Agricultural Extension Service
The University of Tennessee
PB 1609

Commercial Greenhouse Tomato Production

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Introduction

Greenhouse tomato production offers interested growers an opportunity to produce a marketable product at times when supplies are low. It increases the length of time tomatoes are available and improves buyer interest in the area. However, greenhouse tomatoes must be sold for a higher price per pound than field tomatoes to justify the higher production costs. This means the system offers profitable opportunities in the spring before field tomatoes are harvested, and in the fall when field tomatoes have been depleted. Greenhouse tomatoes are usually grown for local sales in Tennessee.

In the spring, plants set more fruit per plant and the heating cost is less, making spring production more profitable than fall production. Also, in the spring, light intensity and duration increase as outside temperatures increase, making it less costly to heat and provide ventilation and humidity control. All of these result in increased yields. In the fall, increased heating costs, greater pollination labor and lower fruit set occur at a time when the average price is not as high as in the spring, resulting in lower profits. However, research being done at The University of Tennessee indicates that fall tomatoes can be profitably produced if plants are transplanted by August 15.

Disease and insect problems can be major difficulties in greenhouses. To reduce such problems, growers must develop good sanitation, prevention and ventilation programs. Just because crops are grown in enclosed structures does not eliminate such problems.

In addition, interested growers should keep in mind that:

1. Greenhouse tomatoes have cultural requirements unlike other crops, such as field tomatoes, tobacco and other crops common to Tennessee. Even growers of field tomatoes may have difficulty growing greenhouse tomatoes without a significant amount of learning time. The management practices are different from those of field tomatoes and will require some production experience.

2. Greenhouse tomatoes are not an easy crop to grow profitably. Growing time, temperatures, pollination, irrigation, fertilization, disease and insects, as well as weeds in a soil system, require different management techniques than outdoor crops. Fertilization of hydroponic systems requires both good management practices and a knowledge of how to mix and apply nutrient solutions in accordance with crop growing conditions. Because of the differences compared to field tomatoes, it is more difficult to grow them in greenhouses.

3. The labor necessary to grow greenhouse tomatoes is much greater on a per-unit basis than that of any field or vegetable crop. The production practices involved require a significant amount of time. The estimated average labor requirement for a 30-foot by 100-foot greenhouse is about 25 person hours per week. With grower experience, this time may be reduced. More time is needed during transplanting and harvest, but less time per plant will be required from transplanting to harvest. Make adequate labor provisions before the labor is actually required.

4. Greenhouse tomatoes require attention on a consistent basis. They cannot be planted and then forgotten for a few days or weeks, as sometimes occurs with other crops. Because there are so many problems that can arise quickly, they require daily observation and attention during the growing season, and the house will require a sanitation program between crops.

5. The greenhouse environment is not problem-free. The problems with greenhouse tomatoes are almost analogous to raising animals in confinement. The higher humidity, temperature and lush green foliage create conditions that enable certain diseases and insects to thrive. In addition, pollination is affected because of less pollen shed. Under these conditions, house ventilation management and pest control programs are essential requirements of production.

Tomato Production Systems

Two systems exist for greenhouse tomato production. They are referred to as either soil or soilless culture. Soil culture means that tomatoes are grown under a greenhouse cover in a plot of soil using similar techniques to those used in the field. Soilless culture (also called hydroponics) refers to growing tomatoes where the necessary fertilizers are delivered to the root system in balanced levels in water solution. With soilless systems, plant roots are growing in water, sand, wood bark or an artificial soil mix available through various greenhouse suppliers.

Of the two systems, the soil system has proven to be the most widely used in Tennessee. Counties using this system have usually increased their number of greenhouses, while most soilless systems have not remained in operation for more than two or three crops due to the high initial cost.

Soil: When the soil system is used, the overall house construction cost is about one-fourth to one-third that of certain soilless systems. Soil systems enable the movement of a house to a new location after two or three years' production if soil disease problems result. The land can then be used to grow a different crop.

With the soil system, a greenhouse structure is constructed over the designated plot of land. There is no land excavation involved as in soilless systems. The house is constructed to fit the slope of the land. Fertilization and staking are almost identical to that of field tomatoes. The house is constructed to enable maximum ventilation. This usually includes double-wide doors at each end with fans positioned high enough in each end to reduce the potential for cold air to be ventilated directly onto the growing plants. Such houses may also have side roll-up capability or windows to increase the ventilation. Double-wide doors also enable the movement of both land preparation and cultivation equipment into the house.

If a fall crop is to be grown in a soil system, it is best to start and grow plants under natural weather conditions for about 1 to 1$^1/_2$ months before the greenhouse must be closed continuously. This will enable plants to get off to a good start and will increase the potential for good set on the first fruit clusters. However, irrigation will be necessary to grow the plants due to the hot, dry weather that is likely at the time of transplanting in August. Drip irrigation is the preferred type to use in greenhouse systems.

Soilless: Nutrient delivery systems and nutrient holding tanks for certain types of soilless systems are being sold with permanent installations that cannot be conveniently moved. These systems require nutrient troughs, plumbing, pumping systems and stock tanks. When they become contaminated with bacteria or fungi, a very rigid and costly sanitation program must be implemented between each crop. Once contamination becomes prevalent, it is very costly to move such a facility. The presence of higher levels of water in certain systems increases greenhouse humidity, making humidity control more difficult than in soil houses. In addition, such systems frequently use expensive and complex computer systems. However, it is possible to develop soilless nutrient tanks that are portable and less costly than permanent systems. Some systems include the "grow-bag" and "composted-cotton" artificial media that add water and nutrients through drip tubing. Such systems are normally less expensive than other soilless systems and they can be used in combination with growers who grow plants using the "float system."

Nutrient solutions must be mixed, maintained and delivered through a trough or pipe delivery to the root system on a regular basis. The nutrient pH and nutrient balance are quite important, since there are 13 nutrients required for production. Each has a different concentration requirement in the nutrient solution that must be maintained. Obtaining both proper balance and application frequency based on plant utilization is not a task for an individual who has no experience with such systems.

To illustrate the different concepts of production, a schematic diagram of the interior of the two systems is provided in Figure 1.

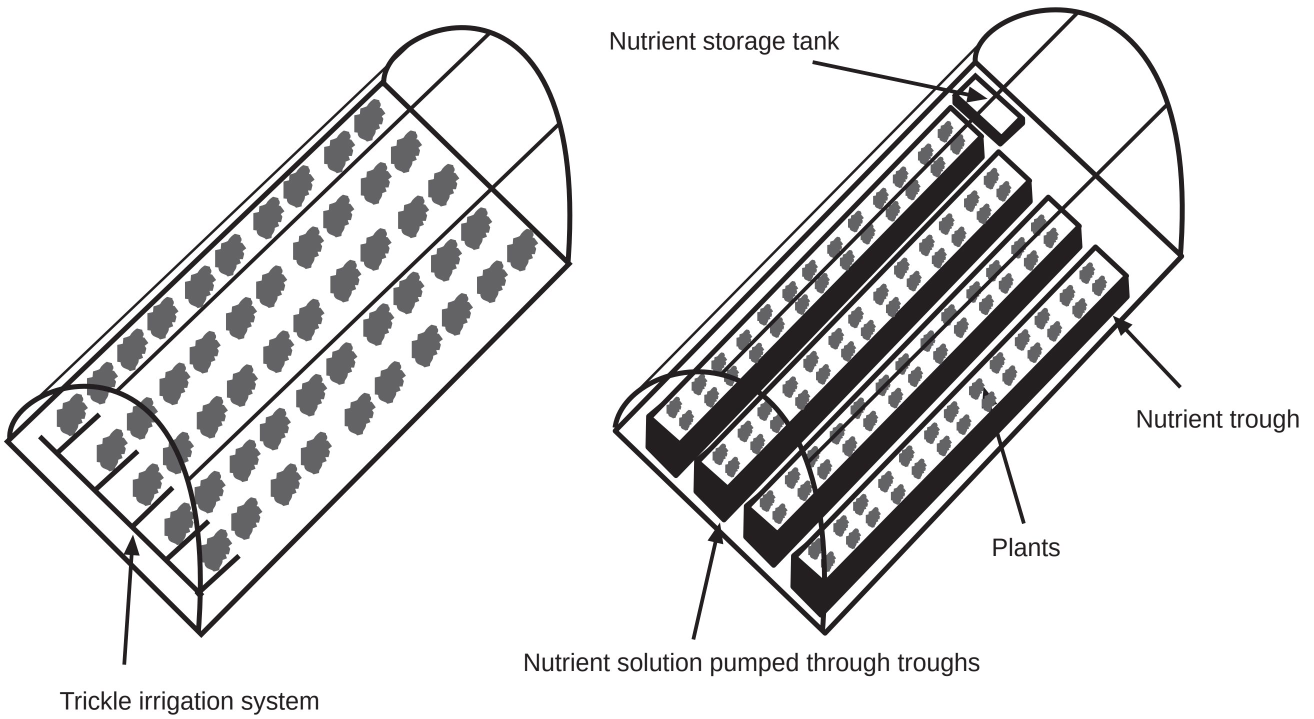


Figure 1. Illustration of basic greenhouse systems (soil house on left. Soilless system on right.)

Greenhouse Site Selection

Select a site that is in full sun and slightly elevated so there will be good air movement and ventilation. If soil culture is planned, the soil should be well-drained, medium-textured and fertile. Avoid sites with a history of disease or weed problems. If the site is infested with a perennial weed, it may need to be treated with Roundup® prior to constructing the house. Treat while the weeds are actively growing. Locate the site near a clean water supply that is adequate for the size of house desired.

For soil culture, the floor can be either level or sloped if trickle irrigation is planned. Certain soilless systems require level floors to install the growing troughs suitable for nutrient delivery across the roots. The "grow-bag" system is feasible on sloping land with trickle irrigation.

Greenhouse Structures

Quonset-type greenhouses using galvanized pipe as the main structural materials with double-layer polyethylene (plastic) covers are the most common type of greenhouse structures, regardless of the production system being used. Double-layer poly is separated by a small fan delivering air between the two layers. This reduces the heat cost by 30 to 40 percent compared to a one-layer system. These greenhouses are the most economical to construct and to move if necessary.

For soil culture, the supporting structures and double-wide end doors should be constructed to allow the use of small tractor equipment within the house. The double doors can provide ventilation capability, as well as allowing equipment access for cultivation or soil preparation. House sidewalls can be constructed to enable side roll-downs or draw-down windows to increase air movement during appropriate weather conditions. Continuous soil culture may require fumigation to keep disease problems to a minimum. Treatments are more effective if the fumigant is injected and covered with plastic. This type of construction also makes land preparation and plant residue removal much easier.

Design heating capabilities into a greenhouse structure to provide plant protection during the cooler growing months. Also, install cooling fans and small doors for days when the large doors should not be completely opened.

Due to the plant supports required, certain soilless culture structures will require stronger support and bracing structures than a soil house. In many situations, soilless-culture tomatoes are supported by drop strings from overhead pipes to individual plants below. One row of tomatoes containing 80 plants in a 100-foot house has the potential to develop up to 1500 pounds of weight that requires support. Thus, if all rows are supported from drop strings from the overhead supports, the potential weight load from plants and fruit will approximate five tons. Supports for soil production are provided by stakes, the same as for field tomatoes.

Cultivars or V arieties

The first step to growing good greenhouse tomatoes is to select a cultivar or variety that produces the size, shape and color of fruit desired for the market. The cultivar or variety you choose should also set a high number of fruit per plant. Because of high production costs, the number of fruit per plant is very important when considering the potential for a profitable operation. Even though seed costs are quite high for hybrid seed, seeds are still the least expensive cost involved in growing greenhouse tomatoes. Thus, a grower should not look for the lowest cost seed when choosing a cultivar because it is impossible to produce a good-quality product from low-quality seed or plants. There are many cultivars of tomatoes on the market, but only a few have been developed specifically for growing in greenhouses. However, growers are learning that certain other varieties will produce a suitable product.

Cultivars for Soilless Culture: Tomato cultivars for production in greenhouses have been developed primarily in Holland. Thus, several of the seed companies that supply them are in Holland and other European countries. Some, however, have distribution points in the United States. They are De Ruiter Seeds, Inc. (614-459-1498), Bruinsma Seeds (owned and distributed by Asgrow (601-845-7125) and Nunhems (Canners Seed Corporation in the U.S., 208-754 8666). Cultivars that are presently being grown are 'Caruso' and 'Trust' from De Ruiter and 'Dombito' and 'Dombello' from Asgrow-Bruinsma, as well as Rupp Seeds in the U.S. (419-337 1841). 'Trust' is showing very good performance in the fall at The University of Tennessee in Knoxville.

Cultivars for Soil Culture: Established greenhouse tomato growers are presently growing the determinate varieties, "Celebrity," "Mountain Pride" and "Mountain Fresh." A 'determinate' type is one that normally sets a high number of fruit on a plant that stops growing at a height of 4 to 5 feet. However, a few growers are still growing the 'indeterminate' (one that does not terminate growth at a low height) types such as "Better Boy" and "Fantastic." These cultivars are available from several U. S. seed companies.

Growing Time

There are two periods for economically growing greenhouse tomatoes in Tennessee. One is in the spring and the other is in the fall.

Spring: For spring production, time the crop to transplant in the greenhouse in late February or early March. This means that seeding must be done the last week of December or in early January. Both personal observation and grower experience indicate that this is a relatively good time to grow spring tomatoes. Plants are transplanted at a time when the heat requirement is decreasing, day length and light intensity are increasing and outdoor temperatures are increasing. This makes it more conducive for daily ventilation. Ventilation helps in drying the tomato foliage and reducing disease problems, as well as improving pollen shed due to a lower humidity in the greenhouse, compared to poor ventilation and high humidity. Experience has shown that keeping the foliage as dry as possible with sufficient air movement to enhance pollen shedding has more than doubled per-plant yields. Due to these factors, spring production is practiced more widely than fall production.

Fall: Present research work being conducted at The University of Tennessee in Knoxville and cooperative trials with local growers indicate that it is possible to profitably grow fall tomatoes if plants are transplanted to the greenhouse by August 15. Planting at this time enables plants to set a high number of fruit while the temperatures and light intensity are still high, ventilation is still quite feasible and heating requirements are low. High numbers of fruit per plant set under these conditions can usually be matured at a profit.

Questions may arise concerning production in December, January, February and March. If tomatoes can be grown profitably at this time, there is usually no problem in selling them on a local retail market. However, there are more serious problems in obtaining a profitable yield during these months than during the spring or fall. Low outdoor temperatures make it highly improbable to provide good ventilation to control humidity. Under such conditions, leaf mold usually becomes a major problem. Flowering and fruit set are reduced, which results in low yields per plant. Low light intensity reduces fertilizer uptake, resulting in reduced fruit size and visual fertilizer deficiency symptoms on the foliage. Heat costs increase due to lower temperatures, resulting in higher production costs. In general, producing during the winter has not proven to be profitable due to high fuel costs and low yields.

Growing Plants

A major recommendation is to start plants and grow them under disease-free conditions. It is much better to grow your own plants rather than risk importing certain diseases or insects that transmit diseases. Plants can either be grown in a greenhouse with protective systems for a spring crop, or the “float plant” system can be used to effectively start plants for a fall crop. For further information on growing plants, refer to **Extension PB 819**, “**Vegetable Transplant Production**,” available at your county Extension office. When plants are transplanted to the greenhouse, they should not be infested with diseases. Starting with plants that are disease-free increases the potential for controlling diseases during the growing season.

Use sterilized growing media and growing containers. Start plants from seed rather than using suckers from an already-existing crop. Suckers may already be heavily infested with diseases such as early blight if good control programs have not been practiced.

Start seed in seed flats and transplant to individual containers or to plant cells (when using the float system) when the first true leaves are visible. Keep the growing media moist but not saturated. Depending upon the fertilizer supplied with the growing media, it may be necessary to provide low levels of fertilizer during the growing stage. When the float system is used to grow fall plants outdoors, about six ounces of water-soluble 20-20-20 fertilizer per 100 gallons of water should provide plants about 8 inches tall within five or six weeks. Plants grown in the “float system” for fall production will need to be hardened for a few days before they are transplanted to the greenhouse. Plants can be easily hardened by removing them from the float bed about one week prior to the expected transplant date. They can be held in partial shade for a day or two, then moved to full sun with appropriate watering as necessary.

The conditions under which plants are grown will influence the number of flowers formed and the number of fruit set per cluster. For spring plants, research has indicated that the number of fruit on the first cluster is increased if the nighttime temperature can be held between 50 and 55 degrees from first true leaf development until the first flower cluster is fully developed. To obtain maximum yields, try to set an average of five to seven fruit per cluster.

Temperature conditions suitable for good plant growth are outlined in Table 1.

Table 1. Temperature Requirements for Growing Greenhouse Tomatoes

Growth stage	Temperature (degrees F)	
	Night	Day
1. Seed germination.	65-70	65-70
2. For spring crop, after seed leaves unfold, begin a "cold treatment" and continue for 10-14 days.	53-55	55-60
3. From "cold treatment" until plants are trasplanted into greenhouse.	60-65	65-70
4. During flowering and fruiting.	60-65	65-86

Seeding Dates

The approximate seeding dates for two crops are:
Spring crop: Late December through early January
Fall crop: Late June through early July

Transplanting Dates

Transplanting into the greenhouse should occur about seven to eight weeks from the seeding date, or about February 25 to March 5 for a spring crop, and August 10 to 20 for a fall crop. Avoid setting plants on a ridge. This makes roots very susceptible to damage by cultivation.

Plant Spacings

Soil Systems: For the soil system, plants can be spaced 15 to 20 inches apart in the row and 42 to 54 inches between rows. This will accommodate good movement about the plants for suckering, supporting, spraying and harvesting. Plants grown in a soil system are usually trained, staked and tied using the "Florida Weave" system common to field production. For further information about this system, refer to **Extension PB 737, "Staked Tomato Production in Tennessee,"** available at your county Extension office.

Soilless Systems: For the soilless system, 42-inch wide troughs can be used to grow two rows, with plants spaced 10 inches inward from each side of the trough and on a 18x24 inch spacing, as illustrated in Figure 2. Growers who use the "grow-bag" system normally lay the bags end-to-end, space two or three plants per bag, and separate them about 3½ feet between rows.

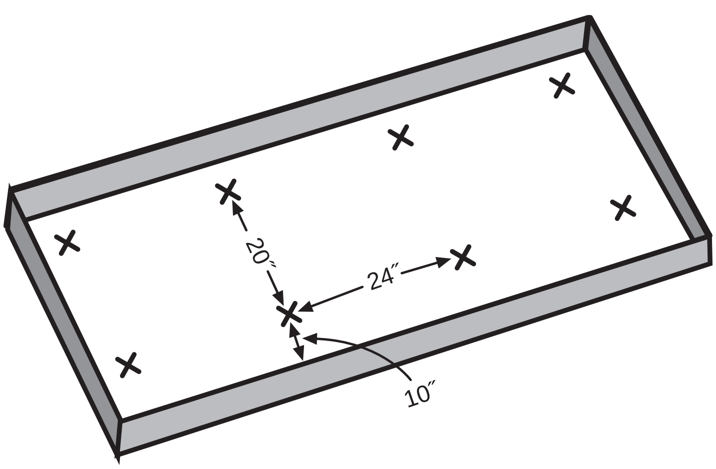


Figure 2. Schematic of a trough used for soilless production of tomatoes

Tomatoes grown in soilless systems are usually trained to a one-stem system due to the closeness of plants. However, growers can avoid heavy pruning by wider spacings, if desired.

Plants Required

The plants required in a 30-foot by a 100-foot greenhouse at spacings for the two systems are shown in Table 2.

Table 2. Plant spacings and plant requirements for greenhouse tomatoes.

Soil Systems

In row (inches)	Between row (inches)	Rows per house	Total plants
15	42	8	640
15	48	7	560
15	54	6	480
18	42	8	535
18	48	7	466
18	54	6	400
20	42	8	480
20	48	7	420
20	54	6	360

Soilless Systems

Trough width	Plant spacing	Plants per trough	Total plants per house
42"	20" x 15"	144	720
42"	20" x 24"	90	450

Estimated Costs and Retur ns

Spring Crop Grown in Soil: The following budget is **merely a guide** to estimating costs and returns for soil-produced tomatoes grown in the spring in a 33-foot by 144-foot greenhouse. *(It should be used as a guide only because there is no guarantee that the figures provided will fit all* *situations. Growers must use their own figures in place of those included in this budget example when that information is known.)*

House Cost: Double-layer polyethylene covered; \$13,500 prorated 5 years = \$2,700 per year.

a. If house is prorated 3 years, annual cost is \$4,500/year.
b. Every third or fourth year, replacement of plastic must be included into the cost.

Table 3: Yields of 13 pounds per plant and 900 plants per house (This budget assumes top greenhouse management and production practices.)

Revenue:

Harvest season	Distribution of crop sales (%)	Total pounds sold	Price per pound	Total revenue
Early	40	4680	\$1.20	\$5,616
Mid	40	4,680	.90	4,112
Late	20	2,340	.50	1,170
Total	100	11,700	0.93 Av.	\$10,898

a. Determined by dividing the total revenue by total pounds sold.

Expenses:

Prorated house cost= 5 years	\$2,700.00
Prorated construction cost(\$0.65/ft^2 if done by self)	561.60[a]
Plants; \$.06 to grow x 900 plants	54.00
Total heat cost Jan - April	1,900.00
Electricity	50.00
Stakes and string	69.50
Bumblebees for pollination	190.00[b]
Fertilizer and lime	11.00
Fungicides	20.00
Insecticides	20.00
Irrigation supplies	70.00[c]
Irrigation water (if purchased)	200.00
Baskets	195.00
Labor[d]	891.00
Transportation	150.00
Interest (\$13,700 @ 7.25%)	978.75[e]
Total expenses	\$8,060.85[f]

a. Construction costs are pro-rated five years for a total of \$2,808.
b. A new hive should be purchased with each crop.
c. Irrigation supplies such as pumps, fittings and carrier lines are pro-rated for three years. However, unless a loan is taken to provide for this expense, the total cost is up front and is not pro-rated. Thus, this could be a one-time cost with the addition of replacement materials during the second and subsequent years.
d. Labor is calculated at \$5.25 per hour for a total of 170 hours.
e. Interest is included for a full year because it is assumed that a loan made over a 5-year period will probably require annual payments. However, as the principal is paid, the annual interest will decrease, causing the per-plant profit potential to increase.
f. This does not include a brokerage fee or insurance.

Returns **\$2,837.15**

Table 4: Net Return from Greenhouse Tomatoes at Varying Per-plant Production Costs and with High Yields

Total cost per plant[a]	Return/plant at an av. price of $0.93/lb and at per-plant yields of:				
	11 lbs.	12 lbs.	13 lbs.	14 lbs.	15 lbs.
$10.95	$(0.72)[b]	$0.21	$1.14	$2.07	3.00
9.70	0.53	1.46	2.39	3.32	4.25
8.95	1.28	2.21	3.14	4.07	5.00
8.46	1.77	2.70	3.63	4.56	5.49
8.10	2.43	3.06	3.99	4.92	5.85

a. Each of the figures in this column represents the per-plant production cost when the house cost is pro-rated 3, 4, 5, 6 and 7 years, respectively.
b. Numbers in parenthesis are negative. This means that either the production cost must be lowered or the yield must be higher to have a potential profit.

There have been situations when yields are much lower than those shown in Table 4.

However, total production costs do not change greatly when low yields occur. Let's consider the net returns under lower per-plant yields.

Table 5: Net Return from Greenhouse Tomatoes at Varying Per-plant Production Costs and with Low Yields

Total cost per plant[a]	Return/plant at an av. price of $0.93/lb and at per plant yields of:[b]				
	4 lbs.	5 lbs.	6 lbs.	7 lbs.	8 lbs.
$10.95	($7.23)	($6.30)	($5.37)	($4.44)	($3.51)
9.70	(5.98)	(5.05)	(4.12)	(3.19)	(2.26)
8.95	(5.23)	(4.30)	(3.37)	(2.44)	(1.51)
8.46	(4.74)	(3.81)	(2.59)	(1.95)	(1.02)
8.10	(4.38)	(3.45)	(2.52)	(1.59)	(0.66)

a. Same as "a" in Table 4.
b. This table is included to allow a comparison of the potential profit when production costs do not change, but yields are low. Numbers in parenthesis represent a negative profit. It is obvious from these figures that low yields are not a paying proposition at the per-plant production costs provided. Production under such conditions should be avoided. Low yields can result from improper planting time, improper ventilation, low light intensity, high nitrogen, improper nutrient balance, low pollination, incomplete combustion of heating materials and many other factors. Thus, any grower contemplating production under such systems must thoroughly weigh production practices that will consistently maintain high yields.

Comments: The above returns and expenses represent the economics of systems where growers transplant tomatoes into the greenhouse in late February or early March. There is no cost for house excavation because production occurs in houses adapted to the existing slope. Under such conditions, growers have normally completed harvest by the time field tomatoes from the area appear on the market. As a result, greenhouse growers normally receive a higher price than those with field tomatoes. However, the higher production costs indicate that greenhouse growers need to obtain good prices to be profitable.

Fall tomatoes: From the present research data at The University of Tennessee in Knoxville, it appears that tomatoes grown in containers with artificial growing media may turn a profit if they are transplanted by August 15 and are completely sold out by late November or early December. The reason is that certain production costs can be reduced in the fall compared to planting later than August 15. However, the statements that follow should be considered when evaluating the potential for fall tomatoes. Present research indicates that the greenhouse-developed variety "Trust" is producing yields in the 10 pound per-plant range during the fall rather than 12 to 15 pounds now commonly produced in the spring. This is almost double previous fall yields from research efforts in Knoxville. With lower production costs for an August 15 planting compared to later fall planting, one can evaluate the returns per plant at a lower yield in Table 4, even though 10 pound per-plant yields are not provided in either Table 3 or 4.

Some tobacco growers who grow plants in float beds and who have an interest in greenhouse tomato production for times when their house is not being used should grow fall tomatoes in artificial media or "grow bags." Balanced fertilization can then be provided through a trickle irrigation system. Where excavation of the property has occurred for the construction of float beds, it is not suitable to produce tomatoes in the excavated soil. To do so would require the replacement of top soil.

If tobacco producers growing float plants use their houses for tomato production, it is not likely that there will be a transfer of compatible diseases if there is a good sanitation program between the tobacco and tomato crops. Sanitation, however, is a key to reducing the potential for disease transfer. Sanitation should include changing the plastic liners used in the float beds and sterilizing existing concrete walkways, as well as existing walls and containers, by rinsing with a 10 percent chlorine solution.

In addition, the following cost-and-return items are likely to be different for fall tomatoes than for spring tomatoes.

1. Heat costs are likely to be about one-third lower if plants are transplanted no later than August 15.
2. Yields may be one-fourth to one-third lower than spring tomatoes due to lower light intensity, lower temperatures, less ventilation and pollination capability.
3. Fertilizer costs will probably increase in certain soilless systems, compared to soil culture, because of the necessity to provide water-soluble fertilizer and the labor involved in application. In addition, fall's low light intensity is likely to require a different frequency or rate of fertilizer application than spring-produced tomatoes.
4. Prices are not likely to approach the $1.20 per pound level common for spring tomatoes until all field tomatoes have cleared the market. However, some observations indicate that November/December tomatoes may receive slightly higher prices than the $1.20 per pound spring prices due to a low supply.
5. Ventilation requirements for August 15-transplanted tomatoes are high. Temperatures will be very high under the plastic cover during this time of year.
6. Because of higher temperatures, water requirements during August and early September will be very high for plant survivability, but will decrease as temperatures cool down. In the spring, the reverse is true as water requirements increase with temperature, foliage and fruit load.
7. As the growing season moves further into the fall, temperature problems will be less, and light intensity, humidity and ventilation problems will increase, resulting in decreased fruit set.
8. If a greenhouse has been excavated for float bed tobacco plant production, an excavation charge should be included in the above budget. This will provide an estimate of the profit potential if the excavation charge is to be pro-rated across both crops.

Markets: Unestablished growers will have to develop markets. Generally, buyers who have dealt with dependable growers over the years are reluctant to deal with someone who has not been in the business and has not yet developed a reputation as a dependable supplier. In the fall, it is likely that a local area could easily support tomato sales from one or more houses in that area. To evaluate wholesale profit potential, growers should have some wholesale price figures for the time of year they will be selling. Prices under those conditions are likely to be different from the $0.93 per pound average used to estimate returns in this budget.

The initial cost of a complete hydroponic house is two to four times that of a soil house, while the yields per plant are generally no greater with an equal growing time. Thus, the potential return on investment is usually less with a hydroponic house than with a soil culture house.

Fumigation of Soil Systems

Soil culture will eventually require the soil to be fumigated if continuous production occurs in the same location. Control will be needed for increasing problems with nematodes, verticillium, fusarium or various bacterial diseases. Unfortunately, fumigation will not eliminate all of the problems associated with greenhouse tomato production, but it will help to hold certain problems at a manageable level. However, manufacture and sale of the most commonly used fumigant, methyl bromide, is scheduled to be stopped by 2002. At the present time, there is no suitable substitute. However, work is under way to develop suitable replacements.

Remember to construct the house to allow small tractor equipment to enter and prepare the soil and to inject any planned fumigation materials. Best control occurs when the fumigant is injected and then covered with plastic. Due to warmer soil temperatures, fumigation is more effective if done in the fall. Fall fumigation also does not delay spring transplanting in February or March.

Plant residue must be either completely removed or turned under at least six weeks ahead of the planned date of fumigation. The residue must be completely decayed before fumigation or it will block the injectors, giving poor fumigation results. The soil should be prepared to a minimum depth of about 6 inches, preferably with a rototiller. This prepares the soil for satisfactory fumigation. It pulverizes large clods and assists in further breakdown of plant residue to enable effective and uniform injection.

The soil temperature must not be below 60F or the fumigant will freeze on the injectors and block application. The best soil temperature for fumigation is 70F or above.

Fumigation is expensive and, if done, requires smaller equipment than that commonly used in the field. Suitable injector equipment should be designed and constructed by the grower, since presently available equipment is too large for use in most greenhouses. The fumigation equipment should contain a fumigant tank, carrier tank, control valves and hoses from the tanks to the injector. The system is mounted on a three-point, hitch-connected frame which injects the fumigant through injector knives, installs a plastic cover over the fumigant-treated strip and seals it, all in one operation. The injector width should be wide enough to make five or six passes through a 30 ft.wide house. The fumigation technique could be done in strips in the greenhouse in the same manner as is common in the field. A strip as wide as the injector is treated, then a strip of the same width is skipped. The tractor could be backed the entire length to begin the next treated strip. Use methyl bromide formulations, "Vorlex" or other suitable fumigant according to manufacturer's directions. This is repeated until the entire area is covered. The untreated strips are treated about three or four days later, after the plastic from the first treated strips is removed. This technique is illustrated in Figure 3.

Caution: Methyl bromide, if used, is a very toxic material. Thus, during the fumigation process, the house should be kept under maximum ventilation to remove any escaping gas. In addition, applicators should wear protective clothing and facial protection at all times.

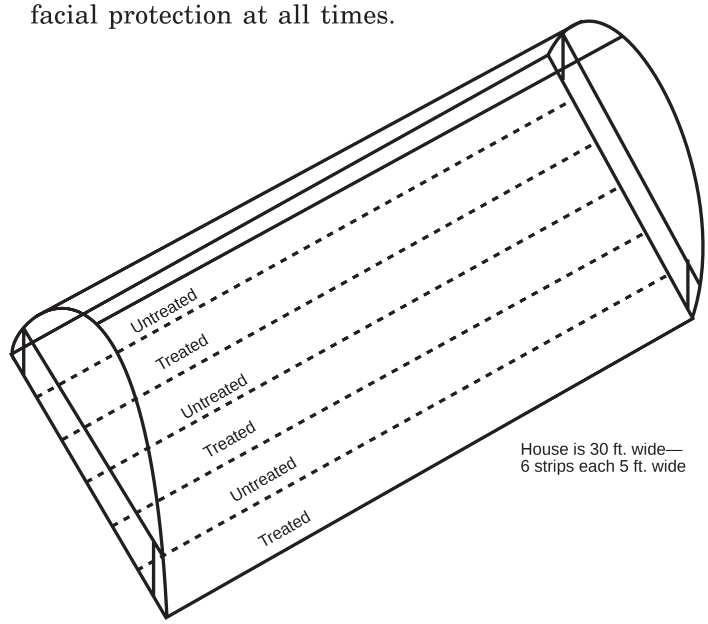


Figure 3: Illustration of fumigation procedure where tomatoes are grown in the soil.

Greenhouse Sanitation

Good sanitation programs are paramount to keeping disease and insect problems at a minimum. These pests can greatly reduce marketable yields if they are not kept under control. One way to reduce problems is to provide a good sanitation program. A good sanitation program, for both soil and soilless systems, includes:

1. Sterilizing all plant-growing containers and trays between each crop. Rinse each with a 10 percent chlorine solution followed by a water rinse, and then aerate for three to four days before using.
2. Do not transfer disease-infested plants to the greenhouse.
3. For soil culture, the soil should be fumigated between crops and houses should be rotated every three or four years. In soilless culture, growing troughs, trays and nutrient solution stock tanks should be cleaned between crops.
4. Remove and destroy all plant residue as soon as the crop is finished. Wash the walls with a sterilizing solution.
5. Do not work in an infested area and then move to an uninfected area without cleaning hands, equipment and clothing.
6. Before entering a house, dip the soles of shoes on a pad saturated with a disinfectant.
7. Keep weeds and grasses adjacent to the greenhouse under control to reduce the habitat for pests.
8. Irrigate plants by applying water to their base rather than by using sprinkler irrigation. Sprinkling wets the foliage, encourages fungal and bacterial development and may contribute to a reduction in pollen shed.
9. Keep windows and vents covered with screens to prevent insect movement and wind-blown weed seeds from entering the house.

Rotation of Houses Used for Soil Production

With soil culture, it is possible for continuous cropping of tomatoes to result in high populations of nematodes, verticillium, fusarium, botrytis, grey mold or even an increase in insects such as pinworms or white flies. Fumigation, sanitation, the use of resistant cultivars, etc. will reduce these problems, but it is also possible, and expensive, to move a double-layer polyethylene greenhouse every three or four years to further keep these problems under control. If double-layer polyethylene is used, it should be replaced about every three or four years. This is an excellent time to rotate house sites if problems become uncontrollable.

If a soilless system is used that requires the construction of nutrient-holding tanks and nutrient delivery systems with considerable plumbing, rotation of houses is not very practical due to the cost of construction.

Fertilization of Soil Systems

When spring tomatoes are grown in greenhouses with soil, growers can use about the same fertilizer programs that are used in the field. Be sure to take soil samples prior to planting. Good calcium levels, above 500 pounds per acre, should be available to reduce blossom-end-rot. The pH should be 6.1 or above.

Lime and fertilizer used in soil systems can be applied and worked into the soil before planting, just as they are applied to field tomatoes. Table 6 provides the lime and fertilizer recommendations for soil-grown greenhouse tomatoes.

Table 6. Recommended Fertilizer Rates for Soil Systems

Fertilizer (lbs./1000 sq. ft.			
Nitrogen	Soil test levels	P_2O_5	K_2O
1.5 at planting[a]	L	6	6
4.5 sidedressing[b]	M	3	3
	H	2	2
	VH	0	0

a/ 1.5# of N can be supplied by 4 lbs. of ammonium nitrate.

b/ Split this amount into three equal applications and apply the first sidedressing when the first fruits are about 1 inch in diameter. Repeat twice at four-week intervals.

Lime applications will be based on both the water pH and buffer pH. Thus, a standard lime application is not included because of variations in both water pH and buffer pH.

If trickle irrigation equipped with a fertilizer injector is used, it is possible to apply a water soluble fertilizer such as 20-20-20 or other suitable water-soluble fertilizers through the system. However, it may be difficult to meet the total fertilizer requirements with 20-20-20, especially when phosphate (P_205) and potash (K_20) both vary in soil residual levels. If application is made based on the P_20_5 requirements at either the medium or high level, then nitrogen levels are likely to be too low. If applications are made based on the nitrogen requirements, then P_205 or K_20 will be applied in excessive quantities.

In soil systems, one half of the recommended nitrogen and potassium and all of the recommended phosphate are applied prior to planting. A phosphate material commonly used includes 0-46-0 applied as in the field. The remaining one half of the nitrogen and potash can be distributed through the trickle system directly to the root zone on a daily or weekly basis. The fertilizer material most commonly used to meet these needs in the field is water-soluble potassium nitrate (16-0-44). The application rate is normally based on the nitrogen requirements with no emphasis given to potash.

Determining Trickle Rates of Nitrogen for Soil Systems: To figure the rate of 16-0-44 required to meet the remaining one half of the nitrogen recommendations, multiply the nitrogen rate per acre times the percent of an acre that the house covers, and divide by the percentage of nitrogen in KNO_3 (potassium nitrate). For example, a 30-by-100 foot house is 3000 sq. ft., which is 7 percent of an acre. Thus, if a total of 120 pounds of nitrogen is recommended per acre and 60 pounds were applied at planting, then 60 more pounds are to be distributed over the remaining growing season of about 12 weeks. Thus, 60 x 0.07=4.2 lbs. nitrogen divided by 0.16 (16% N in 16-0-44) = 26.25 pounds of KNO_3 to be applied over the 12-week period. If it is to be applied weekly, then 26.25/12 = 2.18 lbs. x 16 ozs. per pound = 35 ozs. to be injected through the trickle system per week per house. By the same token, it would require a total of 28 ounces of 20-20-20 to provide equivalent levels of nitrogen.

Almost all of the minor elements required for growth will be supplied by the soil when soil systems are used, if the pH is maintained in the favorable range and the soil is not sand.

Fertilization of Soilless Systems

When soilless systems are used, a plumbing system must be provided that allows frequent deliveries of water-soluble nutrients to the root zone. The frequency of delivery will depend upon the growing media. Sand will require more frequent delivery than an artificial mix of peat moss, perlite or vermiculite, due to the nutrient retention differences. Soilless systems require that appropriate concentrations of each of 13 nutrients be supplied to the plants. The required concentration varies with each nutrient. In most cases, the best way to accomplish this is to purchase pre-mixed, water-soluble nutrients and mix them into the appropriate water volume suggested by the manufacturer.

This stock solution is pumped daily on an intermittent basis. It is constantly monitored and adjusted to maintain the proper concentration of each nutrient and solution pH. The daily frequency of nutrient delivery will depend upon the weather, with more cloudy days receiving a lower number of daily feedings and sunny days receiving a higher number. Recycling nutrients may cause a major problem by creating the potential to pick up certain disease organisms and distribute them throughout the greenhouse.

pH of the Nutrient Solution: The pH of a plant nutrient solution should be in the 5.6 to 5.8 range to keep nutrients from becoming unavailable. Too high pH (greater than 6.5) increases the potential for micronutrient deficiencies. Too low a pH (less than 5.3) may result in calcium or magnesium deficiency or manganese toxicity. Thus, the nutrient solution pH should be checked every time a solution is prepared. A pocket pH meter is not an extremely expensive tool. As long as it is kept properly cleaned and maintained, it is a good quick check and should be a tool for every greenhouse grower.

If the pH of the solution is too high due to alkaline water, add an acid in small quantities to lower the pH into the 5.6 to 5.8 range. Allow the solution pH to equilibrate after the addition of acid, then recheck the pH. Acid-supplying materials include sulfuric acid (H_2S0_4), nitric acid (HNO_3) and phosphoric acid (H_3PO4). Sulfuric acid is the least expensive of the above materials and can be purchased from an auto supply store as battery acid. Even though they are expensive, there is an advantage to using either nitric or phosphoric acid due to the nutrients they can supply.

Caution: When handling acids, remember that they are hazardous and can result in considerable damage when mishandled. It is best to use them directly from the original container so there is no risk in pouring them.

To determine how much acid to add to a tank or bulk container of nutrient solution, use one gallon of the solution and add one milliliter of acid at a time until the pH is in the desired range. Then multiply the amount in milliliters times the number of gallons in the tank. This is the quantity of acid needed per tank. Remember, one pint is equal to 473 milliliters or 1,000 milliliters is equal to 1.057 quarts. Keep in mind that the pH scale is logarithmic, not linear. This means that if 10 drops are required to lower the pH from 8.0 to 7.5, 20 drops will not be required to lower the pH from 7.5 to 7.0. Take considerable care to measure each quantity of acid carefully and allow the pH to fully equilibrate before making another addition.

General Fertility

There are two basic methods of meeting the nutrient requirements of a soilless system.

One is to purchase pre-mixed fertilizer formulated by commercial companies. The other is to purchase the appropriate ingredients and mix your own. As you will see as you read this information, it is usually much easier and less complicated to purchase a pre-mixed material. There are several on the market that are available through various greenhouse suppliers. Pre-mixed soluble fertilizers usually contain a proper balance of both the macro- and micro-nutrients. Follow the manufacturer's directions for proper application.

A fertility program in a soilless system is one of the more confusing and difficult aspects of production for greenhouse tomato growers. However, it is very important to success. The keys to a successful nutritional program include:

1. Using fertilizer designed for greenhouse tomatoes.
2. Knowing the amount of each fertilizer needed in a stock solution.
3. Knowing how to correctly make the fertilizer application.
4. Observing plants for signs of a deficiency or excessive levels of a nutrient.
5. Monitoring plant nutrient status by periodically taking samples for tissue analysis. The tissue samples must be sent to a private laboratory for analysis.
6. Understanding the influence of light intensity on nutrient uptake and plant use and adjusting the frequency of applications accordingly.

Fertility Measurement: Several units are used to express the fertility level of nutrient solutions (fertilizer dissolved in water). This may be confusing, since the use of different units makes it difficult to understand different readings. This section helps to explain the differences in these units.

Electrical conductivity (EC) is used to measure the ability of a solution to conduct electricity. The more electricity it will conduct, the higher the EC reading. The general unit used is mho (pronounced MO), with the plural being mhos (pronounced MOZE). Notice that mho spelled backwards is ohm (pronounced OM). Ohm is the unit of electrical resistance, while mho is the unit of conductivity.

Two units of mhos are commonly used: micromhos (umhos) and millimhos (mmhos). A micromho is one-millionth of a mho; a millimho is one-thousandth of a mho. 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 micromhos are 0.30 to 2.50, while typical readings of millimhos are 300 to 2,500. Millimhos are more commonly used than micromhos on today's EC meters. An illustration to make the conversion is provided below.

To convert millimhos to micromhos, multiply by 1000. For example, a millimho reading of 1,000 would be 1,000,000 micromhos (1,000 x 1,000 = 1,000,000). To convert umhos to mmhos, divide by 1,000. Thus, a micromho reading of 1000 is 1 millimho (1,000 divided by 1,000 = 1).

Some portable EC meters measure the range of electrical conductivity from 0 to 30. These units are microsemens (us). They are simply 10 times the reading in millimhos. So to convert from *us* to mmho, slide the decimal point one point to the left. For example, if the meter reads 15, it is 1.5 mmhos. All three of the above units are easily interchanged if necessary.

The most commonly used and easily understood method of expressing the nutrient status of a nutrient solution is to use parts per million (ppm). Parts per million is the unit used to measure the concentration of a specific nutrient in a solution. These units are usually within the range of 50 to 300 ppm for nitrogen. General guidelines for the ppm of nitrogen to use at different stages of growth are given in Table 7.

Another way of measuring the amount of fertilizer in a solution is to measure the total dissolved solids (TDS) as shown in column 3 of Table 7. The unit commonly used for TDS is ppm. If you know the ppm of each dissolved nutrient, add them together to determine the total dissolved solids. This is a measure of all salts in a solution, not just nitrogen. However, TDS is not a reliable measurement of all nutrient levels. Some of the salts could have been in the water before any fertilizer was added. For example, if you had a reading of 1,500 TDS, you do not know if the reading is due to nitrogen or some other nutrients. It could also have been due to sodium, or something else, in the water. Thus, this is not a reliable method of measuring fertility of a nutrient solution.

It is important to know the dissolved solids or EC of the water source used to make the solution (do not assume it to be 0). Subtract the water source EC or TDS measurement from that of the nutrient solution to find the true value of the nutrient solution.

Methods of Mixing and Applying Fertilizers

Two principal methods exist for mixing fertilizers used in nutrient solutions: the bulk tank system and the injector or proportioner system. Both methods are acceptable and can be adjusted to maintain a good nutrient level that maximizes both yields and quality of tomatoes.

Bulk Tanks: A bulk tank may be constructed of plastic, concrete, steel, PVC, etc. at the appropriate size for the greenhouse. Bulk tanks are usually used for self-mixed nutrients. A nutrient solution of the correct concentration for plants is mixed in the tank and pumped directly to the plants. A 100-gallon tank may be suitable for a single greenhouse, while a 1,000- or 2,000 gallon tank may be better adapted to several greenhouses. The larger the tank, the less frequently fertilizer will have to be mixed. However, if it is too large, the fertilizer may sit too long between mixes, which may result in a change in the fertilizer concentration. If you are considering a bulk tank system, be sure to follow the fertilizer manufacturer's directions for best results.

Mixing fertilizer is a matter of adding a certain quantity of a specific nutrient (pounds or ounces) to a specific number of gallons of water. An example that illustrates this procedure is shown in "Mixing Your Own Nutrients," which follows in this publication. The fertilizer must be completely dissolved in water. Any material that settles out onto the bottom of the tank is not available for plant usage. If this happens, be sure to check the pH and bring it into the appropriate range or stir the mix with a paddle. Do this each time a new mix is made.

Determining Bulk Tank Size: To determine the size of bulk tank you need, you must know the flow rate per minute per 100 feet of irrigation

Table 7. Nutrient Concentrations Required for Greenhouse Tomatoes at Different Growth Stages

Stage of growth	Nitrogen (ppm)	Total dissolved solids (TDS) (ppm)	Electroconductivity (EC) (mmhos)
Germination to 1st true leaf fully expanded	50	450-550	0.6
1st true leaf to 3rd true leaf fully expanded	50-75	550-600	0.6-0.7
3rd leaf to transplanting	75-100	600-800	0.7-0.9
Transplanting to 2nd cluster set	100-150	800-1350	0.9-1.8
2nd cluster to topping	150-200	1350-1600	1.8-2.2

tubing, the total number of feet in your greenhouse, the total minutes of run time and the number of applications per day. Then you will multiply this by seven days per week. For example, if the flow rate is 0.33 gallons per minute per 100 feet of tubing or tape at 8 psi, the total length of irrigation tubing per house is 800 feet, the timer is set to run 15 minutes per run, application is made four times daily and is done for each day of the week, then the gallons required are 0.33 x 8 x 15 x 4 x 7 = 1,108 gallons per week, or 158 gallons per day. This will provide an estimation of the size tank desired and the number of times per week that mixing must be done.

Injectors: A fertilizer injector is used to mix or proportion a concentrated nutrient solution, such as a premixed fertilizer, into an existing flow of water moving to the root system. A concentrated nutrient solution is usually withdrawn into the carrier line from a container much smaller than the bulk container. An injector is usually placed ahead of the filtration unit in the line. There are several injectors on the market. Generally, the more you spend for an injector, the more accurate it will be in mixing the solution. The more accurate models are dose-specific, meaning that the concentrate injected depends on a given volume of water passing through the line. An injector that operates based on volume is more accurate than one based on time. Injectors usually have a knob that can be adjusted to increase or decrease the dose of fertilizer concentrate injected into the water.

The fertilizer solution flows from the concentrate container (bucket or other container) to the injector, where it is then diluted or mixed into the irrigation system. A water meter monitors the flow of water, and then sends a signal when enough water has passed through. The concentrate is held in small volumes (10 to 50 gallons). A minimum of two heads and two concentrate tanks are necessary; one tank (B) is for calcium nitrate and the other (tank A) is for all other nutrients. Two tanks are necessary because calcium will chemically combine with phosphate when the two nutrients are in high concentration, especially when the pH is high. The two nutrients can react and form a very insoluble compound called calcium hydrogen phosphate, which can plug the injector and irrigation lines. Once diluted, there is no problem unless the water pH is higher than 5.8. If this is the case, then you may need to add a third head to inject acid. Acid injection, however, must be done very carefully and slowly to avoid dropping the pH levels too low for good solubility.

An injector system enables better control of fertilizer applications than bulk tank systems, because the dose can be quickly adjusted. As improvements are made to the system, it is also possible to add an injector for each nutrient. This will enable individual nutrient adjustment based on normal tissue analysis. Computer systems may be available to control this operation, but they could be expensive.

Injector Calibration: It is important to know the injection ratio (ratio of the output to the input) so the amount of fertilizer to mix into the concentrate tanks can be determined. Some injectors come with tables that designate the ratio, i.e., 1:10, 1:15; 1:30, 1:100, 1:200, etc. If this information is not provided, then you must calibrate the injector to find this number. Using a container that can provide an accurate measurement of water (graduated cylinder or beaker), measure the amount of water the injector sucks in one minute. Then, using several of the measuring containers, one at each of several emitters (if used) along the irrigation system, measure the amount of water delivered to the plants in one minute. Average the water in all of the containers by dividing the total volume by the number of measuring containers. Multiply this average by the total number of emitters in the greenhouse. Divide the total amount emitted in the greenhouse by the total amount the injector sucks in one minute. This is the ratio. State it as 1:X, where X is the number obtained after the above division. This means that X parts of water are to be mixed with each part of concentrated nutrient solution.

Pre-Mix Fertilizers: Pre-mixed, water-soluble materials are available for use in soilless systems. They include products such as the general purpose 20-20-20, 20-10-20, 15-11-29 and 5-11-26 "Hydro-Sol" with micronutrients. Follow the basic instructions for using these materials, and you will find that it is easier to use them rather than trying to mix your own in appropriate proportions. The reasons for this become quite obvious when one considers the complication in developing and maintaining a balanced mix. One example of a self-mixed process follows.

Mixing Your Own Nutrients: A self-mixed solution is usually mixed in a bulk tank. Proper mixing and maintaining a balanced nutrient solution is complicated unless you are well versed in fertilizer chemistry. One of the first steps in mixing your own nutrient solution is knowing the concentration of each element in the solution. One of the better nutrient solutions that provides this information is the "Modified Steiner Solution." The various nutrients and their concentration in this solution are shown in Table 8. One way to use a nutrient solution is to mix a solution containing the concentration of each nutrient provided, and then dilute the solution to provide the concentration of nutrients necessary to feed the plants.

Table 8. Modified Steiner Solution Illustrating the PPM of Each Nutrient Required in the Solution

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 (molybenum)

The next step in mixing a nutrient solution is to know the ppm of each nutrient provided by a specific quantity of a material containing the nutrient. If you understand molecular formulas, you can figure this on your own. If you do not, then you could use the following table to determine the quantity to mix with a given volume of water. The calculation is based on the percentage of nutrient contained in the compound. The concentration of each nutrient will be shown as the amount required to provide 1 ppm in 265 gallons of water (Table 9). This proportion is used because 265 gallons equals 1,000,000 milliliters. Thus, if one gram or one milliliter of the nutrient is mixed with this quantity of water, then a concentration of 1 ppm exists for that specific nutrient.

If you mix the quantities of each of the first nutrient listed in each row in column 3 of Table 9 into 265 gallons of water, you will have

Table 9. Calculation of Nutrient Solutions (Amount of chemicals, in grams, used to make 1,000 liters (265 gal) of nutrient solution.)

Chemical compound	Supplied nutrient	Grams required for 1 ppm per 1,000 liters (265 gal.)
Ammonium sulfate (21-0-0)	Nitrogen Sulfur	4.76 3.22
Calcium nitrate (15.5-0-0)	Nitrogen Calcium	6.45 2.56
Potassium nitrate (13.75-0-36.9)	Nitrogen Potassium	7.30 5.26
Sodium nitrate	Nitrogen	6.45
Urea (46-0-0)	Nitrogen	2.17
Water soluble N, P, K (9-45-15)	Nitrogen Phosphorus Potassium	11.11 2.22 6.66
Monopotassium phosphate (0-22-28)	Potassium Phosphorus	3.53 4.45
Potassium sulfate (0-0-43.3-18)	Potassium Sulphur	2.31 5.5
Potassium chloride (0-0-49.8)	Potassium	2
Monocalcium phosphate (0-20.8-0) 13 Ca.	Phosphorus Calcium	4.78 7.69
Monoammonium phosphate (11-20.8-0)	Phosphorus Nitrogen	4.78 9.09
Calcium sulfate (gypsum)	Calcium Sulfur	4.80 8.33
Boric acid	Boron	5.64
Copper sulfate	Copper Sulfur	3.91 7.81
Ferrous Sulfate	Iron Sulfur	5.54 5.26
Chelated Iron (9%)	Iron	11.1
Manganese sulfate	Manganese Sulfur	4.05 6.89
Magnesium sulfate (Epsom salts)	Magnesium Sulfur	10.75 7.69
Molybdenum trioxide (MoO_3)	Molybdenum	1.5
Sodium molybdate	Molybdenum	2.56
Zinc sulfate (reagent grade)	Zinc Sulfur	2.78 5.26

a solution that has the nutrient concentrations of each element provided in Table 10.

Table 10. Actual Concentration of Each Nutrient in Solution When the Quantities Given in Table 9 Are Mixed

Nutrient	PPM[a]
Nitrogen	6.52
Calcium	4.20
Potassium	7.87
Phosphorus	7.98
Sulfur	6.29
Boron	1
Copper	1
Iron	2
Manganese	1
Magnesium	1
Molybdenum	2
Zinc	1

[a] *The ppm for each nutrient was determined by adding the amount supplied by each of the compounds supplying specific nutrients.*

If you now compare the level of nutrients necessary from the Modified Steiner Solution (Table 8), you find that N, Ca, K, Fe and Mg requirements are low, while Cu, Mo and Zn levels are too high. Thus, further mixing is required to provide the concentrations specified in the Modified Steiner Solution.

Meeting calcium requirements: To meet the appropriate requirements, other mixing must be done. We will start with calcium. We need to add 175.80 ppm (180 ppm needed-4.20 ppm provided in the solution = 175.80 ppm.) We will use calcium nitrate as the base material. It contains 19 percent calcium. Thus, 5.26 grams of calcium nitrate will be required to provide 1 ppm of calcium. Multiplying 175.80 x 5.26 = 924.7 grams (32 ounces) of calcium nitrate required.

Meeting nitrogen requirements: The calcium nitrate mixed above will also provide nitrogen. For each 5.26 grams of calcium nitrate added, the concentration of N will increase by 0.82 ppm. Thus, 924.7/5.26=175.80 x 0.82=144.2 ppm N supplied. We need 171 ppm. Thus, 144.2 + 6.52=150.72 total ppm N provided. We have 20.3 ppm (171-151.82) to make up. To accomplish, we will use only a nitrogen-supplying material such as urea. Checking Table 9, we find that 2.17 grams of urea will provide 1 ppm N. Thus, 2.17 x 20.3 = 44 grams of urea are required to meet all of the nitrogen requirements.

Meeting phosphorus requirements: We have 7.98 ppm of the total requirement of 48. To meet the shortage, we will need to provide another 40.02 ppm of P. Monopotassium phosphate provides 1.26 ppm of P for each 3.53 grams added. Adding 31.8 grams (40.02/1.26) will provide the amount of P necessary.

Meeting potassium requirements: Each 3.53 grams of monopotassium phosphate also supplies 1 ppm of K. Thus, another 9.00 ppm of K from monopotassium phosphate has been added for a total of 16.87 ppm. To bring the K up to the desired level will require another 287.13 ppm. To meet this requirement, there is a choice of potassium sulfate or potassium chloride or a combination of both. We will choose potassium sulfate. Each 2.31 grams will provide 1 ppm K. Thus, 287.13 x 2.31 = 663.27 grams or 1.5 pounds. This material will also add another 121 ppm of sulfur, for a total sulfur concentration of 127.3 ppm. There is none provided in the Steiner Solution.

Meeting minor element requirements: To meet the copper, iron and molybdenum requirements, add only 0.78 grams of copper sulfate, 16.6 grams of ferrous sulfate and 0.5 gram of sodium molybdate to provide the concentration specified in Table 8.

Using the nutrient solution: Now that we have gone through the process of mixing a nutrient solution, how can it best be used to fertilize tomatoes? It was mentioned in Table 7 that greenhouse tomato fertilizer programs use nitrogen as the guide for fertilization, even though other elements are provided in the Modified Steiner Solution. Table 7 indicates that tomatoes need 50 to 75 ppm N from the first true leaf until the third leaf is fully expanded. The solution that we have just mixed provides 171 ppm N. Each gallon of the solution must be further diluted to provide the appropriate levels at this growth stage. To determine the gallons of nutrient mix to water, divide 171 by either 50 or 75, depending on the level you intend to feed. Thus, 171 divided by 75 equals 2.28 gallons. Dividing 171 by 50 equals 3.42. This means that each gallon of solution will require that 2.28 to 3.42 gallons of water be mixed with it to place the nitrogen in the required range. By making this dilution, all other nutrients in the mix will also be diluted in the same proportion. As the plant grows into the other stages, the dilution rate will be adjusted accordingly.

From these calculations, you can see that the purchase of a pre-formulated material is much easier.

Identifying Nutr itional Problems

High Nitrogen: Learn to monitor the plants visually to determine if there is a potential nutrient problem. The most common nutrient problem occurring with soilless greenhouse tomatoes is high nitrogen. Symptoms of high nitrogen are given below.

Excessive nitrogen can result in fairly serious problems in greenhouse tomatoes by shifting the plant into a vegetative plant. How do you know if you are over-applying nitrogen? There are several symptoms, which include:

1. "Balling up" of leaves in the top of plants. This term refers to the curling under of the small leaves in the terminals.
2. The midrib of leaves tends not to grow in a straight line. It will grow in a curved manner, resulting in growth to one side of the leaf.
3. Small, vegetative growth will emerge from the top of the leaf midrib.
4. Shoots of vegetative growth will grow at the ends of flower clusters. These can be removed.
5. Fruit set will usually be decreased, with one or two fruit per cluster instead of four or five. Usually, these occur on three or four clusters and will disappear when the nitrogen levels have decreased. In terms of pounds, this could result in $1^1/_2$ to $2^1/_2$ pounds of fruit loss per plant.
6. Leaf growth will increase in size and will be dark green.

Nitrogen deficiency: A deficiency results in restricted growth of tops, roots and lateral shoots. Plants become spindly, with a general yellowing of the entire plant. Plants will turn to a light green, with increasing intensification of yellow. The older leaves yellow first, then yellowing proceeds toward the younger leaves. Older leaves also defoliate early.

Phosphorus deficiency: The leaf color is usually a bluish-green; the petioles and veins of the undersides of the leaves become purple. Young leaf veins turn dark purple.

Potassium deficiency: Mature, lower leaves first show marginal yellowing, followed by dessication (burning) of the tissue along the margins. The symptoms progress both inward on the leaf and upward on the plant as the deficiency becomes more severe. The fruit will often ripen unevenly or will show blotchy green to yellow patches.

Calcium deficiency: The most common foliar symptom is the scorching of new leaf tips and die-back of the growing points, but the best known and most identifiable symptom is blossom end-rot of the fruit. Boron deficiency also causes scorching of new leaf tips and die-back of growing points. However, 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 deficiency: Magnesium deficiency is most commonly characterized by interveinal chlorosis (yellowing between the veins), which starts in the older leaves and proceeds toward the younger leaves as the deficiency becomes more severe.

Sulfur deficiency: Sulfur deficiency resembles nitrogen deficiency in that older leaves become yellowish-green and stems become thin, hard and woody. Some plants may show a colorful orange and red tint rather than yellowing. The stems, though hard and woody, increase in length but not in diameter.

Iron (Fe) deficiency: Iron deficiency usually starts as a yellowing of the immature leaves and growing points. As it progresses, this tissue may turn almost white.

Manganese (Mn) deficiency: Manganese deficiency starts with interveinal chlorotic mottling of the immature leaves. In many plants, it is indistinguishable from iron deficiency. As the deficiency becomes more noticeable, necrotic spots usually appear in the interveinal tissue. Sometimes bloom buds on the flowering clusters show incomplete growth and do not develop. During the short days of December and January, the plants often produce no blooms at all.

Zinc (Zn) deficiency: Symptoms are very similar to iron and manganese deficiency, except that small leaves result. When zinc deficiency is sudden, such as when zinc is left out of the nutrient solution, the chlorosis can appear similar to iron and manganese deficiency without the small leaf.

Boron deficiency: Symptoms include slight chloris to brown or black die-back of the growing points similar to calcium deficiency. The die-back tissue is usually very dry, brittle and easily crumbled. The pith of affected stems may be hollow, and the epidermis becomes roughened and cracked. Plants may also have short internodes with prolific lateral shoot development on midribs of the leaves and the flower clusters. The mildest symptom shown on mature fruit is very small cracks to heavier concentric cracking in the skin on the shoulders.

Copper deficiency: With copper deficiency, leaves at the top of the plant wilt easily. This is usually followed by chlorotic and necrotic areas in the leaves. Leaves on top of the plant show unusual puckering with veinal chlorosis. Splitting of ripe fruit, especially under warm temperatures, is an indication of low copper.

Molybdenum deficiency: The older leaves show interveinal chlorotic blotches, and become cupped and thickened. This deficiency is very seldom seen in greenhouse tomatoes.

In addition to the above deficiency symptoms, a deficiency of one micronutrient can result from an excess of another. Thus, the importance of maintaining a nutrient balance cannot be overemphasized. Temperature and pH can affect nutrient solubility and concentration. Recycling nutrient solutions can create an imbalance in the stock nutrient solution.

Trellising or Providing Supports

Tomato plants must be supported, regardless of the growing system. In soil systems, they can either be staked individually or the “Florida Weave” system can be installed. The “Florida Weave” is most commonly used and is illustrated in Figure 4.

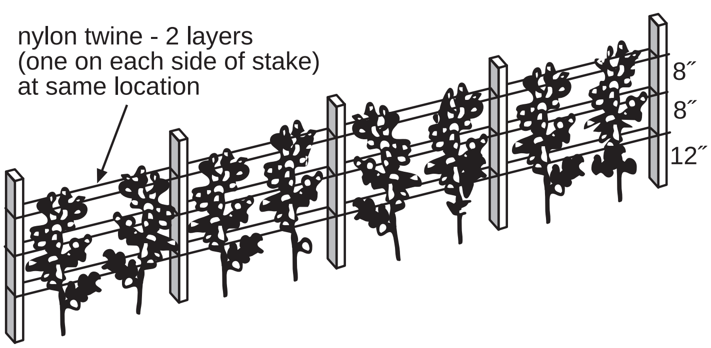


Figure 4. Illustration of supporting tomatoes grown in soil using a “Florida Weave.”

With the “Florida Weave System,” two plants are spaced between stakes and supported by nylon string tightly connected to both sides of the stakes and running parallel to the soil surface, at about the 12-inch height. Strings are then repeated about every 8 inches until supporting is complete.

Soilless systems use a different support system. These systems drop strings from overhead pipe

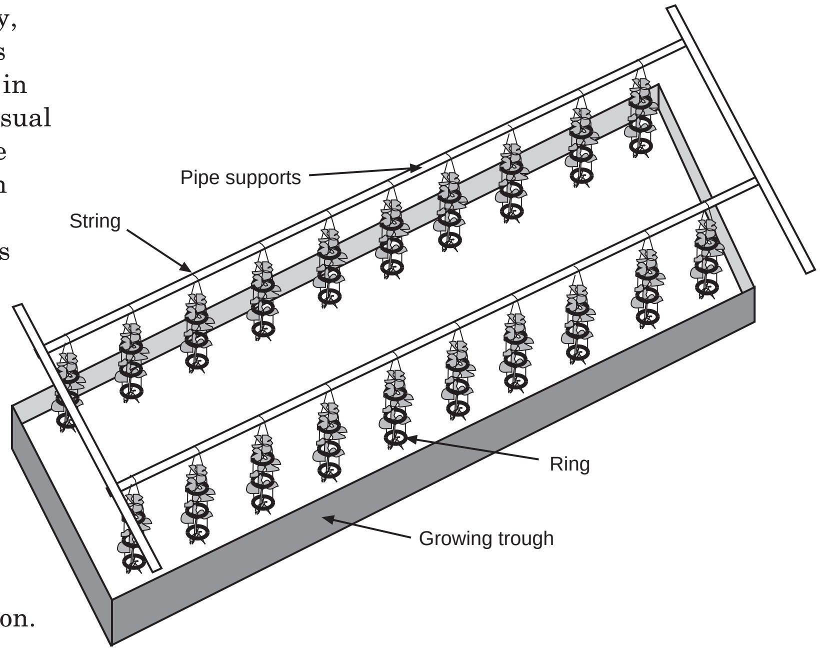


Figure 5. Providing tomato plant support in hydroponic systems through the use of overhead supports and drop-string.

supports tied to a rigid plastic ring at the base of each plant. The plants are then supported by the string through repeated connections of plastic rings about every 8 or 10 inches up the plant. The system is illustrated in Figure 5.

Maintaining support, regardless of the system used, requires daily observation and labor.

Pruning

A sucker is new growth that occurs between the axis of the leaf and stem. There will usually be one sucker at the axis of every leaf. If suckers are allowed to grow, they will also produce suckers. Suckers produce both foliage and fruit. If not removed, they will produce more foliage than the root system can adequately support and provide additional material to harbor disease and insect organisms.

The enclosed environment and close plant spacing of greenhouse tomatoes make it necessary to remove a high percentage of the sucker growth. The severity of pruning may be dependent on the method of production and the variety or cultivar used. Growers using determinate varieties in soil systems may not prune, while growers using indeterminate varieties in hydroponic systems over a long period may prune extensively. If suckering is done, begin the process when the first suckers are about 2 inches long and continue thereafter as new suckers reach that length. If the suckers become much longer, they are difficult to remove without leaving a wound on the stem. Wounds become points of entry for fungal organisms, which are major problems as greenhouse humidity increases.

Usually, a plant can be pruned to a two-stem system, although soilless systems are normally pruned to one stem. One-stem plants are desirable when close spacings are used, but are less necessary with wider spacings. To develop the two stems, allow the main stem to grow, then allow the first sucker underneath the first flower cluster to grow. Keep all others removed. This will form a two-stem system and will increase the chances of higher yields. The idea is presented in Figure 6.

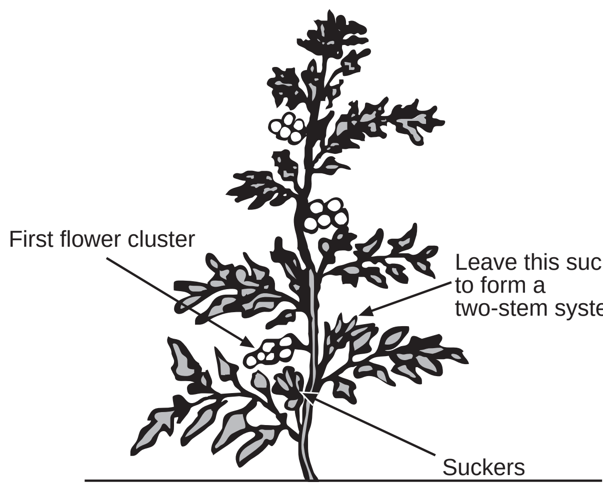


Figure 6. Illustration of suckering or pruning tomatoes.

Weed Control

Weed control in a soil system is very much like cultivation in the field, because there are no herbicides labeled for greenhouse use. However, fumigation will reduce the requirement for weed control. Cultivation can begin when weeds and grasses are very small, and should be done as shallow as possible to reduce root damage. Cultivation is usually accomplished by running a roto tiller between the rows.

Some growers have tried production on plastic for weed control, earlier yields and higher quality fruit. If you use plastic, remember to install a trickle or drip tape underneath so water can be applied as necessary.

Organic mulch materials have been used to reduce weed growth, but they also serve to keep humidity high and may serve as a habitat for both fungi and insects. These are all very undesirable in the greenhouse and should be kept to a minimum.

Soilless systems normally do not require weed control programs because the system itself usually prevents weed growth.

Irrigation

Soil Systems: Tomatoes grown in soil culture should be irrigated so water is delivered to the base of the plant rather than through overhead sprinkler systems. This keeps water off the foliage and reduces the potential for fungal diseases such as botrytis or leaf mold, which can devastate crop yields. Greenhouse tomato growers have improved their yield per plant by shifting from sprinkler to trickle irrigation.

Water application at the base of the plant in soil systems also reduces greenhouse humidity and weed growth between rows. Systems can be designed with a minimum of one plastic line per row; however, some growers use a line on each side of the row. Each line is designed to operate at eight to 10 pounds pressure.

The trickle tubing can be purchased with many options, but a good rule of thumb is to use tubing with a flow rate of 0.3 to 0.4 gallons per minute per 100 feet of tubing at an in-line pressure of 8 psi. In a soil system with eight rows of 90-feet length, it requires a water flow of 2.16 to 2.9 gallons per minute to meet the total water requirement. To apply enough water to wet the root zone will require 450 gallons of water applied in a 1-foot band to be equivalent to 1-acre inch. To apply this amount will require about 2.6 (155 minutes) to 3.5 hours (210 minutes) run time.

The frequency of application will vary with the rate of drying and water use. To reduce the potential for inadequate water, monitor the soil and apply water frequently enough to keep the root zone moist. This assures that adequate quantities of water are available to maintain maximum fruit set and size but reduces the potential for high humidity build-up within the greenhouse. It is important to keep the soil in the root zone moist because, once dry, it may be very difficult to bring it back to the required level.

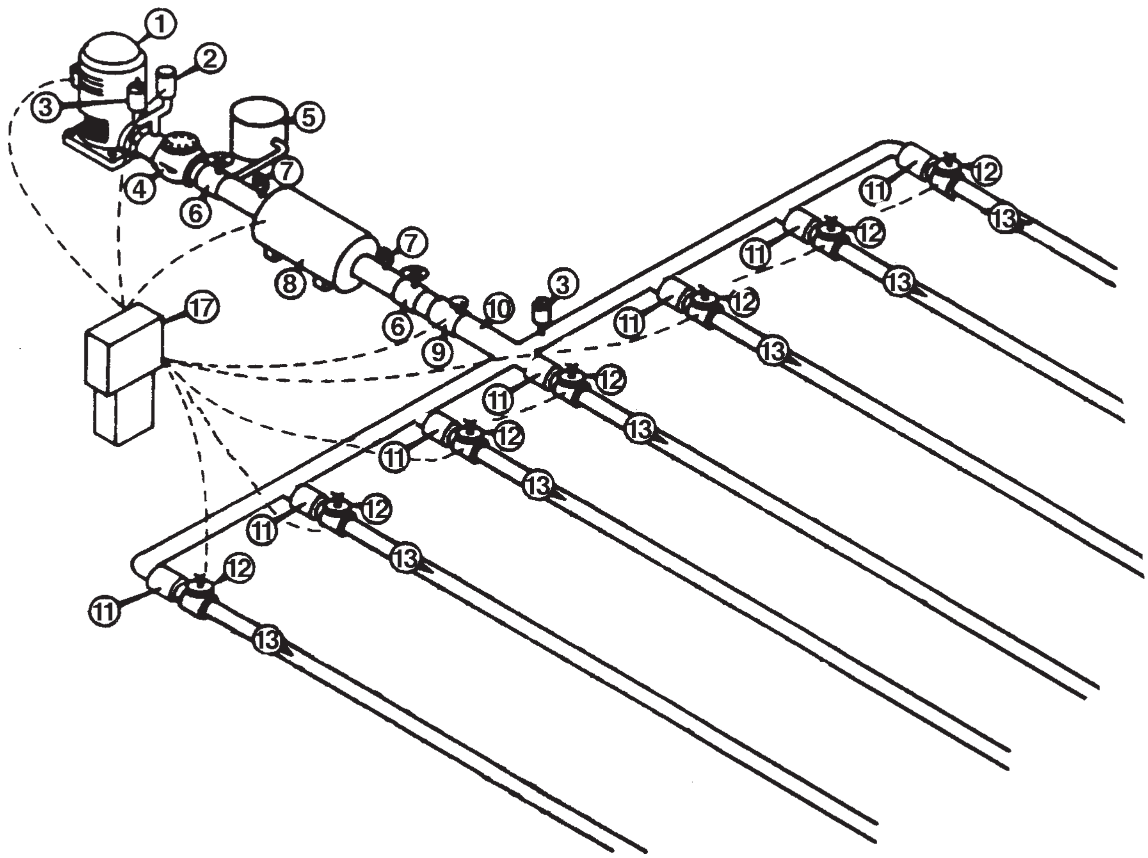
The components of a drip irrigation system include a fertilizer injector, filtration units, pressure regulators, drip tape, supply lines and various connectors, seals and plugs or clamps. An illustration of a suitable system and its components are shown in Figure 7.

Hydroponic Systems: Usually, water and fertilizer are applied simultaneously to the roots through the plumbing system installed in the growing trays, troughs or bags.

Light Requirements

Best fruit set and plant growth occur when tomatoes are grown under full sunlight or maximum light intensity. This helps to explain why spring yields are usually higher per plant than fall yields. Light intensity in the spring is much greater than in the fall.

Supplemental fluorescent lighting has not proven to be worth the cost of installation. Therefore, most greenhouse growers in Tennessee do not use supplemental lighting.



1. Pump
2. Pressure Relief Valve
3. Air Vents (at all high points)
4. Check Valve
5. Fertilizer Injector or Tank
6. Mainline Valve (Gate or Butterfly Valve)
7. Pressure Gauges
8. Filter
9. Flowmeter
10. Mainline
11. Submain Secondary Filter (only if required)
12. Field Control Valves (Manual or Automatic)
13. Laterals

Figure 7. Schematic of a drip irrigation system for soil production system.

Carbon Dioxide Enrichment

In areas where several days may pass without ventilation, carbon dioxide enrichment up to 10 times normal results in increased yields. However, if growth occurs at a time when ventilation can be adequately provided, carbon dioxide enrichment usually does not prove to be economically feasible.

Ventilation and Humidity

Air movement through the greenhouse is important to improve pollination and reduce diseases enhanced by high humidity. The ideal humidity level for greenhouse tomatoes is between 60 and 70 percent.

On rainy days, the above humidity levels will be difficult to obtain by ventilation, but a greenhouse should not be kept totally closed on sunny, cool days. When the air is cool and dry, ventilation will enable air to be pulled through the house and reduce internal humidity if it is kept above the plants. If cool air is drawn into the house and warmed up, it will hold greater moisture at the higher temperature. Complete exchange of air in this manner helps reduce problems. Since greenhouse growers have improved their ventilation systems compared to those used in the early '80s, crop yields have increased and foliar disease problems have decreased.

A good ventilation system has the capability to change the air once per minute, even though there will be times when cold outside temperatures will not allow an exchange this rapidly. When moisture condenses on the internal plastic surface, ventilate the house and continue as long as the internal temperature does not become too cool, or as long as the moisture on the plastic surface is being removed. Keep ventilation in accordance with the external temperature, because air that is too cool drawn continuously over the foliage will reduce plant growth. Do not allow too cool air to make contact with the plants and do not ventilate the house long enough to reduce the internal temperatures to undesirable levels.

Management of ventilation is of major importance. Avoid keeping the house closed on days when the outside temperature will allow maximum ventilation. If this happens, humidity and temperature both increase to unfavorable levels, increasing conditions favorable for disease development. In addition, learn to use intermittent ventilation on cool days to reduce moisture condensation inside the house. The drier the foliage can be kept and the more air movement in the greenhouse, the more favorable the conditions for pollination.

Growers who have previously had low ventilation capability have doubled their yields of spring tomatoes in several situations when they replaced old houses and increased their ventilation capability.

Pollination

If flowers are not too wet due to high humidity in the greenhouse, they will shed pollen satisfactorily, resulting in good fruit set. However, pollen grains that are too wet become sticky and do not shed from the stamen for transfer to the pistil very well. Good air movement can provide effective pollination on a spring crop, but is more difficult to achieve on a fall crop due to decreasing outdoor temperatures.

In addition to good ventilation, many greenhouse growers are now providing one hive of bumblebees per greenhouse per crop to assure better pollination. The cost of each hive is about $200 at the time of this printing.

When good ventilation does not occur and if bumblebees do not do the job, each flower cluster will need to be vibrated every other day until fruit set is accomplished. The best time to hand pollinate is between 10:00 a.m. and 2:00 p.m. during the drier portion of the day. Electric toothbrushes or any hand-held rapidly vibrating device will contribute to increased pollination. Using such devices, however, requires considerable time to complete pollination as frequently as required, causing an added production expense.

Diseases

Tomatoes grown in soil culture are subject to nematodes, fusarium and verticillium wilt, botrytis, leaf mold, early and late blight, foliar and fruit bacterial problems and viruses. These can occur as a single problem or a combination of two or more at a time. Total or marketable yields can be reduced by 10 to 80 percent, depending on the severity of one or a combination of these diseases. A description of several diseases is provided in Table 11.

The importance of good sanitation, preventative and ventilation practices cannot be over emphasized, because the array of chemical controls labeled for greenhouse production is much more limited than for field tomatoes. Also, the necessary spray program must be accomplished with either hand equipment or small, walk-type motorized sprayers. Because application with hand equipment is not uniform, chemicals provide less control than the same material applied with better equipment in the field.

Diseases affecting tomatoes grown in soilless culture include various root bacteria, leaf mold, botrytis and viruses. The total number of diseases

Table 11: Description of Greenhouse Tomato Diseases

Disease	Description
Bacterial spots	Small, raised spots on fruit. They are usually brown to black. Bacterial canker is a white spot on the surface of the fruit.
Early blight	A problem in soil houses. It is identified by the presence of small, brown-to-black spots which develop into target-like spots. The spots appear on the lower leaves first. They appear as a dark, leathery spot on the stem end of the fruit.
Fusarium wilt	Not likely to be a problem in soilless houses. Typical symptoms include a yellowing and wilting of the foliage. Stem tissue near the ground line is likely to show brown streaks.
Gray mold (botrytis)	Very common in both soil and soilless houses. It is usually recognized by a fuzzy, gray growth on the stems or flower pedicels. The leaves turn brown beginning at the tip and progress backward. It becomes a major problem when the house is not ventilated and the humidity is continuously kept at high levels.
Leaf mold	Different than gray mold. Symptoms include yellow, circular-like spots on the upper surface of leaves. Spots are olive to gray on the underside of leaves. Occur in both systems when the humidity is kept constantly at a high level.
Nematode injury (root knot)	Is likely to be found in soil houses where continuous production has occurred. Plants will wilt rapidly during periods of moisture stress. Leaves turn yellow and may appear to have a nutrient deficiency. Plants become stunted and the roots develop galls or knots.
Tobacco mosaic virus	Leaf symptoms include mottling, with raised dark green areas and some distortion of younger leaves. Severe symptoms include leaves which may turn downward, become rough, crinkled or corrugated, and may curl downward at the margins. Plants may become stunted.
Southern blight	Is more of a problem in a soil house. Plants wilt and die very rapidly without a distinctive yellowing of the foliage. The stem at the ground line will usually be decayed and covered with a white mold and small light-brown fruiting bodies.
Verticillium wilt	Not likely to occur in soilless systems. The foliage will yellow and wilt. It forms v shaped lesions on the leaves. Internal tissue near the base of the plant will usually show brown discoloration.

in soilless culture may not be as great as with soil culture, but the magnitude of their effects are no less important. They can still be devastating.

When fungicides are available and used, they should be handled and applied as indicated by the label. Every effort should be made to apply them to both sides of the leaves as well as stems and flower peduncles. Fungicides available for greenhouse tomato use are listed in **Extension PB1282, "Commercial Vegetable Disease, Insect and Weed Control,"** available at your county Extension office. This publication is updated annually.

Fruit Physiological Disorders

There are several physiological disorders which can occur in greenhouse tomatoes. Descriptions of some of the more common disorders follow.

Blossom-end-rot (BER): This disorder appears on the blossom end of the fruit, usually after the fruit is three-fourths to full size. It appears as a light tan, brown or black sunken area. It is not a soft rot, but is a firm, somewhat leathery condition accompanied by a dry rot. The disorder may not be any more than $^1/_8$ inch deep into the outer carpel wall of the fruit.

BER is caused by a calcium deficiency. It can occur when adequate calcium is present, but conditions exist which reduce its uptake such as an insufficient amount of water in the root zone. Other causes include improper pH or wide ranges in certain fertilizer salts in the root zone. For example, it is possible to have an ammonical nitrogen-induced calcium deficiency because the ammoniated nitrogen levels in the root zone are high enough that it is substituted for calcium during uptake. To prevent BER, maintain adequate levels of calcium and prevent wide fluctuations in water levels in the root zone.

Puffiness: Puffy fruit have an angular appearance, with one or more sides becoming flattened. In some cases, fruit may appear to be triangular rather than round. Such fruit weigh less than non-puffy fruit and the locules are not well filled with both seed and gel. Some locules may even be empty.

Puffiness has been associated with poor pollination and several of the following environmental conditions:

1. High temperatures, especially consecutive temperatures above 90 degrees during flower development.
2. Temperatures below 55 degrees during flower development.
3. Wide differences between day and night temperatures.
4. Water stress: both too much and too little. This could include high humidity that reduces pollen shed.
5. Excessive nitrogen.
6. Use of fruit-set hormones.
7. Lack of adequate carbon dioxide.

The best way to cure puffy fruit is to prevent it from occurring by monitoring the environmental conditions which favor its development. If puffiness occurs on early-set fruit and it can be associated with any of the above conditions, then adjust the conditions as close to normal as possible to reduce the potential for problems in later-set fruit. If conditions exist that result in poor pollination, correct them as soon as possible.

Fruit Cracking: This is one of the more serious problems with greenhouse tomatoes. Cracks radiating from the stem are the most prevalent, but some concentric cracking also occurs. Like blossom-end-rot, cracking is associated with water stresses within the plant. Fluctuating water levels within the root system may increase the incidence of cracked fruit. Cracking has also been associated with genetics of the plant. As a result, some recent varieties have been evaluated for crack resistance. When possible, use crack-resistant varieties.

Other information indicates that fruit cracking occurs when high levels of nitrogen are present in the leaf tissue. In addition, low potassium levels seem to increase the number of cracked fruit.

Rough or Catfaced Fruit: This problem has been clearly shown to be associated with low temperatures during flower bud development. Greenhouses which have uneven temperatures due to cold spots or sloping elevation that favors colder temperatures at the lower levels will usually have a high percentage of catfaced fruit produced at the lower levels. The shoulders of large- fruited varieties usually are rougher than smaller-fruited varieties.

Blotchy Ripening: This problem appears as a flattened, blotchy, brownish-gray area on green fruit. As the fruit ripens, these areas may remain gray or turn yellow. Dark brown vascular tissue can be seen in the fruit walls when the fruit is cut. Determining the cause of the problem can be difficult. It may be a result of the many environmental problems already mentioned. In addition, the development of red fruit color is inhibited when temperatures move above 86 degrees during fruit development.

Zipper or Anther Scar: This vertical scar along the side of the fruit 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). The anther appears to adhere to a higher percentage of the fruit when the greenhouse humidity is excessive, increasing the stickiness of the anther to the fruit. As the fruit increases in size, the anther tears away from the fruit, leaving the scar.

Green Shoulders: This condition occurs at the calyx or stem end of the fruit, which never turns red. Often, the area may turn yellow as the remainder of the fruit ripens. It has been associated with genetics, but is usually more prominent during high light and temperature conditions. Recommended conditions to reduce the problem include increasing ventilation during warm periods, being sure that plants are not defoliated above the developing clusters, using shade materials and good P and K fertility levels. In addition, some varieties have been released, especially among field tomatoes, with resistance to this problem.

Insects

Do not think that tomatoes grown in enclosed structures are free of insects. They are subject to infestation by aphids, flea beetles, fruit worms, white flies, mites, leaf miners, pinworms and others. A description of these insects is provided in Table 12.

The first step in insect control is eliminating overwintering and colonizing habitats suitable for insect survival. This means that plant residue should be completely removed from within or near an existing house. Installing screens over fans keeps many insects from entering through the fans. The second step is identifying the insect and applying the recommended control if one exists. Unfortunately, just as with diseases, control chemicals for greenhouses are limited. Sticky tape and certain synthetic pyrethroids are available for use in greenhouses. They are very helpful in early identification of insect problems and in keeping many insect problems to a minimum. Proper use of control techniques and sanitation measures can keep insects under control much more satisfactorily than problems with diseases. However, remember to begin control programs before plants are transplanted to the greenhouse for best results.

Harvesting

Harvest tomatoes for shipment when the star on the blossom end turns pink. Fruit harvested at this time is red internally and will turn red without treatment with ethylene. Such fruit, however, must be packaged and moved to the market immediately for it to be a proper color when placed on the grocery shelf. Mature green tomatoes can be harvested and treated with ethylene (ripening gas) under appropriate conditions to develop color. Green fruit are usually harvested less frequently than ripe fruit. Tomatoes that are to be sold locally and used immediately can be harvested when vine-ripe.

Sorting and Packing

Tomato fruit should be sorted by size and color to have a uniform pack suitable for various markets. Only one size and color should be placed in a box. This allows buyers to know what they are purchasing and improves a grower's reputation for packing a high-quality product. Such techniques bring repeat buyers. If tomatoes are going into chain store outlets, package them in 20- or 25-pound cardboard boxes and stamp them as to size, color and brand. This provides a buyer with both good handling and identification capabilities. Tomatoes that are sold locally through various private market outlets are often packaged in one-half to one-bushel crates and sold in the early-pink stage.

Storage

Keep green tomatoes above 55F until they have ripened. If they are stored at temperatures below 55F while green, the low temperature deactivates the enzyme responsible for color development. The salability of the product and reputation of the grower are then reduced.

After ripening, tomatoes can be kept five to 10 degrees cooler than mentioned above, but the humidity must be high to keep the fruit from swiveling due to water loss.

Table 12. Description of Insects Commonly Found Feeding on Greenhouse Tomatoes

Insect	Description
Aphids	Small, soft-bodied, pear-shaped insects with a pair of cornicles (tailpipe-like projections) protruding from the rear end. They may be red, black or green. They may be winged or wingless and feed in colonies on terminals and leaves. Infested leaves often curl and become distorted. Aphids transmit virus diseases.
Flea beetles	Small (1/16) black or striped beetles that jump like fleas. They attack the foliage, leaving small, round shot-holes. Damage is most serious early in the season. Potato flea beetles may transmit early blight.
Fruit worms	Adult moths are yellowish-olive. Larvae vary in color from greenish-yellow, reddish brown or even black with paler stripes running lengthwise along the body. Fruit worms feed on the leaves and fruit and may bore into the stalk.
Leaf miners	The larvae are yellow and about 1/8 inch in length. They tunnel the leaves between the upper and lower surfaces. This damage results in long, white, winding tunnels on the leaves.
Tomato pinworms	The adult moth is gray with a wingspan of 1/2 inch. The mature larvae may be yellow, green or ash gray and covered with dark purple spots. Pinworms can cause whitish leaf streaks, folded and tied leaves, pinholes in stems and fruit and fruit blotches.
Spider mites	Small, yellowish to dark green spider like pests that are the size of pepper flakes. They may be detected by dislodging them from the plant onto a piece of white paper and viewing them with a 10X magnifying lens. Webbing may be seen over the infested plants. Mites suck the sap from foliage. Leaves take on either a yellowish or bronze cast.
White flies	There are several species of white flies. They may vary in certain aspects of body shape, such as wing shape. However, they are all small insects with broad wings covered with fine, snow-white waxy powder. Both adults and nymphs may feed on foliage by sucking juices from the underside of the leaf. They produce a honey dew which may result in a blackening of the leaf. Some species are also capable of transmitting certain viruses, which greatly damage the plant.

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