Greenhouse Tomato Handbook

Contents

MISSISSIPPI STATE UNIVERSITY EXTENSION SERVICE

Greenhouse Tomato Handbook

Greenhouse tomato production has attracted much attention in recent years, partly because of a new wave of interest in "alternative crops." The attraction is based on the perception that greenhouse tomatoes may be more profitable than the more conventional agronomic or horticultural crops. The popularity may also be due to misconceptions about how easily this crop can be grown.

While the value of greenhouse tomatoes is high on a per unit basis, the costs are also high. The following points are outlined to clear up misconceptions you might have. Keep these in mind before pursuing greenhouse tomatoes, either as a livelihood or as a crop for supplemental income:

• **Greenhouse tomatoes have unique cultural requirements, unlike crops such as soybeans and cotton, and not even similar to other field vegetable crops.** In fact, a grower of field tomatoes would have difficulty in growing greenhouse tomatoes without a significant amount of learning time. Greenhouse tomatoes should be thought of as altogether different from field-grown crops.

• **Because of specific production requirements, greenhouse tomatoes cannot be termed an "easy" crop to grow.** They are one of the more difficult horticultural crops to produce with many procedures that must be followed to insure a healthy, productive crop.

• **The time necessary to grow greenhouse tomatoes is much greater on a per unit basis than any field vegetable crop.** The many weekly cultural practices (pruning, wrapping, pollinating, spraying, etc.) add up to a significant amount of time. The estimated average labor requirement per greenhouse (or bay) is 20 person-hours per week (for an average 24- by 96-foot greenhouse). As a grower gains experience, this time requirement can be reduced. This figure estimates the amount of time per week averaged over the entire crop. More time is needed during transplanting and harvest, and less time is needed while the plants are growing from transplant to the time of first harvest. Adequate labor provisions should be made before help is actually required.

• **Greenhouse tomatoes need regular attention.** Unlike many field crops that can be planted, sprayed on a fixed schedule, and then harvested after so many days have elapsed, tomatoes must be examined daily. Because the growth system is complex, many things can go wrong. Raising a greenhouse tomato crop may be more similar to maintaining a herd of dairy cows than to growing a field crop of vegetables.

• **The greenhouse environment is not a sterile one.** There is a common misconception that crops grown in greenhouses do not have insects and diseases. Just the opposite is true. While a greenhouse environment is excellent for growing tomatoes (and other vegetables), it is even better for propagating insect pests and disease organisms. Due to the higher temperature, higher relative humidity, and lush, green foliage, insects and diseases are constant threats once introduced into a greenhouse. Therefore, weekly sprays with both insecticides and fungicides are standard practice.

These comments are not meant to discourage prospective growers. If you are preparing to invest time and money into growing greenhouse tomatoes, however, you should be fully aware of the pitfalls as well as the benefits before proceeding any further. If you are willing to spend the necessary time to learn how to grow this crop, you can be successful if you follow the basic guidelines in this and other publications.

Plan for Success

The best way to learn is not by your own mistakes, but by other people's mistakes. Visit as many other greenhouse tomato growers as possible and ask questions. Most growers are happy to share information.

• **Collect as much information as you can and read it.** If you don't know where to start, call your county agent or Extension specialist and request a packet of material on greenhouse tomato production.

• **Sell your tomatoes before you plant them.** Line up buyers ahead of time to be sure you have a market for your product.

• **Buy a pH meter and an electroconductivity (EC) meter.** These are relatively inexpensive instruments that will help you make sure that you are putting on the appropriate level of nutrient solution. Check the pH and EC of every tank you mix to avoid mistakes.

• Pollinate every other day with an electric buzzer pollinator or another method.

• Be sure your plants have plenty of water. Any time your plants wilt, they are not growing, and blossoms may drop; increase the water level as needed.

• Water enough so that there is always some drainage from the bags. This ensures that fertilizer salts will not accumulate in your growing medium.

• Don't let diseases or insects (especially whitefly) get out of control. Start weekly sprays or biological controls as soon as your plants are in the greenhouse. Increase the frequency of sprays if a problem arises.

• Keep good records. Record the date and chemical pesticide used each time, the fertilizer ppm (concentration) used and the date it is increased, the amount of water you are feeding per day, and any time you make a change in your cultural program.

• If a problem comes up, get help quickly. Call your county agent or Extension specialist for assistance.

Plant Population

When growing greenhouse tomatoes, it is important to use the proper planting density. Greenhouse tomatoes need at least four square feet per plant or 10,000 plants per acre. In fact, recent research at the Truck Crops Branch Experiment Station shows that using a planting density of 5 sq. ft/plant produced the same per unit area, while reducing the plant population. To determine how many plants can be grown in your greenhouse, multiply the length by the width and then divide by four or five. For a 24- by 96-foot greenhouse, about 460 to 576 plants can be grown; for a 30- by 96-foot greenhouse, 576 to 720 plants will fit, depending on planting density. **Note:** If you will use some of the floor space for other purposes (for example, storage, packing, grading), subtract this area from the total before dividing by four or five.

Using a higher planting density will cause the yield per plant to decrease, while the yield per greenhouse will stay about the same. This is due primarily to plants shading each other. The costs and the amount of labor required, however, increase with more plants. Also, crowding plants tends to promote disease development, since foliage does not dry as readily, and sprays cannot easily penetrate the thick foliage.

Arrange plants in double rows, about 4 feet apart on center. Within a row, plants will average 14 to 16 inches between stems.

Varieties

The first step in raising any crop is to choose the best variety. Growing a variety that is not the best choice, or using seed that are not of the best quality, reduces your potential for success at the outset. It is smart to start off with the greatest potential rather than limiting yourself by using inferior seed, even if it saves a few dollars.

Hybrid tomato seed is expensive. It now costs 10 to 30 cents per seed, depending on the variety and quantity that you buy. This cost reflects the laborious process of hand pollination required to produce the hybrid seed. Although this seems rather expensive, it is still one of the lowest costs of production. After the heating, labor, and fertilizer costs are incurred, the extra expense of using the finest seed is relatively small.

There are thousands of tomato varieties available on the market, but only a few are acceptable for greenhouse production. If you plan to grow tomatoes in a greenhouse, you need to use a greenhouse variety. These are almost exclusively Dutch hybrid indeterminate varieties, bred in Holland specifically for greenhouse production. Field varieties are typically adapted to higher light and lower humidity conditions and probably would not yield well in the greenhouse. A glass or plastic greenhouse has about 20 percent less light than outdoors, and many field types do not tolerate this reduction.

There are many companies in Holland and other European countries that deal in greenhouse varieties; however, only a few have distributors in the United States. You can buy seed from a greenhouse supply catalog, or directly from the seed companies, which are shown in the list of suppliers at the end of this publication.

Base variety selection on these criteria:
- size of fruit desired
- disease resistance
- lack of physiological problems, i.e., cracking, catfacing, blossom-end rot
- yield uniformity of fruit size
- market demand

In Mississippi, as in most of the United States, the market preference is for a red tomato. In Ohio and southern Canada (Leamington, Ontario), the preference is for pink tomatoes. The only physical difference is in the skin color. There are no flavor or biochemical differences.

The varieties most worth considering at the time of this printing are *Trust, Match, Switch,* and *Blitz.*

Tropic cannot be recommended to commercial growers because of its lack of size uniformity, intolerance to high nitrogen fertilizer, and lack of resistance to Tobacco Mosaic Virus (TMV) and other diseases; however, *Tropic* is fine for a hobby greenhouse.

Jumbo may be the largest fruited variety available, but it lacks resistance to TMV and most other diseases, is not tolerant to higher levels of nitrogen fertilizer, and is not as uniform in size as some of the other varieties.

Serious growers should not use outdoor varieties such as *Celebrity, Better Boy, Travellers*, etc., in the greenhouse, although these are fine for the garden.

You can buy seed by the piece with lower costs per unit for larger quantities and higher costs for smaller quantities. Tomato seeds are very small; one-fifth of an ounce contains about 1,200 seeds. If you have a two-bay greenhouse (4,500 square feet) with about 550 plants per bay, this is enough seed. Always plant a few extra seeds (10 - 20 percent) since germination will not be 100 percent. This also gives you the opportunity to discard any seedlings that do not meet your high quality standards. Store extra seed in unopened containers or in zip-locked bags in the freezer.

Table 1. Varieties of greenhouse tomatoes and their characteristics

Variety	Source*	Fruit size (ounces)**	Greenback***	Disease resistance****
Caruso	DR	6-8	SG	TMV,C5,V,F2
Laura	DR	6-8	SG	TMV,C2,V,F2
Capello	DR	6-8	NG	TMV,C5,V,F2,Wi
Perfecto	DR	5-7	NG	TMV,C5,F2,Wi
Trust	DR	6-8	NG	TMV,C5,V,F2,FR
Match	DR	7-9	NG	TMV,C5,V,F2,FR
Switch	DR	7-9	NG	TMV,C5,V,F2,FR
Blitz	DR	7-9	NG	TMV,C5,V,F2,FR
Baronie	RZ	7-9	NG	TMV,C5,V,F2,FR,Wi
Mariachi (74-56RZ)	RZ	8-9	NG	TMV,C5,V,F2,FR,Wi
Mississippi	RZ	6-8	NG	TMV,C5,V,F2,FR,Wi
Zoltano	RZ	6-7	NG	TMV,C5,V,F2,FR,Wi
Electra	HZ	7-8	G	TMV,V,F2
Gabriela	HZ	5-7	G	TMV,V,F2,N
Dombito	B	6-8	G	TMV,C2,F2
Dombello	B	7-9	G	TMV,C5,V,F2,N,Wi
Jumbo	B	7-10	G	C2,V,F2
Belmondo	B	6-8	NG	TMV,C5,V,F2
Medallion	B	7-9	NG	TMV,C2,V,F2,FR
Tropic		5-11	SG	tmv,V,F1,ASC
Vendor	S	6-8	NG	tmv,C2,F1
Vendor VFT	S	6-8	NG	TMV,V,F2

* DR = De Ruiter; B = Seminis (Bruinsma/Asgrow); S = Stokes; RZ = Rijk Zwaan; HZ = Hazera.

** Actual fruit size is variable, depending on pollination, cultural practices, and environmental conditions.

*** G = greenback; SG = semigreenback; NG = non-greenback type.

**** TMV = resistant to Tobacco Mosaic Virus (TMV); tmv = tolerant to TMV; C2 = Cladosporium races A and B; C5 = Cladosporium races A, B, C, D, and E; V = Verticillium Wilt; F1 = tolerance to Fusarium Wilt race 1; F2 = Fusarium Wilt races 1 and 2; Wi = tolerance to Silvering; N = most Nematodes; ASC = resistant to Alternaria Stem Canker; FR = resistant to Fusarium Crown and Root Rot.

Table 1 lists some of the common greenhouse tomato varieties and some of their characteristics. Note that only some of the varieties have resistance to Fusarium Crown and Root Rot (FR). This disease has been in Mississippi greenhouses since 1990. The variety Trend is not recommended for Mississippi greenhouses.

Growing in Aggregate Media

Many types of growing systems for greenhouse tomatoes are available. These systems include NFT (nutrient film technique), PVC pipes, sand, ground culture (in the soil), troughs, rock wool slabs, and various types of aggregate media. This latter group includes peat moss and peat-lite mixes, perlite, rock wool aggregate, glass wool, pine bark, and many others. Most of the multi-acre greenhouse ranges in the U.S. use rock wool. This inert, highly porous material is made by melting volcanic rock, limestone, and coke at 292°F and spinning it into fibers. In Mississippi, pine bark is the leading growing medium due to its suitable properties, availability, and low cost.

For growers using pine bark, it is recommended that the bark be composted fines. Fines are particles less than 3/8 of an inch in diameter. Initial composting is necessary so the bark does not damage roots of tomato transplants from high temperature, and so that there is no nitrogen depletion caused by the decomposition process. If you cannot determine the age of bark, purchase the bark at least 3 months before it is to be used; this allows time for composting at your site.

The recommended volume of aggregate medium is 1/2 cubic foot per plant. With pine bark, this is easily achieved by using 2 cubic-foot bags and transplanting three or four plants per bag. You can buy these pine-bark filled, perforated, polyethylene bags from Mississippi suppliers (see list at end of this publication). Alternatively, two plants can be grown in a 7 1/2-gallon bag or bucket, or you can grow one plant in a 3- or 4-gallon container (1 cubic foot equals 7 1/2 gallons).

Planting Schedule

There are two principal cropping systems for growing greenhouse tomatoes: two crops per year and one crop per year. With the one-crop system, set plants in mid-September or later and grow until mid- to late June. For Mississippi, the two-crop system, with a spring crop and a fall crop, is preferred. This is because plants held over the winter are more likely to be infected with diseases such as *Botrytis* (gray mold) and *Cladosporium* (leaf mold) that thrive in damp greenhouse conditions during December, January, and February. Plants that have been growing for several months have dense growth by winter, reducing airflow and aggravating humidity problems. These conditions are favorable to disease development. Also, plants that have been growing since September do not have the same vigor as young plants transplanted in January.

Alternatively, one, shorter crop can be grown just in the spring, or through the late winter and spring. Marketing conditions should determine the cropping season.

July and August are too hot to have producing tomato plants in greenhouses in the Midsouth. Summer fruits are plagued with splitting, cracking, blotchy ripening, and generally poor quality and yield. In addition, the market price is down because field tomatoes are available.

For the two-crop system, seed the fall crop after the middle of July in trays, with one seed per cell. If you plant earlier, young plants will be subject to high summer temperatures and will be off to a poor start. Allow plants to grow for 4 $^{1}/_{2}$ to 5 weeks. Transplant during mid-August into bags, buckets, or rock wool. The first harvest will be late October or early November.

Seed the spring crop in late November, transplanting this crop soon after the first of January, when transplants are about 6 weeks old. This means you will have young seedlings at the same time you have mature plants. It is preferable to have a separate propagation house for new seedlings. If seedlings are grown in the same greenhouse with mature plants, it is likely that insects (whiteflies, leafminers, etc.) and diseases will contaminate the new crop. The first harvest should occur in March. The spring crop can be grown until late June, or until the temperature becomes too extreme for quality production (see section on *Greenhouse Cooling*).

Top the plants 6 weeks before the intended termination date. Termination should be close to the end of December for a fall crop and mid- to late June for a spring crop. When topping, remove the tops of plants from marble-sized fruit and higher. Such small fruit will not have time to mature before termination of the crop. Leave one or two leaves above the highest cluster of fruit that remains. This helps shade the fruit and prevents sun scald.

Pruning and Training

For best production, prune tomato plants to a single stem by removing all lateral shoots, commonly referred to as "suckers." One sucker will form at the point where each leaf originates from the main stem, just above the leaf petiole (stem). Allowing all suckers to grow and bear fruit would increase the total number of fruit, but they would be small and of poor quality. It is better to have one main stem that bears fruit, as this will produce larger, more uniform, and higher quality fruit.

Removing suckers once per week will keep them under control. It is advisable to leave one or two of the smallest suckers at the top of the plant. Then, if the plant becomes damaged and the terminal breaks off, one of these suckers can be allowed to grow and become the new terminal. Generally, remove any sucker longer than one inch.

Rig a support system of wires above the crop. Use 9-gauge or 3/32-inch galvanized wire or stronger (a 100-pound box contains about 1,700 linear feet). These wires should run parallel to the direction of the rows and 7 feet off the ground. Cut strings 14 feet long, so there is enough slack to allow the plant to be leaned and dropped when it reaches the height of the wire. Tie one string loosely (not a slipknot) or clip it to the bottom of each plant, throw it over the wire, and then tie it to the wire with a slip knot. Plastic clips are commercially available (see Appendix 1 for list of suppliers). **Note:** Be certain the greenhouse frame can support the weight of fruit-laden plants, or that a sturdy frame is constructed at the ends of rows to support the wires. Plan on the wire bearing a load of 15 pounds per linear foot, or 3 tons for 600 plants.

When the plant reaches the wire height, it should be leaned and dropped. Hold the string securely with your left hand just above the plant; loosen the knot with your right hand. Simultaneously let the plant down about 2 feet below the wire and slide the string to the right. The plant must be leaned over while it is dropped; otherwise the stem will probably break. Always lean in the same direction. Do not lean some to the right and some to left or they will shade each other. Lower all plants to the same height so they don't shade each other. Repeat this operation each time plants grow higher than the wire. This is another reason the two-crop-per-year system is preferable–there is less labor needed for leaning and dropping the plants.

As you prune the plant to one main stem, wrap it around the support string. You can prune and wrap in one operation, doing both to a plant before moving on to the next plant. Always wrap in the same direction—if you start

Pollination is best accomplished with an electric pollinator.

A simple slipknot is used to tie string to the plant support wire.

clockwise, continue clockwise; otherwise, when the plant gets heavy with fruit, it may slip down the string and break. Some growers prefer to use plastic clips to secure the plant to the string, either in combination with wrapping or to replace wrapping.

Cluster pruning will also improve size and uniformity. This involves removing small fruit from some clusters, leaving three, four, or five of the best ones. Remove misshaped or deformed fruit first. Otherwise, remove the smallest fruit, which is usually the last one formed on each cluster.

Pollination

Pollination of the female flower part must occur before fruit will set. Any activity or inactivity that prevents thorough pollination reduces the number of fruit set per plant. Several problems can result from poor pollination: off-shaped fruit if seeds do not develop uniformly throughout the fruit, smaller fruit, and fruit that are rough (ridged) along the tops. Pollination can be prevented by various stresses such as cold or hot temperatures, drought, high humidity, nutrient deficiencies, nutrient toxicities, etc., as well as lack of pollen transfer.

Tomato flowers have both male and female parts within every flower. Botanically, these are termed “perfect” flowers. Field tomatoes are pollinated primarily by wind rather than by bees, which pollinate many other types of vegetables. Most of a flower’s pollen fertilizes the ovary within the same flower, although some of the pollen reaches surrounding flowers. Wind shakes the flower so that pollen leaves the anther and travels to the stigma. In the greenhouse, wind is not strong enough to shake the flowers sufficiently to transfer the pollen. Even though the greenhouse is ventilated with fans, on cooler days when the fans are not operating, the air is relatively motionless.

The optimum temperature for pollination is within the range 70 to 82 °F. Optimum relative humidity is 70 percent. Above 80 percent relative humidity, pollen grains stick together and are not dispersed well. With relative humidity less than 60 percent for extended periods, the stigma may dry out so that pollen grains will not stick to it. With ideal conditions, fertilization occurs 48 hours after pollination. Serious greenhouse tomato growers should use an electric pollinator to ensure good fruit set. (What is a “serious” grower? — one who grows tomatoes for a profit.)

In a hobby greenhouse, the expense of a pollinator is probably not necessary. You can purchase an electric polli-

Touch the pollinator wand to the upper side of each pedicel (flower stem). Do not touch individual flowers.

nator from most greenhouse supply distributors. These can be powered with a disposable alkaline battery or with a rechargeable 6-volt battery. Purchasing a rechargeable battery with a charger may be less expensive than continually buying alkaline batteries. Also, you should never be without power. The rechargeable battery can be plugged in after use to be sure it is ready for the next pollination. How much time does it take to pollinate? Vibrate each cluster (not each blossom) for about half a second. Touch the wand to the top side of the pedicel (flower stem). Do not touch individual blossoms, as this will damage them, causing damaged fruit. One acre (10,000 plants) is estimated to take 5 to 6 hours to pollinate. For a 24- by 96-foot greenhouse, this would be about 20 minutes. New growers may take an hour or more until they gain experience.

If you have 10,000 square feet or more under one roof, seriously consider using bumblebees for pollination. Purchase your bumblebee hives from commercial suppliers (see list at end of this publication). Use an electric pollinator if you have one or two gutter-connected bays, or more bays that are not under one roof. For ranges between 5,000 and 10,000 square feet under one roof, you need to compare the cost of the bee hives to the cost of labor to achieve pollination. Generally, a hive will last for about 8 weeks before you need to replace it with a new hive. It is a good idea to allow for some overlapped time between the old and new hives. **Note**: Even if bumble-bees are used, an electric pollinator will still be needed to pollinate the first few flowers that open. Hives should be introduced when 50 percent of plants have open blooms.

Questions About Pollination

How often should I pollinate?

Pollinate every other day or three times per week. Pollinating less often is taking a chance on reducing fruit set; but more often is very likely a waste of time.

Does the time of day matter?

Yes. The best time for pollinating is when the relative humidity is between 60 and 70 percent. If you live in an area with high humidity, find when the relative humidity is at its daily low point. If the amount of moisture in the air stays constant, the relative humidity decreases as the temperature increases because warm air can hold more moisture than cool air. The warmest time of day is usually mid-day. This is why the best time (in humid areas) to pollinate is generally between 11 a.m. and 2 p.m.

How do I know if pollination is actually taking place?

You can see it happen. If the air is relatively dry and the light is good, you can see a small cloud of yellow powder around the flower when the cluster is vibrated. These are the pollen grains. This is your insurance that conditions are excellent for pollination.

How does cloudy weather affect pollination?

In cloudy weather, the relative humidity is high. In such conditions, pollination is not as effective because pollen tends to stick together in clumps rather than dispersing as individual grains. It is important to stay with the schedule of every other day because if the cloudy days turn into a cloudy week without pollinating, fruit set and quality will certainly be decreased.

What if it is cloudy for a long period of time?

As mentioned, pollination in very wet conditions is not as effective as in dry weather. One technique you can try is to dry the air before pollinating. Turn on the heating system for 30 to 60 minutes before pollinating. Ventilate to maintain the temperature requirements. This will dry the flowers and the air, improving pollen transfer.

Is the expense of an electric pollinator really necessary?

If you want to get maximum yield, the answer is certainly "yes." If you would be happy with a lower yield, then it is not so important. In an experiment at the University of Southwestern Louisiana Center for Greenhouse Research, pollinating with an electric air blower resulted in a 7 percent decrease in yield, while not pollinating resulted in a 21 percent decrease in yield, compared to using an electric pollinator. You can purchase a pollinator from most greenhouse suppliers.

Temperature

A day temperature of 70 to 82 °F is optimum, while night temperature of 62 to 64 °F is optimum for greenhouse tomatoes. During cloudy weather, a temperature closer to the lower end of these ranges is preferred, while in sunny weather, temperatures closer to the higher end are better. Below 60 °F, nutrient deficiencies may occur because plants cannot absorb some elements at cool temperatures. The first sign of cool temperature stress is purpling of the leaves, indicating lack of phosphorus uptake (even though there may be adequate phosphorus in the nutrient solution). One or two nights of 56 or 58 °F temperature can cause a considerable number of rough fruit several weeks later when fruit exposed to the cold temperature reach full size. **You should maintain a minimum temperature of 64 °F.** Ideally, the thermostat should be located at blossom height rather than above the tops of plants.

Avoid temperatures over 90 °F if at all possible. At 86 °F, lycopene (the pigment that makes tomatoes red) no longer develops. See the section *Greenhouse Cooling* for help in managing high temperatures.

Locate thermostats near the center of the greenhouse for good temperature control. Also, enclose the thermostat in an aspirated box, or shade it so that it indicates the air temperature correctly. If the sun is allowed to shine directly on the thermostat, it will read a higher temperature than the air surrounding it.

Relative Humidity

The optimum relative humidity for greenhouse tomatoes is 60-70 percent. This is very difficult to obtain in Mississippi greenhouses and is given for your information only.

Locating thermostats in a box will avoid direct sun on them. An aspirated box is best.

Greenhouse Cooling

Greenhouse tomato growers in Mississippi have to deal with high temperatures. When greenhouse temperatures go into the high nineties or even higher, poor-quality fruit, especially fruit splitting, is the usual result. The splitting in the skin is caused by the surface of the fruit reaching a higher temperature than the layer just beneath the surface. This causes a rupturing between adjacent cells, showing up as a split or burst skin. The mechanism is similar to that of the bimetallic coil in a thermostat, except that the thermostat coil can tighten or loosen as the temperature changes, while the tomato skin cannot; therefore, the skin tears.

When the sun shines through the plastic greenhouse covering onto the plants, it is common for leaf temperature to be 30 degrees higher than the air temperature in the greenhouse. As leaf temperature increases, leaves lose more water to the atmosphere and make up for this loss by taking up more water through the roots. This is how the plants keep from overheating. As long as there is ample water surrounding the roots, this system works fine, up to a point. If there is ever a water shortage, plants wilt at the tops, reducing the water loss. If the water loss is very severe, plants wilt completely from top to bottom. Plants revive from a mild wilt condition when water becomes available or the stress situation is removed (as it is at night). But, if plants reach the "permanent wilting point," tissue is permanently damaged and they will not recover, even with plenty of water.

Also, if the temperature climbs into the upper nineties, plants may not be able to retrieve enough water through their roots to make up for the rapid loss from their leaves, even if there is plenty available in the growing medium. At this point, leaves become burned or scorched. They look as if they have been touched with the flame of a propane torch. Remember —so long as the sun shines, the leaf temperature is considerably higher than the air temperature.

There are several ways to lower the air and plant temperature in the greenhouse. None are 100 percent successful by themselves in this climate because of the extreme heat in Mississippi. However, any one of these methods will lower the temperature to some extent.

All of the following methods are used as additional cooling after exhaust fans have already been installed:

• **Evaporative cooling** is probably the best way to reduce greenhouse temperature. The principle is simple. As the exhaust fans blow air out of one end of the greenhouse, they draw in moist air from the other end. As the moist air moves through the greenhouse, some of the water vaporizes, absorbing heat in the process. Moisture is supplied at the end opposite the fans with a system that drips water through an absorbent material such as cellulose or a synthetic fiber (commonly called "cool pads" or "wet pads"). All incoming air passes through this wet fiber. Any water that drips through the fiber is collected in a gutter at the bottom, and drains into a small holding tank. Water is recirculated from the holding tank back to the top of the cool pads. There needs to be a provision for replacing water that is absorbed by the air passing through the cool pads. This is usually done with a "toilet tank-type" float valve controller.

Evaporative cooling is more effective when the air outside the greenhouse has a low relative humidity. As the relative humidity of the outside air increases, this technique becomes less effective. But so long as the relative humidity is less than 100 percent, this method will have some cooling effect on the air.

• **A shade cloth** can be used over the top of the greenhouse (outside) or suspended inside the greenhouse above the crop. The most common materials are polypropylene, polyethylene, polyester, and saran, although cheesecloth and tobacco netting can also be used.

If used internally, the cloth can be suspended on wires or some other type of framework. The advantage of an internal shade curtain is that it can be pulled back on cloudy days and spread out on sunny days as needed, either manually or with small motors. The internal curtain usually has a reflective silver upper surface, with the lower surface dark or white. Do not use a curtain that is black on top because it will accumulate heat.

The disadvantage of using an internal shade cloth is that light is converted to heat inside the greenhouse; although plants receive less light, they don't get the same reduction in heat. If the shade cloth is used outside the greenhouse, sunlight is converted to heat before entering the greenhouse.

Shade cloths must be custom ordered to fit a greenhouse. Provide the supplier with the greenhouse dimensions so the company can sew together pieces to fit the structure. Grommets are sewn into the edges to provide a secure way of fastening the material down.

Shade cloth is available in a number of different "percent shade" formulations. The appropriate amount depends on the season it is applied and how many cloudy days are expected during the time period it is on. It is not convenient to remove the external shade cloth on cloudy days. For tomatoes, 50 percent shade during May and June for the spring crop, and August and September for the fall crop, is recommended in Mississippi.

Be aware that the percent shade is not the same as the percent reduction in temperature. Research by Dr. Dan Willets at North Carolina State University shows that polypropylene shade cloth labelled at less than 30 percent shade did not decrease greenhouse temperatures at all. With higher percent shade ratings, the decrease in heat gain was about half of the shade rating. The covers were also more effective on windy days because heat was dispersed more efficiently from the cover outside the house.

Shade cloth costs 10 to 20 cents per square foot, with additional charges for grommets, sewing panels together, sewing reinforcement tape to edges, etc. For a standard-sized, free-standing greenhouse (24 by 96 feet), this may amount to $300 to $400.

• **Shade compounds** have the same effect as shade cloths except they come in liquid form and are usually sprayed onto the outside surface of the greenhouse after being diluted with water. They can also be brushed or rolled like paint.

The most common product is Kool-Ray, from Continental Products Co. This material is diluted with water; use 2 to 20 parts water for 1 part Kool-Ray, depending on the amount of shading desired. It is better to apply a thin coat early in the season (using more water) and then darken it later if needed. It is much easier to darken the shade than to lighten it once it has been applied. The ratio of 1 part Kool-Ray to 7 or 8 parts water has worked well in Mississippi. About 10 gallons of dilute solution covers a standard greenhouse (24 by 96 feet). It is best to apply it as small droplets and try to avoid streaking. Apply it during warm, dry weather so it sticks well. Another product from this company, E-Z Off Kool-Ray, is easier to remove from plastic and fiberglass greenhouses. These products cost about $20 per gallon.

Use a thermometer that records the high and low temperatures.

Rain during summer and fall wears most of the compound away. Wash off any remaining compound with water and rubbing. One technique is to tie rags or burlap bags to a rope, toss the rope over the top of the greenhouse, and rub it back and forth over the top (with a partner on the other side). It works even better if a hose is tied to the midpoint, so that it sprays water on the roof as you rub. If necessary, commercial cleaners are available. If you use commercial cleaners, be sure to rinse the greenhouse off with water afterwards since the acid in these cleaners can be corrosive to metal.

Varishade, from Sunstill, Inc., is a product that turns darker in bright light and lighter in bad weather. When it gets wet or moist, it is almost transparent, allowing 80 percent of the light to enter. In sunny, dry weather it transmits only 35 percent of the light. It can be applied on glass or plastic.

Inexpensive white latex paint will shade just as well as shade compound. However, you may not be able to remove it from plastic at the end of the hot season. **Use paint only if you will be replacing the plastic before the fall crop of tomatoes.** Then you won't have to worry about trying to clean off the paint. Mix 1 part white latex paint with 10 parts water. Apply with sprayer or long-handled roller.

Other cooling techniques:

• Use as much white in the house as possible. White floor covering, bags, even strings, reflect light rather than absorb it and convert it to heat. Insulated north walls can be painted white or silver. An additional benefit from using white is that the light level is increased during the darker winter months.

• While "low profile" houses, those with a low roof, require less heat during the cold season, they tend to be hotter in warmer months than those with a high roof. With more head room, the heat has space along the peak where it collects before being exhausted. Without this extra head room, the heat remains at plant height; therefore, greenhouses with vertical side walls of at least 9 feet are recommended.

• You can alleviate some of the fruit splitting during hot weather by adding copper to the fertilizer solution. See *Splitting* section under *Physiological Disorders*.

Irrigation

Except in small hobby greenhouses, irrigation should be controlled automatically, with the use of time clocks or electronic controllers. The volume of water will vary depending on the season and the size of plants. New transplants need only about 2 ounces (50 ml) per plant per day. At maturity on sunny days, however, plants may need up to 3 quarts (2.7 liters or 2,700 ml) of water per plant per day. Generally, 2 quarts per plant per day are adequate for fully grown or almost fully grown plants. Monitor plants closely, especially for the first couple of weeks following transplanting, so that the volume of water can be increased as needed. Water should be delivered to each plant. This is usually done with "spaghetti tubing" and emitters that carry water from main lines to the base of each plant.

Each watering should include fertilizer (see section on *Fertility)*; therefore, the process is more appropriately referred to as "fertigation." Most growers use from 6 to 12 waterings per day once plants are established. In a medium that drains extremely well, such as rice hulls, 12 or more waterings per day may be needed to keep plants from drying out between waterings. In pine bark, 6 to 12 waterings per day are usually adequate. The important point is that plants should receive enough water so they do not wilt. A wilting plant is not growing. If the permanent wilting point is reached because of a prolonged period without water, the growing point may be killed. To be certain that plants receive enough water, allow enough so some drainage from the bags (10-20 percent) is apparent after each watering.

Be aware that a prolonged cloudy period followed by bright sun may cause severe wilting. Be ready to increase the amount of water in this situation.

pH

It is a good idea to check the nutrient solution pH daily with a pH meter. At a minimum, check pH every time you prepare fertilizer solution. A "pocket" pH meter is a tool every grower should have.

The optimum pH range for the nutrient solution is 5.6 to 5.8. If the pH of the solution is too high, caused by alkaline water, add an acid in small quantities to lower the pH to within this range. The choices of materials to use are sulfuric acid (H_2SO_4), nitric acid (HNO_3), or phosphoric acid (H_3PO_4). Sulfuric acid, the least expensive, can be purchased from an auto supply store as battery acid. However, there is an advantage to using phosphoric or nitric acid, since they supply nutrients in addition to lowering the pH. (Phosphoric acid supplies phosphorus and nitric acid supplies nitrogen.) Although they are more expensive than sulfuric acid, they may be preferred for this reason. Phosphoric acid and nitric acid are inexpensive sources of these elements when compared to other fertilizers.

Handle all acids very carefully because they can cause injury. Nitric acid can be very hazardous. Phosphoric acid lowers pH more than the other two for a given volume. It is advisable to use these acids directly from the drum or container in which they are purchased so there is no risk involved while pouring them. Never use vinegar (acetic acid) or swimming pool acid (sodium bisulfate) to lower the pH.

To determine how much acid to add to a bulk or concentrate tank of nutrient solution, take 1 gallon of solution and add 1 ml of acid at a time until the pH of the nutrient solution is within the range stated. Then, multiply the amount added to 1 gallon times the number of gallons in the tank. If

Shown are 10 greenhouse bays in a gutter-connected range (1/2 acre).

you are using a bulk tank, this is the amount of acid to add. However, if you are using an injector system, multiply this amount by (times) the ratio.

Be aware that the pH scale is not linear; it is logarithmic. For example, if 10 drops lower the pH from 8.0 to 7.5, there is no reason to believe that 20 drops will lower the pH to 7.0. You may reach the point where one more drop lowers the pH to 5.0 or lower. So, be careful! A pH that is too low can be very damaging to the crop. Check and double check the pH after adjusting it with acid.

If the pH is too low (below 5.5), you can bring it up by using materials such as sodium carbonate, caustic soda, potassium bicarbonate, potassium hydroxide, or caustic potash. The recommended material is potassium carbonate, which has a pH of 8.2. This will also supply potassium. Avoid the sodium sources since plants do not need sodium.

If the irrigation system, or emitters, become clogged during the production of a crop, they can be cleaned out after the cropping season is over. Use an acid mixed with water to adjust to a pH of 4.5. While this acidic mixture is running through the system, tap emitters to break up any crust that has formed. **Do not do this while tomato plants are growing in the greenhouse—a pH this low may kill plants!**

Fertility

The subject of fertility is probably among the most confusing for growers of greenhouse tomatoes; however, it is important to production. The keys to a successful nutrition program include the following:

- Use fertilizer designed specifically for greenhouse tomatoes.
- Know how much of each fertilizer element is needed.
- Know how much is being applied.
- Check the electrical conductivity (EC) and pH levels.
- Be observant for signs that plants may be deficient or have an excess of a nutrient.
- Monitor plant nutrient status by periodically taking samples for tissue analysis (see section on this topic).

Fertilizer Measurement and Vocabulary

Several units are used to express the fertility level of nutrient solutions (fertilizer dissolved in water). This causes confusion among growers since the use of different units makes it difficult to understand different readings among growers. This section explains the different units.

Electrical conductivity (EC) is a measure of the ability of a solution to conduct electricity—the more concentrated the fertilizer solution, the more electricity it will conduct and the higher the reading will be. The general unit is mho (pronounced MO) with the plural being mhos (pronounced MOZE). You will notice that mho spelled backwards is ohm (pronounced OM), the unit of resistance in electrical jargon. Mhos, the reverse of ohms, is a measure of conductivity rather than resistance.

There are two units of mhos commonly used: micromhos (μmhos) (pronounced micro-MOZE) and millimhos (mmhos) (pronounced milli-MOZE). A micromho is one millionth of a mho and a millimho is one thousandth of a mho. Therefore, there are 1,000 micromhos in a millimho. Another way of looking at it is that a millimho is 1,000 times bigger than a micromho. Either scale can be used. Convert from micromhos to millimhos by sliding the decimal point 3 places to the left, and vice versa. Typical readings of millimhos are 0.30 to 2.50, while typical readings of micromhos are 300 to 2,500. Millimhos are more commonly used than micromhos on most meters today.

Some portable EC meters measure in microsemens (μs). These are equivalent to micromhos (μmhos), and are more commonly used in European countries.

The best way to understand the nutrient status of a fertilizer solution and to communicate with other people is to know how many parts per million of each element you are applying. Parts per million (ppm) is the unit used to measure nitrogen concentration, or any other specific nutrient in solution. These units are usually within the range of 50 to 300 ppm for nitrogen. For mature, producing plants, 125 to 200 ppm nitrogen (N) is needed, depending on the particular circumstances. This is not directly related to or convertible to an exact measure of EC or total dissolved solids (TDS) in a nutrient solution (see below). This is because both EC and total dissolved solids are measurements of everything dissolved in the solution, not just nitrogen.

Table 2. General guidelines for amount of fertilizer to use

Stage of growth	Nitrogen (ppm)	Total dissolved solids (TDS) (ppm)	Electroconductivity (EC) (mmhos)
Germination to first true leaf fully expanded	50	450-550	0.6-0.7
First true leaf to third true leaf fully expanded	50-75	550-600	0.6-0.7
Third leaf to transplant	75-100	600-800	0.7-0.9
Transplant to second cluster set	100-125	800-1,100	0.9-1.8
Second cluster to topping	125- 200	1,100-1,600	1.8-2.2

Another way of measuring the amount of fertilizer in solution is by measuring dissolved solids. This is also referred to as total dissolved solids or TDS. The units commonly used for TDS are also parts per million (ppm). If you knew the ppm of each element dissolved in the solution, and added them up, along with the ppm of the water, you would get the ppm TDS. This is a measure of all salts in solution, not just nitrogen, so it is not the same as measuring ppm of nitrogen. Some of these salts may have been in the water supply before any fertilizer was added. For this reason, this form of measurement is not recommended. If a reading is 1,500 ppm TDS, how do you know if this is due to nitrogen or some other nutrient? You don't. You even may have water very high in sodium (salt) with no nitrogen. TDS is not a reliable measurement for this reason.

The readings of ppm dissolved solids are not directly convertible to millimhos or micromhos for a fertilizer; however, the conversions can be calculated for specific fertilizers. A rule of thumb (very crude conversion) is if your millimho reading is in the range 0.9 to 1.9, then mmhos x 680 = ppm total dissolved solids. If your millimho reading is in the range 2.0 to 2.8, then mmhos x 700 = ppm total dissolved solids. Remember–this is only a rule of thumb and does not give an exact conversion.

An important point: Any time dissolved solids or EC are measured in a solution, it is very important to know the dissolved solids or EC of the water source used to make the solution (it cannot be assumed to be 0). There may be sodium or some other dissolved element in your tap water that can lead to false readings when you measure your nutrient solution. Subtract the water source EC or dissolved solids measurement from that of the nutrient solution to find the true value caused by fertilizer. This is the number to compare to charts to decide if the correct amount of fertilizer is in solution.

Exhaust fans are essential to remove heat even in the winter.

Methods of Mixing Fertilizers

There are two principal systems for mixing fertilizers: the bulk tank system and the injector or proportioner system. Both methods are acceptable and can produce high yields and excellent quality tomatoes.

Bulk Tanks

The bulk tank system consists of a tank (plastic, concrete, steel, PVC, etc.) of appropriate size depending on the square footage of the greenhouse(s). A 100-gallon tank is fine for one greenhouse, whereas a 1,000 to 2,000 gallon tank may be preferable for several greenhouses. The larger the tank, the less frequently it will have to be filled. But if the tank is too large, you will have to wait too long until it is empty to mix up a new batch of fertilizer of a stronger concentration or with some other change in the formula. For a new grower, or a grower with only one or two bays, the bulk tank system is easier to understand and probably causes fewer mistakes, providing that the directions that come with the fertilizer are followed.

Mixing fertilizer is a matter of adding so many ounces (or pounds) of dry fertilizer per 100 gallons of water. The fertilizer must be completely dissolved in the water. Any precipitate (settled out fertilizer) will not reach the plants. Therefore, it may be necessary to stir the solution, by hand with a "paddle" or with an electric mixer, or use a circulation pump. Be sure to check the pH and EC of the solution each time you mix a new batch.

Injectors

With the injector system, a concentrated mixture of fertilizer solution is diluted with the injector (proportioner) to the final concentration required by the plants. The simplest and least expensive type of injector is a hozon proportioner, often used for fertilizing lawns and garden plants, but it is not appropriate for commercial production. The most complicated and expensive is the Anderson Injector; there are many intermediate models in cost and complexity.

Generally, the more you spend, the more accurate the injector is. Inexpensive models will vary their injection ratio depending on water pressure, which is often variable. This is because the injection is timed rather than depending on volume of water. Better models are dose specific, meaning that the concentrate injected depends on a given volume of water passing through the device. Equally important, the higher priced injectors are adjustable. A knob or dial on the head can be turned to increase or decrease the dose of fertilizer concentrate injected into the water. The fertilizer solution goes from the concentrate tank to the injector, where it is diluted by being injected into the irrigation system. A water meter monitors the flow of water and then sends out a signal when enough water has passed through. The meter can be mechanical or electrical. This signal from the meter is a pulse of water, which is sent to the pilot valve (skinner valve). This small volume of water is discarded after it passes through the pilot valve.

Concentrate is held in small containers (e.g., 10 to 50 gallons). Two heads and two concentrate tanks (at a minimum) are needed: one for the calcium nitrate (tank B) and the other for all other nutrients (tank A). This is necessary so calcium does not combine chemically with phosphates or sulfates when the elements are in high concentration, especially under a high pH. The resulting compounds, calcium hydrogen phosphate or calcium sulfate, are hard precipitates and can clog the injector and irrigation system. However, once these elements are diluted, there is no problem. If the pH is higher than 5.8, it is advisable to use a third head to inject acid. This is needed to keep the pH in the 5.6 - 5.8 range (see pH section above).

With an injector system, there is no cost involved for the large tank needed for the bulk tank system. However, a high quality injector can be expensive.

You can control the fertility level with an injector system better than with a bulk tank system since you can adjust the dose by simply turning a knob or dial. Furthermore, as better precision in the fertility program is desired (as money permits), you can add more injector heads. Ultimately, a head can be used for each fertilizer element. Individual adjustments can be made based on regular tissue analyses.

Injector Calibration

It is important to know the injection ratio so you can calculate how much fertilizer to mix in the concentrate tanks. Some come with tables that designate this ratio, i.e., 1:9, 1:16, 1:100, 1:200. On certain brands, the ratio is designated as a percent, i.e., 1 percent rather than 1:100. Some injectors let you adjust this ratio by turning a knob or a dial, or by adding rings, while others are fixed at one setting.

If you do not know the ratio, it is necessary to calibrate the injector to learn this important number. Using a beaker or graduated cylinder, measure how much water is sucked up by the injector in one minute. Then, using several beakers, one at each of several emitters (that is, ten locations), measure how much water is distributed to plants in one minute. Take an average of the number of beakers in which water is collected in the greenhouse. Multiply this average amount emitted per plant in one minute by the number of emitters in the greenhouse. The injection ratio is the ratio of the output to the input. Divide the total amount emitted in the greenhouse in one minute by the total amount sucked up in one minute. State the ratio as 1:X, where X is the number you get after dividing. Your concentrated solution is diluted X times with water. (There are X parts water for each one part of concentrated fertilizer solution.)

Plant Response

How do you know what is the right amount of fertilizer? In addition to following the directions on the bag and taking regular foliar analyses, the plant also gives an indication. If tops of plants "ball up" with dense, curling-under growth, the nutrient solution is a little high in nitrogen. Another sign of having nitrogen too high is when the clusters of flowers end in leaves or shoot growth (these should be pruned off). This condition will not necessarily decrease yield unless nitrogen is excessively high.

If stem diameter is extremely small and plants are spindly, fertilizer concentration is too low. Other signs include faded or yellowed foliage, decreased vigor, blossoms that don't set fruit, and yield reduction. Other fertilizer deficiency symptoms are discussed in the section *Nutrient Deficiency Symptoms*.

Modified Steiner Solution

One of the most recognized nutrient solutions is the Modified Steiner Solution. The original Steiner Solution was published by Dr. Abram A. Steiner in an article called "Soilless Culture," in the Proceedings of the 6th Colloquium of the International Potash Institute at Florence, Italy, in 1968. Dr. John Larsen (Professor Emeritus, retired, of Texas A&M University) modified this formula according to his research involving plant requirements and tissue analysis. According to Dr. Larsen, there is no need to exceed a level of 200 ppm nitrogen.

The Modified Steiner Solution will supply nutrients as follows:

ppm in solution at 100% strength	
171	N (nitrogen)
48	P (phosphorus)
304	K (potassium)
180	Ca (calcium)
48	Mg (magnesium)
3	Fe (iron)
1-2	Mn (manganese)
1	B (boron)
0.4	Zn (zinc)
0.2	Cu (copper)
0.1	Mo (molybdenum)

The suggested use of the Modified Steiner Solution is as follows:

Fall Crop

1) transplant to first bloom on fourth cluster	40 - 50%	concentrate
2) above to end of crop	85 - 90%	concentrate

Spring Crop

1) transplant to first bloom on fourth cluster	40 - 50%	concentrate
2) above to first bloom on fifth cluster	85 - 90%	concentrate
3) above until May 1	100%	concentrate
4) above to June 1	75%	concentrate
5) above to end of crop	60%	concentrate

As you can see, the Modified Steiner Solution never calls for more than 171 ppm nitrogen during the life of the crop. Most of the time, the fertility level is much lower. There are many disagreements about the proper level of fertilizer solution to use. Some people feel that the levels in the Modified Steiner Solution are too low for optimum production; however, the majority of researchers agree that these levels and ratios are appropriate to grow greenhouse tomatoes, and, therefore, they are the basis of many of the commercial fertilizers on the market today.

Commercial Fertilizers

Various commercial fertilizer mixes are available for use in bulk tank systems or with injectors. Some mixes are "complete," while others require the purchase of additional calcium nitrate, potassium nitrate, magnesium sulfate (same as epsom salts), sequestered iron (Fe 330), or some other fertilizer. Follow the recommendations on the bag exactly as stated if you use these commercial blends. Adjust as needed after gaining experience. The most common mistake new growers make is not following the directions concerning amount of fertilizer.

The choice of a commercial fertilizer is up to the grower. However, be certain that the mix has been formulated specifically for greenhouse tomatoes. An all-purpose fertilizer such as 20-20-20 is not appropriate for this crop, although it is fine for bedding plants and other general use in the greenhouse.

For educational purposes, three examples showing how to use some of the commercial mixes are provided. The mention of a brand name is not an endorsement and is not meant to exclude other brands on the market.

TotalGro Bag Culture Tomato Special (3-13-29)

Source: TotalGro, P.O. Box 805, Winnsboro, LA 71295 (1- 800-433-3055).

For the southern part of the United States, this is a low nitrogen-type fertilizer designed especially for growing greenhouse tomatoes using pine bark. It contains 3 percent nitrogen (N), 13 percent phosphate (P_2O_5), and 29 percent potash (K_2O). In addition, it provides all of the magnesium (Mg) required, as well as S, B, Cu, Fe, Mn, Mo, and Zn. This fertilizer does not contain calcium, so use in conjunction with calcium nitrate.

When used at the recommended rates (Table 3) and combined with calcium nitrate as shown, it will supply 100 ppm nitrogen and all of the calcium and magnesium needed, in addition to the other nutrients (Table 4).

Submit tissue samples for laboratory analysis to determine when fertilizer rates need to be adjusted.

Table 3. Amount of TotalGro (3-13-29) plus calcium nitrate to use per 100 gallons of water for 110 ppm N

Ounces of fertilizer per 100 gallons water	ppm Nitrogen	EC (mmhos/cm)
13.3 ounces 3-13-29	30	1.26
7 ounces calcium nitrate	80	0.60

Table 3 shows how much will be applied at the rates indicated. With this table, you can check the concentration with an EC meter. The EC of the solution with both fertilizers should be 1.86 when mixed as shown. Be sure to subtract the ppm or TDS of the source water from the reading of the nutrient solution before comparing the reading to the table. The relationship between TDS, EC, and ppm N is unique for each fertilizer. Therefore, Table 3 does not apply to other fertilizers. Make it a practice to check the EC of the solution each time that you mix a new batch.

Table 4. Concentration of nutrients supplied from TotalGro 3-13-29 plus calcium nitrate at rates in Table 3

Nutrient	PPM
Nitrate Nitrogen (N)	110
Phosphorus (P)	49
Potassium (K)	240
Calcium (Ca)	100
Magnesium (Mg)	54
Sulfur (S)	110
Iron (Fe)	3.4
Manganese (Mn)	1
Copper (Cu)	1
Zinc (Zn)	0.46
Boron (B)	1
Molybdenum (Mo)	0.1

Hydro-Gardens Chem-Gro Tomato Formula (4-18-38)

Source: Hydro-Gardens, Inc., P.O. Box 25845, Colorado Springs, CO 80936-5845 (1-800-634-6362).

This is a low nitrogen-type fertilizer, supplying 4 percent nitrogen (N), 18 percent phosphate (P_2O_5), and 38 percent potash (K_2O). In addition, it provides Mg, B, Cu, Fe, Mn, Mo, and Zn. This fertilizer does not supply calcium, so calcium nitrate must be used in conjunction with the 4-18-38.

The recommendations for mixing Chem-Gro are shown in Table 5. In addition, if the source water has less than 50 ppm calcium, then add calcium chloride in an amount equal to 25 percent of the calcium nitrate used per 100 gallons water. This can be added to the calcium nitrate concentrate tank, if an injector system is being used.

Table 5. Amount of Chem-Gro (4-18-38) and other fertilizers to use per 100 gallons of water for each stage of plant growth

Plant age	Chem-Gro (4-18-38) (ounces)	Calcium nitrate (ounces)	Magnesium sulfate (ounces)	Potassium nitrate (ounces)
Seedlings	8	4	4	0
Second to fourth flower clusters	8	8	4	0
Fourth and higher flower clusters	8	8	5	1.6

Peters Peat-Lite Special (15-11-29)

Source: Peters Fertilizer Products, The Scotts Company, 14111 Scotts Lawn Rd., Marysville, OH 43041 (1-800-492-8255).

This supplies 15 percent, 11 percent, and 29 percent of nitrogen (N), phosphate (P_2O_5), and potash (K_2O), respectively, in addition to small amounts of Mg, Fe, Mn, B, Zn, Cu, and Mo.

According to the directions, 9 ounces of fertilizer per gallon of concentrate will provide 100 ppm N if a 1:100

injector is used. For 50 ppm N with a 1:100 injector, use half this amount. Likewise, for 200 ppm N with a 1:100 injector, use 18 ounces per gallon of concentrate. Adjust the amount of fertilizer up or down, depending on the maturity stage of the crop. The same amount would be used for a bulk tank system per 100 gallons of water (since 1 gallon of concentrate used with a 1:100 injector is the same as using 100 gallons of mixed nutrient solution in bulk).

Table 6 coordinates the EC reading with the ppm of nitrogen for this fertilizer. Be sure to subtract the EC of the water from the reading of the nutrient solution before comparing the reading to Table 6. This fertilizer does not contain adequate calcium or magnesium, so these must be added from other sources. To accomplish this, use only half 15-11-29 with the other half of the nitrogen source coming from calcium nitrate. This way, you are able to supply calcium as well. To supply 100 ppm nitrogen, use 4.5 ounces 15-11-29 (instead of 9 ounces) and 4.5 ounces calcium nitrate (calcium nitrate is 15.5% N; about the same N content as 15-11-29) per gallon. In addition, add 1.8 ounces magnesium sulfate (epsom salt) and 0.07 ounces (2 grams) iron chelate per gallon to supply magnesium and iron. As you need to go up or down in feed, maintain the same ratios of these fertilizers. For example, for 150 ppm N, use 6.75 ounces 15-11-29, 6.75 ounces calcium nitrate, 2.7 ounces magnesium sulfate, and 0.105 ounces (3 grams) iron chelate per gallon.

For source water with a high alkalinity (total carbonates), the manufacturer suggests using Peters Excel K-Cell 14-5-38.

Table 6. Nitrogen concentration supplied at various EC readings using Peters Peat-Lite Special (15-11-29)

EC mmhos/cm	Nitrogen (ppm)
0.34	50
0.52	75
0.69	100
0.86	125
1.03	150
1.21	175
1.38	200
1.55	225
1.72	250
1.90	275
2.07	300

How To Calculate Element Concentration in a Fertilizer

There are many times when you need to know how much of a fertilizer element (such as nitrogen) is contained in the fertilizer solution. The concentration is usually measured in units of parts per million (ppm). This simply means the number of parts of a fertilizer element per million parts of water, on a weight basis. For example, 1 part nitrogen per 1 million parts of water is 1 ppm; or, 1 pound of nitrogen per 1 million pounds of water is 1 ppm.

The following formulas are ways to calculate the concentration of any fertilizer element in water. They are easy to use, and a couple of examples are shown. By using these equations, you will be able to know exactly how much of each fertilizer element you are feeding your plants.

You can use the following formulas to calculate the amount of any fertilizer element, not just nitrogen.

There is essentially only one formula; however, if you are using an injector system, there is another factor to use, namely the injection ratio. With a bulk tank system, there is no injector, and, therefore, no injection ratio, so this number is left out.

#1. Injector System

ppm = (% fertilizer) x (lb added to tank) x (16 oz per lb) x (.75) x (100 / gal of concentrate) x (1 / ratio of injector)

#2. Bulk Tank System

ppm = (% fertilizer) x (lb added to tank) x (16 oz per lb) x (.75) x (100 / gal of bulk tank)

Examples

Example 1. You use 25 pounds of a 15-11-29 fertilizer mix in a 30-gallon concentrate tank, then use a 1:100 Anderson injector. How much nitrogen are your plants getting?

Since you have an injector system, use formula #1.

ppm = (15) x (25) x (16) x (.75) x (100/30) x (1/100) ppm = 150 ppm nitrogen

Example 2. You use a bulk tank system with 15 pounds of 8-5-16 fertilizer mix. Your bulk tank holds 600 gallons of fertilizer. You also add 10 pounds of potassium nitrate (13.75% N) to be sure the plants get plenty of nitrogen. How much nitrogen are the plants getting?

Since you have a bulk tank system, use formula #2.

ppm from 8-5-16 = (8) x (15) x (16) x (.75) x (100/600) = 240 ppm N

ppm from KNO_3 = (13.75) x (10) x (16) x (.75) x (100/600) = 275 ppm N

Total ppm N = 240 + 275 = 515

This is much too high for greenhouse tomatoes.

Nutrient Composition of Fertilizers

For your handy reference, the list shows the amount of each element in the following fertilizers:

Fertilizer	Percent elemental composition
Calcium nitrate	15.5% N, 19% Ca
Potassium nitrate	13.75% N, 44.5% K_2O
Ammonium nitrate	34% N
Urea	46% N
Phosphoric acid	75% P_2O_5 (% can vary)
Magnesium sulphate	9.7% Mg (same as epsom salt), 13% S
Potassium sulphate	50% K_2O, 14.4% S
Ammonium sulphate	21% N, 24% S
Potassium chloride	60% K_2O, 47% chloride (same as muriate of potash)
Monoammonium phosphate (MAP)	12% N, 61% P_2O_5
Diammonium phosphate (DAP)	16% N, 48% P_2O_5
Monopotassium phosphate (MKP)	52% P_2O_5, 34% K_2O
Calcium chloride	36% Ca

Solubility Limits of Fertilizers

There are limits on how much of a fertilizer will dissolve in water. These are the solubility limits. It is important that you dissolve the fertilizer completely. Otherwise, it will settle out in your tank, and the plants will not get their full dose. The following are the solubility limits of some fertilizers in 100 gallons of cold water. If you put more than these amounts of fertilizer in 100 gallons of cold water, some fertilizer will not dissolve. If there is a problem with dissolving the fertilizer, it may be necessary to mix the fertilizer with a circulating pump or a mechanical mixer **or** use hot water (180 °F).

Fertilizer	Pounds soluble in 100 gallons cold water	Kg in 100 Liters
Ammonium nitrate	984	118
Ammonium sulfate	592	71
Calcium nitrate	851	102
Calcium chloride	500	60
Diammonium phosphate (DAP)	358	43
Monoammonium phosphate (MAP)	192	23
Potassium nitrate	108	13
Urea	651	78
Borax	8	1
Magnesium sulfate (epsom salt)	592	71
Potassium chloride	290	35
Potassium sulfate	83	10

P and K Conversions

If you need to calculate phosphate or potash content of your fertilizer solution, be aware that the middle number in the fertilizer grade is in the form of phosphate or P_2O_5 (not phosphorus) and the third number is in the form of potash or K_2O (not potassium). To convert between units, use the following formulas:

$$K \times 1.205 = K_2O$$
$$K_2O \times 0.83 = K$$
$$P \times 2.291 = P_2O_5$$
$$P_2O_5 \times 0.437 = P$$

Derivation of Fertilizer Calculation Formulas and Further Explanation

If you would like to know where the above formulas come from, read on. If you do not want to know the derivation, skip this section and just use the formulas, being assured they are accurate.

The formulas are based on the following law of physics: 1 ounce of any 100 percent soluble fertilizer in 100 gallons of water always equals 75 ppm. This is always true, regardless of what is being dissolved in the water; however, it does assume the fertilizer is completely dissolved.

Why is this true? First of all, accept the fact that 1 gallon of water weighs 8.34 pounds. Then, if you take 1 ounce of any fertilizer (or anything else soluble) and put it in 100 gallons of water, you are putting that 1 ounce in 834 pounds of water (100 gallons x 8.34 pounds/gallon) or 13,344 ounces (834 pounds x 16 ounces in a pound). One part in 13,344 equals 0.0000749 (divide 1 by 13,344). To find out how many parts per million this is, multiply it by 1,000,000. For example, we have 0.0000749 parts per 1. Multiply by 1 million to find how many parts this is per million. So, 0.0000749 x 1,000,000 equals 74.94 ppm. We can round this off to 75 parts per million (ppm).

Now, to find out the concentration of a fertilizer element in water, you need to know the weight of the fertilizer and the percent strength of the fertilizer, since they are never 100 percent in strength. A 15-11-20 fertilizer is 15 percent nitrogen. Assume you are using 1.5 pounds of a 15 percent nitrogen fertilizer in a 100-gallon water tank, and you want to know how many ppm N this is. You would set up the equation as follows:

ppm N = (15% N) x (1.5 lb) x (16 oz per lb) x (.75).

If you multiply this out, you will get 270 ppm, a very high amount for tomatoes. You are using 0.75 rather than 75 because this lets you use the percent nitrogen (15 percent) rather than the decimal form (0.15). The above formula will work fine as long as you are mixing with 100 gallons of water.

What if you have a larger or smaller tank? You simply set up a multiplier to adjust the equation. If you have a 500-gallon tank, multiply by 100/500, which will adjust the amount in 500 gallons down to what it would be in 100 gallons (since this is how the first rule discussed is set up). If you are using 5 pounds of the 15 percent fertilizer in 500 gallons, this is the equation:

ppm N = (15% N) x (5 lb) x (16 oz per lb) x (.75) x (100/500).

This multiplies out to be 180 ppm N, a reasonable amount for a mature crop of tomatoes. If you had a smaller tank, about 25 gallons, and used 1/4 pound of the 15 percent fertilizer, the equation to adjust the amount in 25 gallons up to 100 gallons would be as follows:

ppm N = (15% N) x (0.25 lb) x (16 oz per lb) x (.75) x (100/25).

Multiplying through, you should get 180 ppm N. This is all you need to know to calculate ppm N in any bulk tank system.

If you have an injector (proportioner), you also need to know the injection ratio. For example, is it injecting 1:9 or 1:20 or 1:100? Whatever the ratio is, multiply it by the rest of the equation. If you have determined that you have a 1:100 injector, and are using 50 pounds of a 15 percent nitrogen fertilizer in a 50-gallon stock solution (concentrate), set up the equation as follows:

ppm N = (15% N) x (50 lb) x (16 oz per lb)
x (.75) x (100/50) x (1/100).

Multiplying this out, you will get 180 ppm N. Set up the injector ratio as 1/100 since the injector is diluting the concentrate with water 100 times.

This system will work with any injector ratio and any size concentrate tank. Simply plug in the numbers to customize the formula to your own system.

Leachate

After each feeding, some fertilizer solution (referred to as leachate) should drain from the bottoms of bags. If there is no leachate, the plants are probably not getting enough water.

Check the EC of the leachate to determine how much fertility the plants are using. The EC of the leachate should be fairly close to the EC of the nutrient solution (less than 0.5 mmhos different). If it approaches 2.5 to 3.0 mmhos, too much fertilizer is accumulating in the bags and the roots may burn from this high concentration.

Leaf Tissue Analysis

It is a good idea to have tomato leaf tissue analyzed periodically to determine if the plants are receiving the best levels of nutrients. This technique can be used to "troubleshoot" problems with unhealthy looking plants, or as a monthly check on nutrient levels. Save these monthly checks so you can refer to them in diagnosing problems that might occur.

It is very important to take leaf samples from the correct location on the plants to get reliable results. Take the sample according to the directions of the lab to which you will send the sample. For Mississippi growers, remove one leaf from each plant, collecting six to eight leaves for one sample. Select the leaf for this sample that is just above a fruit about 2 inches in diameter (about the size of a golf ball). Taking leaves higher or lower on the plant will have serious effects on the level of nutrients shown in the test report, especially for nitrogen and other highly mobile elements.

Send leaf samples to the laboratory at Mississippi State University (Soil Testing and Plant Analysis, Box 9610, Mississippi State, MS 39762) or any private lab. Wrap the leaves in dry paper towels and mail in a large envelope.

At Mississippi State University, the fee is $10 for Mississippi residents, and $15 for samples from outside of the state. Most greenhouse fertilizer manufacturers also have a testing service available.

When sending a sample to Mississippi State University, include a "Plant Analysis Information Sheet" (Extension Form 700) with the sample, filled out as completely as possible. These are available from your county Extension office.

Test results list the macronutrients as a percent, while the micronutrients are listed as parts per million (ppm). The optimum levels of nutrients for tissue of mature (producing) tomato plants are as shown in Table 7. Adjust the fertilizer solution so the appropriate corrections can be made.

Keep in mind that what is in the fertilizer solution is not always what the plants get. If there is any kind of stress situation, plants may not take up all of the nutrients that you are putting into the bags (or other containers). For example, if the root temperature is below 58 °F, you may see purpling in the leaves, a sign of phosphorus deficiency, since phosphorus is not taken up well when roots are cool. If salts have accumulated to high levels around the roots (indicated by high EC readings of the leachate), certain nutrients will not be taken up well. If plants do not receive adequate water, they wilt and will not take up enough fertilizer. These situations support tissue analysis as the best indicator of the nutrient status of plants.

Table 7. Recommended levels of elements in tomato leaf tissue

N	4.0-5.5%	Fe	100-250 ppm
P	0.3-1.0%	Zn	30-150 ppm
K	4.0-7.0%	Mn	40-300 ppm
Ca	1.0-5.0%	Cu	5- 25 ppm
Mg	0.4-1.5%	B	35-100 ppm
		Mo	0.15-5.0 ppm

Nutrient Deficiency Symptoms

In addition to having tissue analysis done periodically to check the nutrient status of plants, growers should be on the lookout for symptoms which occur when plants are deficient in a nutrient. The following will help identify these nutrient deficiencies:

Nitrogen (N) — Restricted growth of tops, roots, and especially lateral shoots. Plants become spindly, with general chlorosis of entire plant to a light green, and then a yellowing of older leaves that proceeds upwards toward younger leaves. Older leaves defoliate early. Generally, veins of younger leaves show purpling on undersides when deficiency is severe in tomatoes.

Phosphorus (P) — Restricted and spindly growth similar to that of nitrogen deficiency. Leaf color is usually dull, dark green to bluish green with purpling of petioles and the veins on undersides of younger leaves. Young leaves are yellowish green with purple veins with N deficiency and dark green with P deficiency. Otherwise N and P deficiencies are very much alike.

Potassium (K) — Mature, lower leaves show interveinal chlorosis and marginal necrotic spots or scorching that progresses inward and also upward toward younger leaves as deficiency becomes more severe. The fruit often ripens unevenly or shows blotchy green to yellow patches on red ripe fruit. Fruit sometimes falls off the plants just before ripening. Deficiency may also cause soft or spongy fruit. If this is the case, increase the K level up to 400-450 ppm.

Calcium (Ca) — From slight chlorosis to brown or black scorching of new leaf tips and die-back of growing points. The scorched and die-back portion of tissue is very slow to dry so that it does not crumble easily. The first symptom is usually blossom-end rot of the fruit (see section on *Physiological Disorders*). Boron deficiency also causes scorching of new leaf tips and die-back of growing points, but calcium deficiency does not promote the growth of lateral shoots and short internodes as does boron deficiency, and boron deficiency does not cause blossom-end rot.

Magnesium (Mg) — Interveinal chlorotic mottling or marbling of the older leaves, which proceeds toward the younger leaves as the deficiency becomes more severe. The chlorotic interveinal yellow patches usually occur toward the center of leaves with the margins being the last to turn yellow. In some crops, the interveinal yellow patches are followed by colorful orange to red coloring. As the deficiency increases in severity, the interveinal chlorosis is followed by necrotic spots or patches and marginal scorching of the leaves. On plants with mature fruit, the interveinal chlorotic yellow patches usually do not start on the oldest leaves but on those toward the middle of the plant. Magnesium can be applied as a foliar spray; use 2 tablespoons of magnesium sulfate per gallon of water.

Sulfur (S) — Resembles nitrogen deficiency in that older leaves become yellowish green; stems become thin, hard, and woody. Some plants show colorful orange and red tints rather than yellowing. The stems, although hard and woody, increase in length but not in diameter.

Iron (Fe) — Starts with interveinal chlorotic mottling or a general yellowing of immature leaves. In severe cases, the new leaves become almost white (completely lacking in chlorophyll) but with little or no necrotic spots. The chlorotic mottling of immature leaves starts first near the base of the leaflet so that the middle of the leaf appears to have a yellow streak. If additional iron is needed, 1/4 ounce of Fe 330 iron chelate (9.7 percent iron) in 100 gallons of water provides 1.9 ppm iron. Achieve this by using 1 $^{1}/_{2}$ teaspoons in 100 gallons. Alternatively, iron can be applied as a foliar spray, using $^{1}/_{4}$ teaspoon per gallon.

Manganese (Mn) — Starts with interveinal chlorotic mottling of immature leaves, and in many plants it is indistinguishable from iron deficiency. On fruiting plants, the blossom buds often do not fully develop but turn yellow and abort. As the deficiency becomes more severe, the new growth becomes completely yellow, but in contrast to iron deficiency, necrotic spots usually appear in the interveinal tissue. In tomatoes that show some interveinal chlorotic mottling caused by a manganese deficiency, some of the bloom buds on the flowering clusters show incomplete development and do not develop into blooms. During the short days of December and January, the plants often show no blooms at all.

Zinc (Zn) — In some plants, interveinal chlorotic mottling first appears on the older leaves, and in others it appears on the immature leaves. It eventually affects the growing points and causes smaller than normal leaves. This is sometimes referred to as "mouse ear." The interveinal chlorotic mottling is the same as that for iron and manganese deficiency, except for the little leaf. When the onset of zinc deficiency is sudden, such as when zinc is left out of the nutrient solution, the chlorosis can appear identical to that of iron and manganese deficiency without the little leaf.

Boron (B) — Symptoms include slight chlorosis to brown or black scorching of new leaf tips and die-back of the growing points similar to calcium deficiency. The brown and black die-back tissue is dry, brittle, and easily crumbled. The pith of affected stems may be hollow, and the epidermis roughened and cracked. In addition to scorching of new leaf tips, die-back of growing points, and cracked stems, plants have short internodes with prolific lateral shoot development that may develop on midribs of the leaves and on the flower clusters. The mildest symptom shown on mature fruit is minute cracking to heavier concentric cracking in the skin on the shoulders. With severe deficiency, fruit may show a distinct cracked, brown, corky area under the calyx.

Copper (Cu) — Leaves at the top of the plant wilt easily. This is followed by chlorotic and necrotic areas in the leaves. Leaves on top half of plant show unusual puckering with veinal chlorosis. There may be an absence of a knot on the leaf where the petiole joins the main stem of plant beginning about 10 or more leaves below growing point. Splitting of ripe fruit, especially under warm temperatures, is an indication of low copper. Increase copper in the nutrient solution up to 0.5 to 1.0 ppm if it is lower, or up to a maximum of 2 ppm.

Molybdenum (Mo) — Older leaves show interveinal chlorotic blotches, become cupped and thickened. Chlorosis continues upward to younger leaves as deficiency progresses. This deficiency is seldom seen in greenhouse tomatoes.

Physiological Disorders

Many problems that occur with tomatoes are not caused by insects or diseases. These problems are due to environment (temperature, humidity, light, water, etc.) or nutrition and are termed "physiological disorders." Listed are descriptions of the most common disorders:

Radial Cracking

These are cracks that radiate out from the calyx (stem end) of the fruit and proceed downwards. If one crack is less than one-half inch long and not deep, the fruit is still marketable. If cracks are deeper, longer, or more numerous, the fruit is not marketable. These cracks are caused by too much water following too little water; very fast growth with high temperature and moisture; or a large difference between day and night temperatures. Also, be sure that the fertilizer level is adequate (check your EC).

Concentric Cracking

These cracks are in the formation of concentric circles, one inside another, around the calyx (stem end) of the fruit. Depending on severity, fruit may or may not be marketable. This cracking is also caused by a water problem. Be sure that fertilizer supply is adequate (check your EC). These cracks are caused by too much water following too little water; very fast growth with high temperature and moisture; or a large difference between day and night temperatures.

Splitting

Splitting is not the same as cracking (see above). When fruit are exposed to very high temperatures, such as those found in many greenhouses in May and June in Mississippi, the fruit have a tendency to split the skin, a result of temperature stress. Solutions include these:

- Lower the air temperature by using shading or evaporative cooling (see section on *Greenhouse Cooling*).
- Increase the supply of copper in the nutrient solution up to 2 ppm. One tablespoon of copper sulfate in 1,000 gallons of water will supply 1 ppm copper.

Do not try to grow greenhouse tomatoes through the summer in Mississippi; the resulting fruit will usually show this disorder.

Splitting can also ocur when the night temperature is too low, followed by a sunny day, such as in late fall or winter. Be sure the night temperature is not lower than 64 ºF.

Catfacing

This is a malformation, scarring, or cracking of fruit at the blossom end, sometimes leaving "holes" in the fruit exposing the locules. This defect is caused by very high or low temperatures during fruit set, or any disturbance to the flower parts. It may also be a result of 2,4-D herbicide injury. Some varieties are less susceptible than others.

Minute Cracking (Russetting)

Russetting is a condition in which the fruit skin appears roughened, especially along the shoulder. Close examination reveals thousands of minute cracks on the fruit surface. This is very different from the more common concentric cracking (rings) or radial cracking (splits coming out from the stem end) on the top of the fruit. These cracks are so small they might be mistaken for a roughened skin. The same situation occurs with bell peppers, pears, and potatoes.

Russetted fruit are not marketable because appearance is below standard, and even more important, the shelf life of russetted tomatoes is greatly diminished. This is because water escapes via the minute cracks, causing loss of weight, shriveling, and breakdown. When fruit lose 5 percent of their weight (due to water loss), they soon become soft, and their shelf life is reduced. Do not ship tomatoes with this condition.

Research conducted at an agricultural research station in Naaldwijk, Holland, has identified two sets of conditions that promote russetting (called "crazing" in some publications).

Condition 1. As the crop approaches the end of its productive season, plants are often topped (terminal cut off) to remove any new flowers and fruit that will not have time to mature. This often promotes a growth of side shoots and results in russetting. The reasoning is that regrowth of the side shoots stimulates activity with the roots, forcing more water and nutrients into the limited number of fruit remaining. Plants that were topped but had all side shoots removed had much less russetting. Plants that were not topped at all had the least russetting. Apparently, allowing small fruit to develop at the tops of plants provides a more balanced growth and better distribution of nutrients and water. Regular, uninterrupted growth is important in limiting this problem. If you have had a problem with russetting, do not top plants as they approach the end of the season. If you have already topped, remove new side shoots.

Condition 2. Low greenhouse air temperature, especially in combination with high day temperature, has been shown to cause russetting. The difference between air and fruit temperatures may be the real culprit. In research at the same station, a temperature of 62 °F caused 46 percent of a crop to be russetted, while three warmer temperatures averaged considerably less russetted fruit. If russetting has been a problem, raise the minimum temperature to 64 °F or above.

Here are some ways to reduce the likelihood of problems with russetting:

- Avoid sudden changes in growing conditions, including climate and electrical conductivity (EC) of the nutrient solution.
- Keep the EC high enough for continuous growth.
- Be sure the potassium level is high enough.
- Avoid situations that cause condensation on fruit. This includes poorly ventilated greenhouses and refrigeration of harvested fruit.
- There are some varietal differences in susceptibility. *Capello* is more prone to this problem than *Trend*, which in turn is more prone than *Caruso*.

Zipper Scar (also called "Anther Scar")

This is a vertical scar along the side of the fruit that resembles a zipper, or perhaps the type of scar left by stitches. It is caused by the anther sticking to the edge of the ovary (immature fruit). As the fruit increases in size, the anther tears away from the fruit, leaving a scar. This is a genetic problem and probably not caused by any environmental conditions.

Blotchy Ripening (also called "Gray Wall")

This problem appears as flattened, blotchy, brownish-gray areas on green fruit. As the fruit turns red, these areas may remain gray or turn yellow, causing uneven ripening. Dark brown vascular tissue can be seen in fruit walls when fruit is cut. Identifying the specific cause for this defect is probably more difficult than for any other defect. It can be caused by low temperature, temperature fluctuations, high humidity, low light intensity, high moisture, high nitrogen, low potassium, compaction of the growing medium, etc. High temperatures (above 86 °F) prevent formation of lycopene, the pigment that gives tomatoes red color. Also, certain fungi, bacteria, or tobacco mosaic virus (TMV) may be involved. Since some varieties are more susceptible than others, it is advisable to switch varieties if blotchy ripening is a serious problem.

Green Shoulder

This appears as a dark-green area at the top (calyx end) of ripening fruit, which never turns red. Often, the area may turn yellow as the remainder of the fruit ripens. The disorder is genetic, but is brought out especially in conditions of high light and temperature. Recommended procedures include increasing ventilation during warm periods, being sure that plants are not defoliated above developing clusters, using some type of shading system (see section on *Greenhouse Cooling*), and adequate phosphorus and potassium fertility. Also, some varieties are immune (non-greenback) or partially immune (semi-greenback) to this defect (see section on *Varieties*).

Blossom-End Rot (BER)

Although referred to as a rot, this problem is not caused by an organism. It appears as a light tan, brown, or black sunken area at or near the base (blossom end) of the fruit. It is not soft, but is firm and somewhat leathery and may be accompanied by a dry rot. Sometimes it appears only inside the fruit as a blackened area, with no symptoms on the outside. Occasionally, a secondary organism invades the tissue causing a soft rot. Remove and discard any immature fruit that show symptoms; once a fruit has blossom-end rot, it will not go away.

BER is caused by insufficient calcium in the fruit. Even though adequate calcium may be applied in the nutrient solution, it may not be reaching the fruit because of insufficient water. If plants wilt, it is difficult for nutrients to reach the fruit. Although BER is a calcium problem, it can result from water stress. Rapidly growing plants suddenly exposed to drought are especially susceptible. Any stress condition interferes with the uptake of calcium, and may cause BER. Some stressors are excessive salinity of the growing medium, high nitrogen, rapid plant growth, high temperature, high humidity, and root damage.

To prevent BER, maintain steady plant growth, and avoid wide fluctuations in water and temperature. The calcium level in the nutrient solution should be at least 125 ppm. Once BER occurs, it can be prevented in nonaffected fruit with a foliar spray of calcium chloride (36 percent calcium) at the rate of 14 to 64 ounces per 100 gallons (or 4 tablespoons/gallon) of water. Or, use calcium nitrate (20 percent calcium) at the rate of 17.5 pounds per 100 gallons (or 9 tablespoons/gallon) of water. For a small-scaled operation, a commercial product called "Stop Rot" is available. Use 1 pint per 7 1/2 gallons, and spray twice per week until the problem is corrected.

Avoid excess nitrogen fertilizer, especially the ammonium forms. Ammonium increases the demand for calcium, limiting the amount available. Some varieties may be more resistant to BER than others.

Puffiness

Fruit that are "puffy" have an angular appearance, with one or more sides flatter than the rest. They also weigh less, and the locules are not well filled; i.e., there is not much gel and seed inside. Some of the locules may be empty.

Puffiness is a product of poor pollination caused by any of the following environmental problems that affect good pollination:

- high temperature, especially above 90 °F
- low temperature, especially below 55 °F
- wide differences between day and night temperature
- drought
- excessive water
- excessive nitrogen
- use of fruit hormones, or
- lack of adequate carbon dioxide (CO_2)

If puffiness is a problem, try to change any of the above conditions that may apply, especially too high a nitrogen level. Also, be sure that you use an electric pollinator every other day and that pollination is done at the proper time of day, or use bumblebees (see section on *Pollination*). Increase air movement within the greenhouse to cool the air and to bring CO_2 closer to the leaf surfaces where it is needed. There are no varieties resistant to this problem.

Sunscald

This appears as a whitish or yellowish patch on the side of the fruit facing the sun. This area may shrink and form a large white spot with a papery surface, or a white, blistered area on a green fruit. This is a "sun burn" caused by sudden exposure of a formerly shaded fruit to direct sunlight, especially during hot, dry weather. The area may be secondarily invaded by a fungus, although this is not the real problem. Uncovering fruit by shifting foliage during harvest is the most likely cause, although death of leaves (which had shaded fruit) due to disease can lead to sunscald as well.

Appendix I. Additional Information

Note: All of the MSU-ES publications listed below are available on the Greenhouse Tomato FAQ website (see below).

Killebrew, Frank, Pat Harris, and Herbert Willcutt. 1999. *Greenhouse Tomatoes – Pest Management in Mississippi*. Mississippi State University Extension Service. Publication 1861.

Snyder, Richard G., and Jim Thomas. 1996. *Fertigation – The Basics of Injecting Fertilizer for Field-Grown Tomatoes*. Mississippi State University Extension Service. Publication 2037.

Snyder, Richard G. 1995. *Starting Vegetable Transplants*. Mississippi State University Extension Service. Publication 1995.

Snyder, Richard G. 1993. *Injector Planner – A Spreadsheet Approach to Fertilization Management for Greenhouse Tomatoes*. Mississippi Agricultural and Forestry Experiment Station. Research Bulletin 1003.

Snyder, Richard G. 1993. *Environmental Control for Greenhouse Tomatoes*. Mississippi State University Extension Service. Publication 1879.

Proceedings of the Joint Conference of the 26th National Agricultural Plastics Congress and the American Greenhouse Vegetable Growers Association Conference, Atlantic City, NJ, June14-18, 1996. (source: Pat Heuser, Executive Secretary, American Society for Plasticulture, 526 Brittany Drive, State College, PA 16803).

Proceedings for the Greenhouse Tomato Seminar, Montreal, Quebec, Canada, August 3-4, 1995. Dr. Richard G. Snyder, Coordinator. (source: American Society for Horticultural Science Press, 600 Cameron Street, Alexandria, VA 22314-2562).

Hood, Ken, Richard G. Snyder, and Charles Walden, 2000. *A Budget for Greenhouse Tomatoes,* Mississippi State University Extension Service. Publication 2257.

Greenhouse Tomato FAQ (Frequently Asked Questions) On the web at http://www.msucares.com/crops/comhort/greenhouse.html.

Listing of Greenhouse Vegetable Production Resources on the web at http://www.ces.ncsu.edu/depts/hort/greenhouse_veg/webresources.html.

Listing of Greenhouse Vegetable Production Resources Print at http://www.ces.ncsu.edu/depts/hort/hil/hil-32-a.html.

Greenhouse Tomato Short Course – In March of each year, the Greenhouse Tomato Short Course is held in Jackson, Mississippi. This is a two-day intensive training for growers and potential growers of greenhouse tomatoes and other vegetables. Attend this program if you are seriously considering going into the greenhouse vegetable business. Expert speakers are brought in from all over the United States and other countries to address their topics of expertise. To have your name added to the mailing list, call (601) 892-3731 or send an email message to RickS@ext.msstate.edu. For more information concerning the short course, visit http://www.msstate.edu/dept/cmrec/GHSC.htm.

Appendix II. Commercial Greenhouse Manufacturers (G) and Suppliers (S)

AgBio Development, Inc.
9915 Raleigh Street
Westminster, CO 80030
303-469-9221
http://www.agrobiologicals.com
(Mycostop biofungicide)

Agra Tech, Inc. (G)
2131 Piedmont Way
Pittsburg, CA 94565
925-432-3399
http://www.agra-tech.com
(greenhouses)

Agro Dynamics
4300 L. B. McLeod Road, Suite C
Orlando, FL 32811
407-872-2250
http://www.agrodynamics.com
(rockwool)

A&L Southern Agricultural Labs
1301 W. Copans Road, Bldg. D#8
Pompano Beach, FL 33064
305-972-3255
http://www.al-labs.com

Agrisales, Inc.
P.O.Box 2060
Plant City, FL 33564-2060
813-754-8885
http://www.agrisales.com

Albert J. Lauer, Inc.
16700 Highway 3
Chippendale Ave. West
Rosemont, MN 55068
612-423-1651
(greenhouses)

American Plant Products & Services, Inc. (G, S)
9200 NW 10th Street,
Oklahoma City, OK 73127
1-800-522-3376
http://www.americanplant.com

Anderson Injectors
2100 Anderson Drive
P.O. Box 1006
Muskogee, OK 74401
918-687-4426
http://www.heanderson.com
(fertilizer injectors)

Atlas Greenhouse Systems, Inc.
Hwy. 82 East
P.O. Box 558
Alapaha, GA 31622
1-800-346-9902
http://www.atlasgreenhouse.com
(greenhouses)

Barnes Brothers Nursery & Garden Center
3359 Medgar Evers Blvd.
P.O. Box 12947
Jackson, MS 39236-2947
601-362-2448
(plastic nursery buckets)

BASF Corporation
102 Rowley Court
Apex, NC 27502-5932
813-960-2644
http://www.basf.com

BFG, Inc. (G, S)
14500 Kinsman Road
Burton, OH 44021
216-834-1883
1-800-883-0234
http://www.bfgsupply.com

BIO-COMP
2116-B Bio-Comp Drive
Edenton, NC 27932
919-482-8528

Bobby's Eastside Market
Route 1, Box 113
Philadelphia, MS 39350

Buckman Laboratories, Inc.
1256 N. McLean Blvd.
Memphis, TN 38108
901-274-8316
http://www.buckman.com

The Buffalo Co., Inc.
503 E. Lakeshore Drive
Ocoee, FL 34761
407-656-3118

BWI, Inc. (G, S)
6013 McRaven Road
P.O. Box 20407
Jackson, MS 39209
1-800-395-2580
http://www.bwicompanies.com

Carolina Greenhouses (G)
P.O. Box 1140
Kinston, NC 28503
919-523-9300
http://www.carolinagreenhouses.com
(greenhouses)

CASSCO (G, S)
U.S. Highway 231, North
P.O. Box 3508
Montgomery, AL 36193
1-800-933-5888

Cathedral Greenhouses
252 West Leavell Woods Drive
Jackson, MS 39212
601-372-1904
(hobby greenhouses)

Caves Enterprises, Inc. (G)
40529 Pumpkin Center Road
Hammond, LA 70403
1-800-535-0800
(greenhouses)

Century Tube Corp.
P.O. Box 7612
Pine Bluff, AR 71611
1-800-643-1523
www.century-tube.com
(greenhouses)

Chapin Watermatics, Inc.
2192 Meadow Lark Road
Spring Hill, FL 34608
904-686-5007
http://www.chapindrip.com
(irrigation)

Chilean Nitrate Corporation
9212 County Line Road
Lithia, FL 33547
941-425-9538
http://www.cncusa.com
(fertilizer)

Compu-Heat
7589 Race Road
North Ridgeville, OH 44039
1-800-776-6829
(waste oil burners/heaters)

Conley Manufacturing & Sales (G)
4344 E. Mission Boulevard
Montclair, CA 91763
1-800-377-8441
http://www.conleys.com
(greenhouses)

Continental Products Company
1150 East 222 Street
Euclid, OH 44117
216-531-0710
http://www.continentalprod.com
(shade compound)

CO-EX Corporation
5 Alexander Drive
Wallingford, CT 06492
1-800-888-5364
http://www.co-excorp.com
(greenhouses)

Coor Farm Supply
3 Malta Street
P.O. Box 525
Smithfield, NC 27577
1-800-999-4573
http://www.scnla.com/coor_farm.htm

CropKing, Inc. (G, S)
5050 Greenwich Road
Seville, OH 44273-9413
330-769-2002
http://www.cropking.com
(greenhouses)

Daniel Label Printing, Inc.
3021 Lincoln Avenue
North Little Rock, AR 72114
501-945-1349
http://www.dlpforlabels.com
(labels)

Dave Butler Rice Hull Compost, Inc.
6021 SR 221
Georgetown, OH 45121-9401
1-800-622-4936
(rice hulls)

De Ruiter Seeds, Inc.
3001 Bethel Road, Suite 207
P.O. Box 20228
Columbus, OH 43220
614-459-1498
http://www.deruiterusa.com
(seeds for greenhouse vegetables)

Dosatron International, Inc.
2090 Sunnydale Boulevard
Holcomb, KS 67851
813-443-5404
http://www.dosatron.com
(fertilizer injectors)

Eakes Nursery Materials, Inc.
249 Bethel Church Road
Sanford, MS 39479
601-722-4797
(ground pine bark)

Energy Management Systems
12560 West River Road
Clearwater, FL 34625-1201
1-800-999-3781

Florida Seed Co., Inc.
4950 Frontage Road South
Lakeland, FL 33801-3193
1-800-342-7333
(seeds)

Forestry Suppliers, Inc. (S)
205 W. Rankin Street
P.O. Box 8397
Jackson, MS 39284-8397
1-800-682-5397
http://www.forestry-suppliers.com
(instruments, wide range of supplies)

GB Systems, Inc.
P.O. Box 19497
Boulder, CO 80308
303-473-9144 (CO office)
216-353-9437 (OH office)
(biologicals, bumblebees)

General Supply Corporation (S)
303 Commerce Park Drive
P.O. Box 9347
Jackson, MS 39286-9347
1-800-647-6540
http://www.generalsupplycorp.com

George Dodd's Nursery Supply
9100 Church Street
P.O. Box 86
Semmes, AL 36575
1-800-821-0243
(ground pine bark)

Glasteel Tennessee
830 Highway 57
Collierville, TN 38017-5202
1-800-238-5546
http://www.glasteel.com

Gothic Arch Greenhouses
P.O. Box 1564
Mobile, AL 36633
1-800-531-4769
1-334-432-7529
http://www.gothicarchgreenhouses.com
(hobby greenhouses)

Grainger's (S)
3551 I-55 South, West Frontage Road
Jackson, MS 39201-4963
601-352-0891
http://www.grainger.com
(motors)

Grayson Research
1040 Grayson Farm Road
Creedmore, NC 27522
919-528-4925

Green Thumb Group, Inc.
3380 Vengard, Suite Two
Downers Grove, IL 60515
(greenhouse screening)

Gromax Plasticulture, Inc.
2250 Gulf Gate Drive, Suite A
Sarasota, FL 34231-4838
904-432-0962
http://www.gromax-int.com/home
frame.htm
(vertical towers)

Grower's Supply Center (S)
3000 South Highway 77, Unit 214
Lynn Haven, FL 32444
850-785-8974

Guelph Twines LTD.
50 Crimea Street
P.O. Box 125
Guelph, Ontario, N1H 6J6
519-821-9140
(plastic twine)

Hardy Mfg. Co., Inc.
Route 4, Box 156
Philadelphia, MS 39350
1-800-431-3239
(wood heaters, waste oil burners)

Hummert International (S)
4500 Earth City Expressway
Earth City, MO 63045
1-800-325-3055
http://www.hummert.com

Hydrogardens, Inc. (G, S)
P.O.Box 25845
Colorado Springs, CO 80936
1-800-634-6362
http://www.hydro-gardens.com
(general supplies, seeds, fertilizers)

Imperial Builders & Supply Inc.
P.O.Box 670
Apopka, FL 32704-0670
1-800-442-4147
407-889-4147
http://www.imperialbuilders.com
(greenhouses)

IPM Laboratories
Main Street
Locke, NY 13092
315-497-3129
http://www.ipmlabs.com

Irrigation Mart, Inc.
3303 McDonald Avenue
Ruston, LA 71270-7412
1-800-729-7246
http://www.irrigation-mart.com
(irrigation)

Janco Greenhouses
9390 Davis Ave.
Laurel, MD 20723
1-800-323-6933
http://www.jancoinc.com
(greenhouses)

J. A. Nearing Co., Inc.
9390 David Avenue
Laurel, MD 20810
301-498-5700

J-F Equipment Co.
1230 Crowley Drive
Carrollton, TX 75006-1315
1-800-344-6767
(Dosmatic injectors)

J. M. McConkey & Co. (G, S)
12321 Western Avenue
Garden Grove, CA 92641
714-894-0581
http://www.mcconkeyco.com

J&M Industries, Inc. (S)
300 Ponchatoula Parkway
Ponchatoula, LA 70454
504-386-6000
http://www.jmindustries.com
(produce packaging supplies)

Jaderloon Co., Inc. (G, S)
P.O. Box 685
Irmo, SC 29063
803-798-4000
1-800-258-7171
http://www.jaderloon.com
(greenhouses)

Keeler-Glasgow Co., Inc.
P.O. Box 158
Hartford, MI 49407
1-800-526-7327
http://www.keeler-glasgow.com
(greenhouses)

Klink Bros., Inc. (G)
4369 Circle Avenue
Castro Valley, CA 94546
415-581-7905

Koppert USA
P.O. Box 19497
Boulder, CO 80308-2497
216-353-9437
http://www.koppert.com
(biological control, bumblebees)

L & L Greenhouses (G)
P.O. Box 90
Poyen, AR 72128
1-800-843-9686

Ludy Greenhouse Manufacturing
Corp. (G)
P.O. Box 141
New Madison, OH 45346
1-800-255-LUDY
http://www.ludy.com
(greenhouses)

Micro-Macro International, Inc.
183 Paradise Blvd. Suite 108
Athens, GA 30607
706-548-4557
(laboratory analysis)

Mid-South E, Inc.
2015 Jackson Street
Monroe, LA 71202
318-322-7239
http://www.midsouthextrusion.com

Mycogen Corporation
5701 SE 22nd Place
Ocala, FL 34471
904-624-1224
http://www.mycogen.com/
Index_NoCookie.asp
(biologicals)

Neogen Corporation
620 Lesher Place
Lansing, MI 48912
1-800-234-5333
http://www.neogen.com
(disease test kits)

Nexus Greenhouse Corporation (G)
10983 Leroy Drive
Northglenn, CO 80233
1-800-228-9639
http://www.nexuscorp.com
(greenhouses)

Paramount Seeds, Inc.
P.O. Box 1866
Palm City, FL 34991
561-221-0653
http://paramount-seeds.com
(seeds)

Penick's Forest Products
P.O. Box 479
Macon, MS 39341
601-726-5340
(bark, topsoil, pine posts/poles)

Peter Lederer
P.O. Box 271
Big Flats, NY 14814
607-562-8267

Peters Fertilizer Products
The Scotts Company
14111 Scotts Lawn Road
Marysville, OH 43041
1-800-492-8255
http://www.scottsco.com/
(greenhouse tomato fertilizers)

Phillips Brothers Pine Bark
Processing
County Farm Road
Brookhaven, MS 39601
601-833-7858
(pine bark - in bags or bulk)

Plant Products Co., Ltd.
6100 Maryhurst Drive
Dublin, Ohio 43017
614-717-0330
(rockwool, fertilizers, beneficials)

Plantel Nurseries, Inc.
P.O. Box 66553
Los Angeles, CA 90066
310-390-4711
http://www.plantelnurseries.com
(seedling trays)

Poly Drip Irrigation Supply
13799 Airline Highway
Baton Rouge, LA 70817
1-800-676-0979
http://www.polydrip.com
(irrigation)

Poly Growers Greenhouse Co.
P.O. Box 359
Muncy, PA 17756
(greenhouses)

Poly-Tex, Inc. (G)
P.O. Box 458
Castle Rock, MN 55010
1-800-852-3443
http://www.poly-tex.com
(greenhouses and accessories)

Pro-Gro Products
841 Pro-Gro Drive
Elizabeth City, NC 27909
1-800-334-3311

Radiant Equipment Co.
P.O. Box 949
San Andreas, CA 95249
209-754-1801

Roberts Irrigation Products, Inc.
700 Rancheros Drive
San Marcos, CA 92069-3007
619-744-4511
http://www.robertsirrigation.com
(irrigation)

Rough Brothers (G)
5513 Vine Street
Cincinnati, OH 45217
1-800-543-7351
http://www.roughbros.com
(greenhouses)

Rounhouse Mfg. Co. (G)
P.O. Box 1744
Cleveland, TX 77327
713-593-1118
(shade cloth, ground covers, etc.)

S & M Farm Supply, Inc. (S)
13690 SW 248th Street
Homestead, FL 33032
1-800-432-3411
352-620-5581

San Joaquin Sulfur Co.
P.O. Box 700
Lodi, CA 95241
209-368-6676
(sulfur)

Soil Mender Products
3071 HWY 86
Tulia, TX 79088
806-627-4276
www.soilmender.com
(compost)

Solar Components Corporation (G)
121 Valley Street
Manchester, NH 03103
603-668-8186
http://www.solar-components.com/default.htm

Solar Prism Greenhouses (G)
P.O. Box 40-PC4
Amity, OR 97101
1-800-711-7336
http://www.countryfamily.com
(hobby greenhouses)

Southern Agricultural Insecticides
P.O. Box 429
Hendersonville, NC 28793
704-229-2233
http://www.southernag.com

Southern Time and Alarm
1057 South Jackson Drive
Terry, MS 39170
601-878-5066
http://www.fugitt.com/index2.htm
(alarms, computer controls)

Spectrum Technologies, Inc. (S)
12010 South Aero Drive
Plainfield, IL 60544
1-800-436-4440
http://www.specmeters.com
(EC, pH meters, instrumentation)

Steuber Distributing Co.
P.O. Box 100
Snohomish, WA 98290
1-800-426-8815
http://www.steuberdistributing.com
(greenhouses)

Structures, Unlimited (G)
2122 Whitfield Park Avenue
Sarasota, FL 34243-4048
813-756-8129
1-800-541-8129
http://www.structuresunlimitedinc.com
(greenhouses)

Stuppy Greenhouse Manufacturing, Inc. (G, S)
1212 Clay Street
P.O. Box 12456
North Kansas City, MO 64116
1-800-733-5025
http://www.stuppy.com
(greenhouses)

Sunderman Mfg Co.
47143 250th Street
Baltic, SD 57003-5200
1-800-843-3312
http://www.sundermanmfg.com
(heating systems)

Taylor Manufacturing, Inc.
P.O. Box 518
Elizabethtown, NC 28337
1-800-545-2293
http://www.taylormfg.com
(wood heaters)

Terra International
P.O. Box 157
Flora, MS 39071
601-879-3802
http://www.terraindustries.com
(fertilizers, chemicals)

Texas Greenhouse Company (G)
2524 White Settlement Road
Fort Worth, TX 76107
817-335-5447
1-800-227-5447
http://www.texasgreenhouse.com
(greenhouses and accessories)

TotalGro
P.O. Box 805
Winnsboro, LA 71295
318-435-7587
1-800-433-3055
http://www.grannyshouse.com/page.cfm/1035
(fertilizers)

Tubular Structures (G)
129 Radcliff Drive
Lucedale, MS 39452
601-947-9558

United Greenhouse Systems
708 Washington Street
Edgerton, WI 53534
1-800-433-6834
http://www.unitedgreenhouse.com
(greenhouses)

United Irrigation Supply, Inc.
Highway 84 West
P.O. Box 854
Quitman, GA 31643
912-263-9393
(irrigation)

United States Plastic Corp.
1390 Neubrecht Road
Lima, OH 45801-3196
1-800-821-0349
http://www.usplastic.com
(polyethylene tanks)

Van Wingerden Greenhouse Co. (G)
4078 Haywood Road
Horseshoe, NC 28742
704-891-7389
http://www.van-wingerden.com
(greenhouses)

Vicksburg Chemical Company
5100 Poplar Avenue, Suite 2408
Memphis, TN 38137
http://www.kpower.com
(fertilizers)

Wager Company of Florida, Inc.
P.O. Box 520296
Longwood, FL 32752-0296
407-834-4667
http://www.wagerco.com
(irrigation and parts)

The Warehouse
601 Chestnut Street
P.O. Box 699
Summit, MS 39666
601-276-7318
(irrigation)

Westmark Co. (G, S)
3529 Touriga Drive
Pleasanton, CA 94566
415-846-8505

Winandy Greenhouse Co., Inc.
2211 Peacock Road
Richmond, IN 47374
765-935-2111
(greenhouses)

X. S. Smith, Inc. (G)
Drawer X
Red Bank, NJ 07701
1-800-631-2226
http://www.xssmith.com

Z-Top Greenhouse Co., Inc. (G)
64575 Gisclard Road
Plaquemine, LA 70764
504-687-2161
(self-ventilating greenhouses)

Zarn, Inc. (S)
P.O. Box 1350
Reidsville, NC 27320
1-800-367-7687
(plastic containers)

Appendix III. Associations and Short Courses

American Society for Plasticulture
Pat Heuser, Executive Secretary
526 Brittany Drive
State College, PA 16803
814-238-7045
Fax: 814-238-7051
Annual Meetings
Proceedings
Newsletter

Hydroponic Society of America
P.O. Box 1183
El Cerrito, CA 94530
510-232-2323
Fax: 510-232-2384
http://hsa.hydroponics.org/
Annual Meetings
Proceedings
Newsletter
Book Supply Service

Mississippi Fruit and Vegetable Growers Association
Dr. John Braswell, Secretary
South Mississippi Branch Experiment Station
Box 193
Poplarville, MS 39470
Annual Tri-State Fruit and Vegetable Conference
http://www.msstate.edu/dept/cmrec/mfvga.htm

Mississippi State University Extension Service
Truck Crops Branch Experiment Station
P.O. Box 231
Crystal Springs, MS 39059
601-892-3731
Annual Greenhouse Tomato Short Course (March)
http://www.msstate.edu/dept/cmrec/GHSC.htm
Vegetable Press Newsletter
http://www.msucares.com/newsletters/vegpress/index.html

North Carolina Greenhouse Vegetable Growers Association
C/o Dr. Mary Peet
Room 220, Box 7609
Kilgore Hall
North Carolina State University
Raleigh, NC 27695-7609
Annual Short Course
http://www.ces.ncsu.edu/depts/hort/greenhouse_veg/ncgvga.html

Ohio State University Extension Service
Agricultural Business Enhancement Center
440 E. Poe Rd., Suite 201
Bowling Green, OH 43402-1351
419-354-6916
Fax: 419-354-6416
Annual Greenhouse Food Production Short Course (February)
Proceedings
Ohio Hydroponic Vegetable Program
Hydroponic Study Group
Greenhouse Tours

Rutgers University
Dr. A. J. Both, Assistant Extension Specialist
The State University Of New Jersey
Bioresource Engineering
Department of Plant Science
20 Ag Extension Way
New Brunswick, NJ 08901-8500
732-932-9534
Fax: 732-932-7931
Annual Short Course – "Design of Greenhouse Systems" (January)
http://aesop.rutgers.edu/~horteng

Southern Greenhouse Vegetable Growers Association
Terri Buckler, Secretary
P.O. Box 654
Winnsboro, TX 75494
903-365-2457
http://www.sgvga.org
Annual Meetings in Texas (Third weekend in July)
Proceedings
Members receive Vegetable Press Newletter

The mailing address for the author is Truck Crops Branch Experiment Station, P.O. Box 231, Crystal Springs, MS 39059; telephone (601) 892-3731, fax (601) 892-2056. For those with access to the internet or e-mail, you can reach Dr. **Richard Snyder** at Ricks@ext.msstate.edu.

The author gratefully acknowledges the faculty and staff at the Truck Crops Branch Experiment Station and expresses appreciation for their hard work in assisting with the greenhouse research in Crystal Springs. This research is the basis for much of the information in this publication.

This publication is also available on the web at http://www.msucares.com/pubs/pub1828.htm.

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P1828
Extension Service of Mississippi State University, cooperating with U.S. Department of Agriculture. Published in furtherance of Acts of Congress, May 8 and June 30, 1914. MELISSA J. MIXON, Interim Director
POD 01-10

MISSISSIPPI STATE UNIVERSITY
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