feed on foliage, leaving small round holes in the leaves (Appendix, Fig. A-30). Larvae feed on the roots of plants, but cause no damage. A single application of insecticide when 50 percent of leaves show feeding damage effectively controls flea beetles.

Cutworms, *Agrotis ipsilon, Peridroma saucia*. The black cutworm (*Agrotis ipsilon*) and variegated cutworm (*Peridroma saucia*) both can cause damage in the larval stage when they sever newly set transplants. Variegated cutworms can also be a problem on larger plants when they feed on foliage and fruit. Cutworms overwinter as pupae in the soil and emerge in the early spring. Several generations are completed during the season, but early season populations are usually most damaging. Cutworms are frequently a problem on corn and small grains, and fields previously planted to these crops or left fallow are most susceptible to damage. Conservation-tillage systems also provide an excellent habitat for cutworm larvae. Larvae spend the daylight hours under debris on the soil or underground, but at night emerge to feed on plants, often chewing on the stem and cutting it off just above the ground.

Numerous insecticides can be applied to tomatoes to control cutworm infestations, and the decision to chemically control cutworms should be based on the presence of cut plants in the field. Foliar application late in the day may aid contact and control because the caterpillars are active at night. Pre-plant, soil-applied insecticide applications should be used only in those fields suspected of harboring overwintering populations.

Tomato pinworms, *Keiferia lycopersicella*. The tomato pinworm is a common pest in Florida, but it is a sporadic pest in many areas of the Southeast. Infestations are most common late in the season. The source of populations in more northern areas is likely infested transplants or infested greenhouses, as this pest cannot overwinter in nonprotected environments where hosts are destroyed by the cold. Moths deposit eggs on leaves, and the first two larval instars feed in leaves, creating blotched mines. As larvae age they bore into fruit, usually under the calyx. Infested fruit is not marketable.

Pheromone-mediated mating disruption is registered and useful where pinworms are a common pest, but it is not recommended in most areas because of the sporadic nature of the pest. Planting noninfested transplants will reduce pest potential. Chemicals are required to control pinworm infestations. This pest is very difficult to control once established.

Hornworms, *Manduca* spp., and cabbage loopers, *Trichoplusia ni*. The tobacco hornworm, *Manduca sexta* (Appendix, Fig. A-31), tomato hornworm, *M. quinquemaculata*, and the cabbage looper are minor pests of tomatoes. Larvae of all three insects feed on the foliage and, less frequently, on the fruit. Hornworm larvae can grow to almost 3 inches in length, and consequently they can cause extensive defoliation (Fig. A-32). These insects are rarely found in commercial tomatoes because insecticides applied for other insect pests control them. Larval parasites can provide effective control of these larvae. Hornworm larvae are often parasitized by *Cotesia congregatus*, while *Copidosoma truncatellum* is a common parasitic wasp of cabbage looper larvae.

Colorado potato beetles, *Leptinotarsa decemlineata*. This insect is a rare pest of tomatoes throughout most of the Southeast, but can be a problem in eastern North Carolina where populations infesting potato have developed resistance to insecticides (Appendix, Fig. A-33). Colorado potato beetles (CPB) overwinter as adults in weedy field borders. In the early spring they emerge and infest tomatoes, where they feed and lay eggs. Both adults and larvae feed extensively on foliage and can completely defoliate a plant within days.

CPB has a narrow host range, feeding only on solanaceous crops (tomato, potato, and eggplant) and weeds (such as nightshade and horsenettle). Hence, crop rotation between tomatoes and a nonsolanaceous crop is effective in avoiding infestations. Lady beetles are important predators of CPB eggs, but the level of control is usually not adequate for commercial production. The need for insecticide application should be determined by scouting fields for CPB, which infest fields from the border areas inward. Treatment thresholds are 15 adults or a combination of 20 larvae or adults per 10 plants. Spray insecticides after most eggs have hatched but before larvae become large. Because of insecticide-resistant populations in some areas of North Carolina, knowledge of the resistance status is important in choosing an insecticide.

Weeds

Weeds compete with tomatoes for water, light, and nutrients. They are capable of harboring insects and diseases, decreasing working and harvesting efficiency, and reducing yield and quality. In North Carolina, full-season competition of one to three Palmer amaranth plants per tomato hole reduced marketable yield and tomato number by 67 percent and 61 percent, respectively (Garvey 1999). Also, in North Carolina one to five eastern black nightshade plants per tomato hole reduced yield (Buckelew et al. 2006). Generally, weed competition reduces the number of tomatoes harvested in the premium grades. Research indicates that it is critical to implement weed control strategies 2 to 6 weeks after transplanting tomatoes.

Weed Management Programs

A weed management program should be developed for each field, as each field has different weed species, different fertility, different soils, different yield and quality potential, and other characteristics specific to it. The program should include scouting, chemical (herbicides), and nonchemical (hand removal) strategies.

Scouting Strategies

Scouting is an integral part of a weed management program. In fact, an effective scouting strategy followed by implementation of an effective control strategy will ensure success in managing weeds in each field. Scout for weeds at least one to two times per week, and the area scouted should represent each field.

Nonchemical Strategies

Nonchemical methods such as cultivation and hand removal are most effective when weeds are small, usually less than 3 inches tall. Cultivation and hand removal are options for tomatoes growing on bare ground. Frequent and shallow cultivations in bare ground systems are preferred to minimize damage to tomato roots. Although cultivation is not an option for tomatoes growing in a plasticulture production system, hand removal is possible and is effective for controlling weeds that are growing near the crop.

Chemical Strategies

Many herbicides registered for application in tomatoes provide excellent control of specific weeds (Tables 7 and 8). Use the lower rates recommended on sandy soils or on soils with low organic matter content. Higher rates are used only on clay soils or soils with high organic matter content. Always select an herbicide or herbicide combination based on the specific weeds present in each field. Not every herbicide controls every weed. Consult efficacy charts below and the Southeastern Vegetable Crop Handbook to determine which herbicides are best for controlling specific weeds, http://www.sripmc.org/docs/

Table 7. Efficacy chart for preemergence herbicides in tomatoes

Weed	Dual Magnum	Devrinol	Sencor	Treflan	Prowl H_2O
W. mustard/radish	N	N	E	P	P
Pigweed species	E	FG	E	E	G
Velvetleaf	N	N	E	P	N
C. lambs quarters	F	G	E	G	G
Eastern black nightshade	E	N	P	P	P
Hairy galinsoga	E	G	E	P	N
Morning glory (annual species)	NP	P	FG	P	P
Purslane (pink/common)	GE	G	E	FG	F
Yellow nutsedge	FG	N	NP	P	N
Annual grasses	E	E	NP	E	E

Key:
E = excellent control, 90% or better;
G = good control, 80 to 90%;
F = fair control, 50 to 80%;
P = poor control, 25 to 50%;
N = no control, less than 25%;
GE = good to excellent, 80 to 100%;
FG = fair to good, 50 to 90%;
NP = none to poor, 0 to 50%.

Table 8. Efficacy chart for postemergence herbicides in tomatoes

Weed	Matrix	Paraquat	Sencor	Sandea	Envoke
W. mustard /radish	E	F	PF	E	–
Pigweed species	G	E	E	E	GE
Velvetleaf	FG	E	E	E	–
C. lambs quarters	FG	G	E	PF	G
Eastern black nightshade	P	E	F	P	–
Hairy galinsoga	GE	E	E	E	–
Morning glory (annual species)	FG	GE	FG	FG	G
Jimsonweed	–	E	E	E	–
Yellow nutsedge	–	FG	NP	E	E
Annual grasses	FG	FG	NP	N	F

Key:
E = excellent control, 90% or better;
G = good control, 80 to 90%;
F = fair control, 50 to 80%;
P = poor control, 25 to 50%;
N = no control, less than 25%;
GE = good to excellent, 80 to 100%;
FG = fair to good, 50 to 90%;
NP = none to poor, 0 to 50%.
– = No data

SoutheasternVegetableGuide.pdf. Always read the label and follow all precautions and instructions before using any herbicide.

Plastic Mulches and Herbicides

In recent years, the use of plastic mulch in tomato production has become widespread. Several herbicides are registered for application in tomatoes produced in a plasticulture production system. Devrinol, Dual Magnum, Goal, and Sandea are registered for application to the pre-formed bed before laying the plastic mulch. Minimize soil disturbance after application of the herbicide to help weed control and decrease the possibility of crop injury. Goal (30 days) and Sandea (at least 7 days) have plant-back restrictions on their labels that require a waiting period between application and planting. There is no required waiting period for Dual Magnum and Devrinol.

Black plastic excludes light, which prevents some weeds from germinating and growing through the black plastic mulch. With the phase out of methyl bromide, interest in developing herbicides that can be applied to pre-formed beds before laying the black plastic mulch has increased.

To control weeds between rows of plastic mulch, apply only herbicides registered for use on tomatoes. Tomato roots quickly grow into the area between the rows, and using nonregistered herbicides may result in tomato injury or tomatoes having illegal herbicide residues.

According to a survey conducted by the Southern Weed Science Society in 2006, yellow and purple nutsedge are the most troublesome weeds in vegetable crops in the Southeast (Webster 2006). Nutsedge tubers can germinate and emerge through plastic mulch within days of coming into contact with the soil surface, often prior to transplanting tomato. With the phase-out of methyl bromide, nutsedge is likely to become a greater threat in plasticulture tomato production. However, there are several herbicide options to control yellow and purple nutsedge. Sandea is registered for preemergence and postemergence application in plasticulture tomatoes. A preemergence application suppresses only nutsedge; a postemergence application of Sandea provides greater control of nutsedge than a preemergence application. Envoke is also registered for nutsedge control in tomatoes. It can be applied postemergence—directed to tomatoes after transplanting or directed to row middles. Avoid contacting the tomato plant with the spray solution.

Caution: Some herbicides, if sprayed on the plastic, can leave a residue that may be washed into the crop hole after a rainfall or overhead irrigation event. The herbicide can concentrate in the hole and kill or seriously injure the tomato plants (Appendix, Fig. A-34 and A-35). If nonselective herbicides (glyphosate formulations, paraquat) are applied to emerged weeds growing near the plastic mulch prior to transplanting, the plastic should be washed with a sufficient amount of water before transplanting. Refer to herbicide labels for further instructions and precautions.

PHYSIOLOGICAL DISORDERS

Many fruit disorders cause serious losses in marketable yields of tomatoes in the Southeast. Some of the major disorders, their causes, and preventive measures are discussed in this section.

Blossom-end Rot

Blossom-end rot is characterized by a large, leathery brown or black spot on the bottom of the fruit and is due to insufficient calcium supply to the blossom end of the developing tomato fruit (Appendix, Fig. A-36). Lime is the primary source of calcium, and the soil should be limed to a pH of 6.8 in the mountains or 6.0 in the coastal plain. However, prevention of blossom-end rot is not simply a matter of adding calcium. Calcium moves to the developing fruit through the water taken up by the plant. Therefore, maintaining uniform soil moisture by irrigation and mulching tends to reduce this disorder. With extended periods of either extremely dry or wet soil conditions, blossom-end rot can develop regardless of the calcium content of the soil. The condition is worse when soil moisture fluctuates and after fruit are exposed to high temperatures (above 90°F). High concentrations of soluble salts, particularly from excessive nitrogen (and especially from ammonium nitrate) or potash, or excessive use of stable manure can contribute to blossom-end rot.

Puffiness

This problem is worse under conditions of high nitrogen and low light (short days or cloudy weather) and when the nitrogen-to-potassium ratio is unbalanced. It occurs more frequently after rainfall, particularly when accompanied by low temperatures. Conditions that interfere with pollination (low light, excessive nitrogen, temperatures below 58°F, or temperatures above 70°F at night and 95°F in the day) increase the risk of puffiness. Flora-Dade has good resistance to puffiness, and Mountain Pride is moderately resistant.

Catfacing

This problem is more serious with large-fruited varieties. It is more prevalent if the weather is cool or excessively hot or cloudy at the time of bloom. Some publications list "open locule" as a form of catfacing. Open locule occurs more frequently when boron is deficient.

Fruit Cracks

There are two distinct types of fruit cracking: radial and concentric. Radial cracking is the most common and results in the greatest fruit damage (Appendix, Fig. A-37). It occurs more often during rainy periods when the temperature is relatively high, especially when rains follow a long dry period. Radial cracking is more severe on ripening fruits, especially if they are exposed to the sun. Concentric cracks begin on green fruits that are fully exposed to sun. Maintaining a uniform water supply with irrigation, mulches, or both and maintaining good foliage cover will help reduce this problem. Mountain Pride and Piedmont have good resistance to cracking.

Gray Wall

Gray wall, also called blotchy ripening, is characterized by black to dark-brown tissue in the walls of the fruit, with the outer walls most frequently affected as seen when fruit are cut. In some years it causes significant economic loss because affected fruit do not ripen properly and are unmarketable. The conditions causing gray wall are poorly understood, although it is usually more severe when the nitrogen level is excessive, the soil is inadequately drained, the nitrogen-to-potassium ratio is not balanced, and the soil pH is low. A week or two of cloudy weather can also cause this disorder. Selecting well-drained soils and fertilizing according to soil test recommendations should reduce the problem. In some cases certain bacteria, fungi, and tobacco mosaic virus are thought to be involved in gray wall, but plants free of virus and those resistant to virus also develop this disorder. The variety Mountain Fresh is very susceptible to gray wall.

Blossom Drop

Flowers often drop off the tomato plant and do not set fruit. This problem can be caused by faulty nutrition, unfavorable weather, or damage from insects or diseases. Excessive nitrogen, insufficient phosphorus, insufficient light, and excess moisture are often the causes. Unfavorable weather, particularly extremes in temperatures when flower buds start to form (temperatures below 58°F, or above 95°F during the day, or above 70°F at night), results in weak blooms that often drop. Blossoms in the upper part of the plant will often drop because of the heavy load of developing fruit on earlier flowering clusters. To reduce blossom drop, maintain proper fertility based on a soil test, maintain uniform moisture in the field through irrigation and mulches, and control insects and diseases.

HARVESTING

Tomatoes are one of the leading produce items in the U.S. in terms of value and volume consumed. Preserving the quality of the fruit from vine to consumer is essential to successful marketing. Proper management and care in harvesting and handling fruit will help maximize pack-out and profits.

Tomatoes destined for fresh market are hand harvested, either with or without a harvesting aid. Machine harvesting is usually reserved for processing tomatoes. Harvesting is basically a material handling process. At the peak of the harvest season, the rate of production of marketable vine-ripened fruit may reach 100 to 150 field boxes (containing 30 to 35 pounds of fruit each) or 5 to 7 pallet bins per acre per day. The harvest of mature green fruit may yield as much as 25 pallet bins per acre. Enough containers should be available to take care of maximum harvest volume.

A considerable amount of labor is required to harvest tomatoes. The distance traveled through the field to harvest 1 acre of tomatoes is estimated to be more than 100 miles. Providing a cross break every 100 feet along the row for loading containers will reduce this figure considerably. This arrangement is particularly useful if a harvesting aid is used. The following guidelines can also significantly increase harvesting efficiency and reduce wasted effort:

- If field breaks are not used, limit the length of rows by running them parallel to the short side of the field. Rows should be no more than 150 feet long without a break.
- Blocks of 4 to 15 rows can be used, depending on the spraying and harvesting equipment used.

- Provide easy access and ample turn space at each end of the field.
- Use the largest feasible picking containers for your operation. Ideally, picking containers should be wide, shallow, and stackable to avoid excessive weight and bruising of tomatoes at the bottom of the container. For bulk handling, use short (18-inch) bins for vine-ripened tomatoes and standard (28-inch) bulk bins for mature green fruit. Bruised or damaged fruit will be culled during packing. To minimize fruit damage, make sure that picking buckets and bins are free of sand, stems are removed from all fruit at picking, and the fruit are handled gently during harvesting and when they are transferred into bins. Both picking buckets and bins should be washed daily.

Vine Ripe Production

Fruit to be harvested vine ripe should be picked at the "breaker stage" of maturity (Figure 7) and not before to ensure the best quality. A tomato at this stage is physiologically mature and will develop red color naturally. Fruits harvested at the breaker stage can be handled and shipped with less damage than those with more color and will bring a higher price. Harvest often and thoroughly to avoid having too many red fruit. Harvesting every other day may be desirable during the peak of the season. Remove all diseased, misshapen, and otherwise culled tomatoes from the vines as soon as they are discovered. Remove discarded tomatoes from the field to avoid the spread and buildup of diseases and insect pests.

Mature Green Production

Immature green tomatoes will ripen poorly and be of low quality. However, tomatoes harvested at the mature green stage will ripen into a product indiscernible from vine-ripened fruit. In the field, it is often difficult for inexperienced pickers to judge between immature and mature green tomatoes. A simple way to determine maturity is to slice the tomato with a sharp knife. If seeds are cut, the fruit is too immature for harvest and will not ripen properly.

Fruit picked green should be harvested as close to maturity as possible to maximize yield and quality. Harvesting immature fruit can reduce returns because yield will be lower, and smaller fruit generally brings lower prices. The first harvest should occur when about 10 percent of the fruit on first hands are at the breaker stage of maturity. All fruit on the first two fruit hands are generally removed at this harvest. At the second harvest, which normally takes place from 10 to 14 days after the first, mature fruit from the middle of the plant are removed. Maturity for the second harvest is based primarily on fruit size; only fruit that are 2 ½ inches or larger in diameter are removed. At the third harvest, 10 to 14 days after the second, fruit are removed from the upper portion of the plant. Vines and fruit should be completely dry when mature green fruit are harvested. Otherwise, fruit shoulders may develop sunken, blackened areas during ripening.

Field Supervision

The quality and market value of tomatoes depend on the timeliness of harvest and the level of care in handling. Postharvest quality control begins in the field. Clean hands and sanitary personal habits are required of workers at all times when handling produce items. Growers are legally required to provide sanitary facilities and instructions for all workers handling produce. Careful supervision and proper instruction of the harvesting crew are essential to the success of any hand-harvesting operation. Frequent checking of harvesting pails for trash and poor-quality tomatoes is a good idea. Packing house problems and buyer complaints often are the result of a harvesting crew that has been poorly instructed and supervised.

Remove tomatoes from the plants by gently twisting them without tearing or causing undue damage to the fruit or plants. Rough handling will result in both visible and latent damage. Fruit should never be packed tightly into harvesting containers or allowed to remain in the sun for extended periods.

Familiarize the harvesting crew with the maturity color chart and show examples of the various defects they may encounter. Since mature green fruit are often harvested "to size," depending on maturity conditions, the crew should be familiar with the acceptable size range.

Rules for Manual Harvesting

1. Keep your hands clean. Remember that you are handling a food product. The law requires you to wash your hands after each visit to the rest station.
2. Be thorough. Harvest *only* those fruit that are ready. Immature tomatoes should be left for the next harvest. Pick all suitable fruit on the plant before moving on to the next one.
3. Do not squeeze or bruise the tomatoes or allow your fingernails to penetrate the skin.
4. Overfilling your hands will cause you to drop the fruit, which damages it and lowers your picking efficiency.
5. Do not put trash or culled fruit into the picking container with good tomatoes.
6. Never drop or throw tomatoes into the picking container.
7. Slowly pour the tomatoes from the picking pail into the bins from the lowest possible height.

Harvesting Aids

For larger acreages, migrant or other hired labor hand picks the fruit. The picking buckets are emptied into bulk bins and hauled through the field on trucks. Making breaks in the field across the rows every 100 feet allows the pickers convenient access to the bulk bins. (The 100-foot row sections are also a convenience in keeping piecework records during pruning, stringing, and other operations.)

For small acreages, laborers may harvest on foot or by riding on a motorized harvesting aid that carries the pickers as well as field boxes of fruit through the field (Appendix, Fig. A-38). Some growers have modified self-propelled tobacco harvesters for harvesting tomatoes. Others have custom built harvesting equipment to suit their specific needs. Large, over-the-row, self-propelled sprayers that have been equipped with seats and box racks work well as dual-purpose machines for harvesting and spraying. With these machines, the grower can apply pesticides and harvest the fruit using the same machine without leaving out a row, as is necessary with a tractor-mounted machine.

Mechanical harvesting aids reduce the amount of labor for harvesting and make the work easier and more pleasant. Hand-operated carts or wheelbarrows are useful for carrying the tomatoes from the field, but motorized one-, two-, or three-row machines that transport the workers as well as the harvested tomatoes are more practical. Small self-propelled, high-clearance units that travel in the row middles are another option. These machines can also pull an over-the-row trailer on which additional workers and harvesting containers are carried. One or two pickers per row in the middle, harvesting rows both to the left and right, can be used, depending on the amount of fruit ready for harvest and the ground speed of the machine. A cover over the machine will protect the workers from the sun and from rain showers.

Cultural practices, accuracy and consistency of row spacing, uniformity of stake placement, and careful pruning and tying become more important when production and harvesting of tomatoes are mechanized. Very steep slopes are not compatible with mechanization, and site selection is thus more critical. Turn rows must be adequate, and row length should be compatible with the box-carrying capacity of the harvester.

CLEANING AND GRADING

Careful supervision of labor is one key to ensuring uniform cleaning, sizing, and packing of hand-harvested tomatoes. On most tomato grading lines, the fruit is dumped or floated out of bulk bins or hand field crates, which reduces bruising. Passing the fruit along a roller conveyer that slowly turns each tomato is the best way to inspect thoroughly

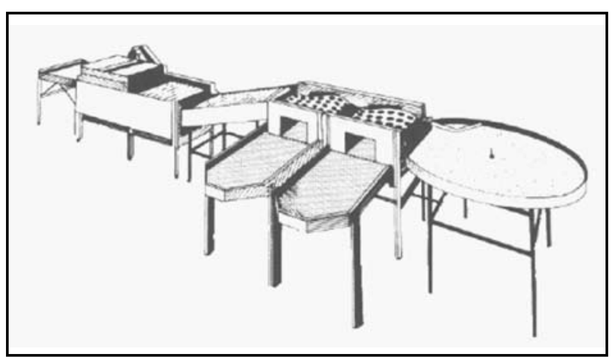

Figure 6. Typical tomato washing and sizing line.

Table 9. Size classification of tomatoes

Size designation	Diameter (inches)	
	Minimum*	Maximum**
Extra small	1-28/32	2-4/32
Small	2-4/32	2-9/32
Medium	2-9/32	2-17/32
Large	2-17/32	2-28/32
Extra large	2-28/32	3-15/32
Maximum large	3-15/32	---

* Will not pass through a round opening of the designated diameter when the tomato is placed with the greatest transverse diameter across the opening.

** Will pass through a round opening of the designated diameter at any position.

for defects. Tomatoes that are misshapen, damaged, decayed, or cracked should be discarded. Firm flesh, shiny skin, and uniform color indicate good quality.

Tomatoes should be washed sufficiently to remove dust and foreign material by spraying them with a small amount of chlorinated water as they move over a set of soft brush rolls. Often, so little water is required that most packers make no attempt to recycle the water. Not reusing the wash water eliminates the problems with trash and disease build-up that normally occurs with wash tanks. The small amount of retained water may be removed by sponge-rubber doughnut rolls alone or in combination with an air-blast drier.

The wash water should be several degrees warmer than the pulp temperature of the tomatoes to avoid drawing water and disease organisms in the fruit. The water should be chlorinated at the rate of 125 parts per million (1 quart of 6 percent chlorine bleach to 100 gallons of water). The chlorine level and pH of the wash water should be checked at least hourly during the day with test papers or a meter. (A neutral pH of 7.0 is desirable.) For more detailed information on chlorination and postharvest disease control, see this link: http://www.bae.ncsu.edu/bae/programs/extension/publicat/postharv/ag-414-6/index.html.

Tomatoes are subject to many postharvest diseases. Some of the more common are alternaria rot (*Alternaria alternata*), gray mold or botrytis (*Botrytis cinerea*), rhizopus rot (*Rhizopus stolonifer*), and sour rot (*Geotrichum candidum*). Although the skin of tomatoes offers some protection against infection, it is easily damaged by rough handling. Pathogens can enter tomatoes through a variety of openings. Wounds, such as punctures, cuts, abrasions, and cracks as well as stems and stem scars, provide potential points of entry. The entry of pathogens into a surface injury is nearly a certainty. Therefore, tomatoes with surface injury should be separated promptly from sound fruit and discarded before decay can spread.

Tomatoes are typically separated by size on one or more belts similar to the one shown in Figure 6. Size classifications are given in Table 9. A rotating bar sizer may be a suitable alternative for the small producer. It is important on such a line that the belt and roller speed and the drop height are minimized and that all impact surfaces are well padded. A layer of ⅜- to ½-inch closed-cell foam with a smooth, washable outer surface should be adequate. Open-cell foam or scraps of carpeting are better than nothing but are difficult to keep clean and generally do not provide proper protection. Lines should be inspected for sharp projections that might injure the fruit and should be kept free of dirt and trash. A daily cleaning with a strong chlorine solution (½ pint of 6 percent

Table 10. Color classification of tomatoes. Refer to Figure 7 to visualize these classifications.

The following terms may be used to describe the color of tomatoes as an indication of the stage of ripeness:

Green - The surface of the tomato is completely green. The shade of green may vary from light to dark.
Breakers - There is a definite break in the color from green to tannish yellow with pink or red skin covering not more than 10 percent of the surface.
Turning - More than 10 percent but not more than 30 percent of the surface, in the green aggregate, shows a definite change in color from green to tannish yellow, pink, red, or a combination of those colors.
Pink - More than 30 percent but not more than 60 percent of the surface, in the aggregate, shows pinkish red or red color.
Light red - More than 60 percent but not more than 90 percent, in the aggregate, shows pinkish red or red color.
Red - More than 90 percent of the surface, in the aggregate, shows red color. Source: *Standards for Grade of Fresh Tomatoes* (7 CFR 51). U.S. Department of Agriculture.

chlorine bleach per gallon of water) followed by a clean water rinse will help prevent the buildup of decay organisms on packing equipment.

For marketing purposes, tomatoes are segregated by grade, color, and variety. Color classifications are given in Table 10 and illustrated in Figure 7 (inside back cover). Size is not an indication of grade. Grades of field-grown tomatoes include U.S. No. 1, U.S. Combination (a mix of least 60 percent No. 1 with the remainder No. 2), U.S. No. 2, and U.S. No. 3. Greenhouse tomatoes are classed into U.S. No. 1 and U.S. No. 2 only. Many buyers will accept only tomatoes of U.S. No. 1 quality. Growers should check with buyers to determine their preference for grade, color, variety, and packaging.

POSTHARVEST STORAGE

Tomatoes are grown in commercial quantities both in greenhouses and in the field. Fresh market tomatoes are usually marketed by fruit type including full-size globe (red or yellow), plum (roma), and cherry. Consumers buy tomatoes primarily for their appearance but are attracted to repeat purchases by flavor and quality. Tomatoes are highly sensitive to mishandling and improper storage conditions. Because they can be injured by either low or high temperatures, proper postharvest handling and storage methods are essential for maintaining acceptable quality and promoting long shelf life. Tomatoes are very sensitive to chilling. Recommended storage temperatures differ with the maturity of the fruit. Precise temperature control is critical to maintaining acceptable quality.

Temperature and Humidity Management

Immediate and thorough postharvest cooling to remove excessive field heat aids greatly in maintaining quality and substantially lengthens shelf life. In addition, prompt and thorough cooling and washing can reduce the effects of dehydration and minimize decay. Postharvest cooling is essential for maintaining quality but will not improve a poor product.

Tomatoes destined for distant markets or tomatoes in the pink or light-red stage should be cooled immediately after harvest to avoid becoming overripe before reaching the consumer. Placing containers of warm tomatoes in a refrigerated space, known as room cooling, is recommended. To aid room cooling and prevent the buildup of heat from respiration, containers of tomatoes should be loosely stacked with space between them to allow for sufficient air circulation.

Table 11. Recommended storage temperatures and storage life for the different stages of tomato fruit maturity

Fruit maturity	Preferred cooling method	Optimum storage temperature	Storage life
Mature green	Room cooling	58 to 60°F	21 to 28 days
Pink		48 to 50°F	7 to 14 days
Red		NA	2 to 4 days

Optimum relative humidity: 85% to 95%.

Tomatoes are also sensitive to chill injury. The recommended storage temperature varies with the maturity of the fruit (Table 11). Proper temperature control is critical to quality and shelf life. 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* species); and internal browning of seeds.

Mature green tomatoes cannot be held at temperatures that delay ripening any appreciable time. When they are stored for several weeks at 55°F, they often develop decay and fail to ripen properly. The optimum temperature for ripening mature green tomatoes is from 65°F to 70°F. At temperatures above 80°F, mature green tomatoes will appear to ripen but may lack good texture and flavor. A temperature of 58°F to 60°F is best for slowing the ripening of mature green tomatoes and preventing existing decay.

Mature green tomatoes stored at temperatures below 50°F are susceptible to decay by *Alternaria* during subsequent ripening. Chill injury is cumulative and is a function of both temperature and exposure time. For example, comparable decay may be expected in mature green tomatoes held at 0°F for 6 days or 5°F for 9 days. Mature green tomatoes may also be exposed to nighttime temperatures below 50°F for a week or more.

Some studies indicate that storage of tomatoes in humidity above 90 percent can increase the incidence of decay.

Light red tomatoes can be stored for 2 weeks or longer at 50°F. Longer storage may result in reduced retail shelf life. Ripe tomatoes may be stored at lower temperatures than mature green tomatoes. Several days at 40°F may be acceptable, but longer storage at this temperature will result in loss of color, firmness, shelf life, and especially flavor. Under extreme circumstances, firm yet well-ripened tomatoes may be stored for as long as 3 weeks at 33°F to 35°F. Such tomatoes will have almost no shelf life and very poor flavor and color.

Pink to firm-red greenhouse grown tomatoes may be stored at temperatures of 50°F to 55°F. Less mature tomatoes should be ripened at 70°F before being stored at 50°F to 55°F.

Ethylene Treatment

Ethylene is a naturally occurring, odorless, tasteless gas produced by many types of produce, including tomatoes. Ethylene accelerates ripening in mature green tomatoes. In commercial practice, mature green tomatoes are exposed to supplemental ethylene treatment to hasten ripening and to ensure uniform ripening throughout a lot. Tomatoes may be exposed to an ethylene concentration of 100 to 150 ppm for 24 to 48 hours at a temperature of 70°F to 75°F and 90 percent relative humidity. Immature tomatoes may be ripened with the application of ethylene, but the resulting fruit will be of poor quality. Likewise, fruit beyond the breaker stage will not benefit from ethylene because the process has been initiated already by the tomato's own ethylene. There is some evidence, however, that additional ethylene may speed the ripening process.

Although there are many large, commercial tomato ripening facilities, small-scale growers and packers often find it convenient to build and operate small on-farm facilities. A tomato ripening room must be nearly airtight to prevent the escape of ethylene. Small ethylene gas generators may be purchased or rented for this purpose.

Tomatoes should not be mixed with other types of produce in storage and transit. The ethylene gas given off by many ripening fruits (such as apples, cantaloupes, and bananas) will hasten the ripening of tomatoes located nearby.

Table 12. Common tomato packaging

Vine-ripened	Mature green	Cherry
20-pound two-layer flat	25-pound loose carton	15-pound 12-pint flat
30-pound ½-bushel carton		
50- to 55-pound bushel basket		
10-pound carton		
25-pound carton (seldom used)		
25-pound loose carton		

Common storage of mature green tomatoes with ripe tomatoes should be avoided also for the same reason.

A mixture of 3 percent oxygen and 97 percent nitrogen will extend the life of mature green tomatoes up to 6 weeks at 55°F without noticeable decline in appearance and taste. Lower oxygen levels will produce an off-flavor.

PACKAGING

Tomatoes may be packed in a variety of containers (Table 12), depending on the intended market. Customarily, individual tomatoes packed in flats are positioned with the stem scar down.

MARKETING

Marketing tomatoes involves more than just selling. Marketing should be considered in every section of your business plan: planning, production, harvesting, packaging, transportation, distribution, warehousing, and pricing. To be successful, marketing must respond to consumer demands. There are several methods by which a grower can sell his or her product. The most common method is by wholesale distribution. An alternative to wholesale is the direct market method. Many growers will diversify their operations to include both sales methods.

Each marketing method has its own advantages and disadvantages in terms of price, profit margins, labor, packaging, and marketing strategy. Wholesale distributors deal with retail or food service buyers and brokers who purchase large quantities of tomatoes for a price based on local and national sales figures. Tomatoes that are shipped from the grower may travel to other parts of the country and therefore may require special packaging and harvesting. The primary labor considerations for this marketing method are harvesting and packing.

The primary objective of wholesale buyers is "to get the best product at the lowest possible cost." This is the number one rule in businesses around the country. There are certain criteria that cannot be overlooked such as USDA grades, safety inspections, country of origin labeling (COOL), and price look-up (PLU) codes. Growers must exemplify quality, consistency, safety, and knowledge of the market.

Quality cannot be undervalued when marketing product to customers. Most buyers are aware of the USDA standards and will regularly test tomatoes to ensure they meet those standards or other requirements. One bad shipment can destroy a relationship. Consequently, attention to detail is necessary for growers to maintain long-lasting business relationships.

In addition to quality, consistency is essential in building a lasting relationship with a buyer. Most businesses move at a fast pace and when a shipment is late, buyers are forced to locate other sources. Dependability is the key to successful marketing regardless of what product is sold.

Product safety is also crucial to your marketing strategy. Most buyers, particularly retail chains, will require $2 million of liability insurance before considering a potential source of tomatoes, especially since the recent disease outbreaks.

Most buyers require Good Agricultural Practice (GAP) certification, denoting that your farm is taking every step necessary to ensure a safe and reliable product. The wholesale market is keenly interested in GAP-certified suppliers who can consistently deliver a high-quality product at a competitive price. The necessity of intense management and quality control cannot be stressed enough.

When dealing with retail buyers, growers will need to label their products with two particular items in mind: PLU codes and COOL regulations. PLU codes are Price Look Up codes that identify a specific product. PLU codes have been used by supermarkets since 1990 to make check-out and inventory control easier, faster, and more accurate. PLU codes identify bulk produce such as tomatoes. They tell the cashier the price of the tomato and whether it is conventionally grown or organically grown, among other things.

Country of Origin Labeling regulations (COOL) specify that perishable agricultural commodities (specifically fresh and frozen fruits and vegetables) must be labeled to indicate their country of origin. The rule prescribes specific criteria that must be met to bear a "United States country of origin" declaration. A grower must provide enough information for an auditor to identify the county, state, and country where the product was grown. More information on COOL and its requirements can be found through the USDA Agricultural Marketing Service. For the grower to be considered as a potential supplier to wholesale buyers, he or she must meet all requirements for packaging, shipping, labeling and pricing.

Direct marketing usually consists of growers selling directly to the end consumer (the person that will consume the tomatoes at home or serve them in a restaurant). Demand for "locally grown" is strong in most areas, and direct marketing allows growers to take advantage of this demand. Special varieties such as heirloom tomatoes also provide an opportunity to reach local consumers through direct marketing.

The grower has different considerations for direct marketing in terms of labor, pricing, and packaging. The grower or the employee will usually sell tomatoes at a farmers market or roadside stand directly to the end consumer and will receive an at-market or better than market price. Therefore, the grower not only deals with a labor force for production but also for marketing at a location (a sales person). Merchandising the product so that it is attractive to customers will increase sales. Bulk displays of tomatoes are set up so consumers can pick through them and select individual tomatoes for purchase. Normally, a customer purchases only a few pounds at a single time.

Whether growers use a direct market or wholesale market method to distribute their product, they must be continuously aware of the tomato market in their localities, as well as throughout the country. Growers must keep abreast of any developments that have a direct or indirect impact on the industry. Knowledge of the competition should also help decide what markets and what areas of the country to target. To be successful, marketing must respond to consumer demands. It must be customer oriented.

The way to keep up with industry changes is through publications that are available free or at a low cost to producers. Attending relevant farm shows, Extension meetings, and association meetings (state and national) are also good ways to follow industry trends. By actively participating in local and national associations, growers will gain a better understanding of what is happening throughout the country.

COSTS AND RETURNS

Total production costs for an acre of staked tomatoes rank among the highest of any crop. Production costs vary among states because of differences in equipment, cultural practices, sources of funds, and grower experience. Although total cost figures are important to consider when borrowing, assessing risks, and estimating cash flow, you should strive for low production costs. Each production practice or equipment purchase should be evaluated in terms of its effect on revenues and costs per unit produced.

Total costs of producing any crop include both variable (operating) and fixed costs. Variable operating costs vary across the states and from one year to the next because of local material needs and costs. Major variable costs for producing staked tomatoes include plant costs, fertilizer, soil fumigation costs, interest on short-term loans, and labor costs. Fixed expenses include the annual ownership expenses (including interest on loans), investment purchases for machinery and equipment used to produce and harvest the tomato crop, and a prorated proportion of general farm equipment costs. For a typical grower, machinery and equipment includes cultivation equipment, tractor, transplanter, high-pressure sprayer, bulk field bins, and harvesting buckets. An increasing number of producers also irrigate; if so the annual ownership cost for irrigation equipment should be included in fixed cost estimates.

If family labor is used to harvest the crop, then approximately 360 hours per acre are needed. If you use family labor, recognize that your net return per acre includes a return for family labor. Under current tax regulations and in selected circumstances, a farmer who establishes an employer-employee relationship with his or her spouse and children can reduce a farm's federal and state income tax obligations as well as realize a reduction in Social Security (FICA) taxes by paying family an hourly wage for services rendered. Thus, for sole proprietorship and partnership farms, it pays to consider keeping hourly time records for each family member who helps produce and harvest the crop.

Yields generally range from 15 to 35 tons per acre. Approximately 150 hours of labor per acre are needed for soil preparation, transplanting, staking plants, managing workers and activities, and scouting the crop periodically. In addition to the fixed and variable production costs, postharvest handling and marketing costs will be incurred. These expenses include transportation and labor charges for hauling the crop from the field to a central shed area, labor costs for grading and packing the tomatoes, the cost of shipping containers, and marketing costs; these costs depend on volume and location.

The net return to land, management, and equity is the difference between gross revenue and total cost. Successful tomato production and marketing requires multiyear planning so that some of the money received during high-income seasons is available during years of below-normal income.

Successful tomato production and management are always challenging and, as for any agricultural commodity, difficult. However, tomato production remains an economically feasible and profitable enterprise for many growers in the southeastern U.S.

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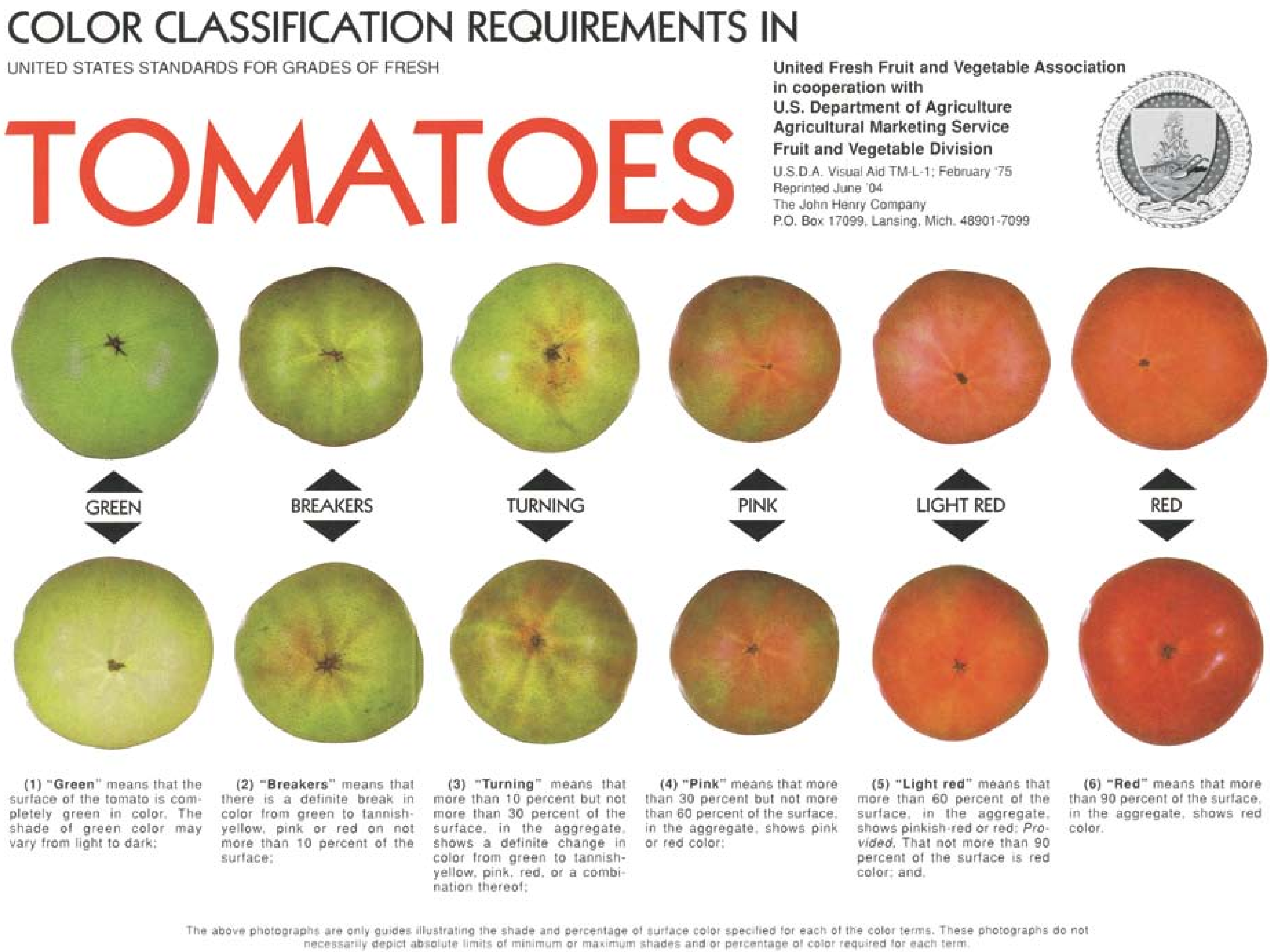

Figure 7. Tomato color chart showing the six official classifications: green; breaker; turning; pink; light red; red. (USDA©, Visual Aid TM-L-1)

This copy of USDA Visual Aid TM-L-1 illustrates the shade and percentage of surface color specified for each color term defined in the U.S. Standards for Grades of Fresh Tomatoes. Duplication of these illustrations may result in changes in color variations; therefore, these illustrations shall not be used as an official visual aid to determine color. To obtain an official visual aid TM-L-1, please contact the Fresh Products Branch at 1-800-560-7956.

Recommendations for the use of agricultural chemicals are included in this publication as a convenience to the reader. The use of brand names and any mention or listing of commercial products or services in this publication does not imply endorsement by North Carolina Cooperative Extension nor discrimination against similar products or services not mentioned. Individuals who use agricultural chemicals are responsible for ensuring that the intended use complies with current regulations and conforms to the product label. Be sure to obtain current information about usage regulations and examine a current product label before applying any chemical. For assistance, contact your county Cooperative Extension agent.

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