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Preface

This manual is intended to help small greenhouse tomato growers in Louisiana and elsewhere grow a successful crop using perlite or pine bark medium. Small growers can produce vine-ripened, high-quality fruit that can be delivered to the local market on the same day of harvest. Greenhouse tomatoes are produced without herbicide application and with minimal or no use of insecticides and fungicides. Improving fruit content of potassium, calcium, and reducing nitrates is feasible and should make the fruit healthier for consumers. Since greenhouse tomato production has become marginally profitable for the small grower, research is needed to reduce operating expenses and increase yield. Labor is the major expense of production and it can take as much as one hour of work to look after one tomato plant during its growing period of 300 days ($7.00). Heating costs are the largest expense after labor during the winter months. Price of fuel has the greatest impact on the cost of heating. Energy consumption to cool the greenhouse in the summer is high too. It may cost $4.00 or more per plant for heating and cooling (high fuel cost in winter 2001 may have doubled this figure). During the growing period, each plant will need about 100 gallons of water ($0.15), one pound of formulated fertilizer ($0.60). Other expenses include: seeds, growing medium, pesticides, twine, clips, irrigation and harvest supplies ($2.00/plant). The total expenses may exceed $15.00 per plant per year including $1.00 of construction depreciation. In our best years, we harvested 30.5 pounds per plant (double-cropping system) and sold them at an average of $0.90/lb. It appears from these statistics that labor and energy consumption may account for 70% or more of the total expense. To maximize profits, new growers should build their own greenhouses to save up to 50% of the construction expense. Building a greenhouse is not difficult and usually only requires the skills to fasten nuts and bolts. Seven hundred plants can be planted in the most popular size greenhouse in Louisiana (30x96 feet) and they will need about 700 working hours a year. Growers who do most of the work themselves can save more and stay in this business longer and enhance their profit. This manual will explore among other things ways to improve the cultural practices of greenhouse tomatoes to increase yield and enhance profit.

Introduction

Improved flavor and shelf life are the driving force for the increased demand for greenhouse-grown tomatoes. Currently, greenhouse tomato fruit are more visible than ever before at the produce section of many grocery stores. Consumers love the taste of a fresh tomato, and they are willing to pay a premium price, especially in the winter. This desire for vine-ripened tomatoes has been stimulating a great expansion in the greenhouse vegetable industry. North America's greenhouse vegetable acreage is estimated at or above 2000 acres. Recent statistics indicate that U.S. production of greenhouse tomatoes has increased significantly. In some states, the production has more than quadrupled in the past few years. Per capita consumption of tomatoes in the U.S. increased to 18.9 pounds per person in 1999, 16% higher than in 1990. Researchers at various learning institutions including Cornell University and the Harvard Medical School found that tomatoes contain compounds that may act as deterrents to certain types of cancers.

Greenhouse tomato production and marketing can be an excellent self employment project for rural Louisiana. One person can manage up to 3000 square feet of greenhouse space on a part time basis, i.e., one bay of size 30 X 96 feet with enough room to grow 700 plants and produce more than 17,000 pounds of excellent quality fruit per year. Work can be done in the evening or at night and marketing can be achieved during off season when competition with field grown tomatoes is minimal and prices are high. Unlike field-grown tomatoes which require harvesting and marketing over a short period of time (3-4 weeks), greenhouse tomatoes are harvested and marketed over a 30-week period. It is expected that the small volume of weekly harvest can be absorbed by the local market. These tomatoes can be delivered to the consumer on the same day of harvest and at the most desired stage of ripening and quality.

Greenhouse tomatoes can be produced without herbicides. Hot water treatment of the growing medium should kill weeds, fungi, and bacteria. Installing screens on the greenhouse vents, using sticky cards, and biological pest control can minimize or eliminate the use of pesticides. A well- planned feeding program can enhance the potassium and reduce the nitrate contents of the tomato fruit leading to more healthier product for human consumption.

Projected gross income per year from one greenhouse of the size mentioned earlier should equal or exceed the gross income from one acre of field grown tomatoes. Net income can be higher if no hired labor is needed. Each bay (30 x 96 feet, i.e., 0.069 acre) can generate more than $15,000 in tomato sales per year.

Who should consider growing greenhouse tomatoes for a profit?

Someone who

•Is willing to work few hours every day for at least 300 days a year.
•Pays attention to details.
•Having an excessive zeal for sanitation.
•Is a good sales person.
•Lives near by the greenhouse.

Greenhouse location

•Should be away from trees which harbor aphids, white flies, spider mites, and block sun light.
•Have an access to good roads and markets.
•Site should be higher than surrounding area to allow for drainage.
•Should have an access to electricity , natural gas, heating oil or any other source of fuel.
•Must have a good water source, each plant will need at least 100 gallons of salt-free water a year. Before building a greenhouse, send a water sample to a well-known laboratory to determine salt contents. Acidity and alkalinity of water should be determined as well. **Hint**: the best source is rain water and it is easy to collect 2000 gallons of water from one inch of rain falling on a roof of a 30X96 feet greenhouse if equipped with gutters and a collection system.

A free-standing or a gutter-connected greenhouse?

- For small growers, a free-standing greenhouse is preferred because:
- It is easy to build.
- Growers can start small with one unit and gradually expand as they gain experience.
- Easier to provide separate environments for plants at different stages of growth, i. e., a fall crop followed by a spring crop in one greenhouse and a long season crop in another.

Greenhouse orientation and size:

- North/south orientation is a must in Louisiana.
- Cooling pads should be installed on the north side and exhaust fans on the opposite side.
- A 30 feet wide by 96 feet long greenhouse is popular in Louisiana.
- Summer temperature at the cool side may drop to 80°F but can reach 100°F at the exhaust side. **Hint**: building two greenhouses of size 30X 48 feet each may be more desirable than building one of size 30X96 feet to control the excessive heat at the exhaust side in the summer.

Greenhouse frame cover

Light inside the greenhouses is relatively weaker than outside (65% of outside light or less). The reduction of inside light is caused by some light reflection off the greenhouse and interception of light by the covering material and greenhouse frame. During winter, the sun's angle is low and a lot of light is being reflected off the greenhouse. It was reported that during conditions of low light, a 1% reduction in light can cause a 1% yield reduction. Greenhouse cover has a strong effect on light transmission and light quality. Glass absorbs most of the UV radiation, while polyethylene allows more UV transmission. You can buy greenhouse plastic film with an ultraviolet and infrared barrier, as well as anti-drip properties. Choose material that allows the maximum possible light transmission to plants inside, especially during the winter months.

Growers can use glass, polyethylene film, or lexan sheets. All these materials perform well and are recommended for greenhouse cover, but they differ in cost. Polyethylene is the least expensive and transmits less light than glass or lexan. Most growers use two layers of 6-mil poly and blow air between them to reduces energy consumption. Use outside air to inflate the double poly. Greenhouse grade polyethylene film has a life span of about 3-4 years. However, the film' s light transmission ability can be reduced over time as dust and dirt accumulate and quality deteriorates because of pestcide spray inside the greenhouse. Most greenhouse film deterioration occur at contact points with the structure, largely due to increased temperature. In general, the initial cost of a polyethylene film greenhouse is less than glass or lexan panels. However, polyethylene requires more maintenance.

Improving light transmission into the greenhouse

Once or twice a year, especially before and during the winter season, wet the top of the greenhouse with a mix of water and a cleaning agent such as spic & span (easy done with a garden hose, syphon mixer , and a grip nozzle). Use a wet flannel cloth to wash the wetted top of the greenhouse in a seesaw motion then rinse with plain water (better if done during cloudy days).

Greenhouse ground cover

A concrete floor is the best solution for preventing weed growth and general sanitation inside the greenhouse. It allows for pressure washing of the floor with hot water between crops to kill diseases and insects. However, few growers can afford to have a greenhouses with a concrete floor. If you choose to concrete the floors, permanent drains should be installed during the process of pouring the slab. Later, the drains can be covered with plastic grills and tomato bags can be arranged in rows over the drains. If you choose not to have a concrete floor, make sure to cover the ground with black type cloth to prevent weed growth and top it with a white layer to improve light reflection inside the greenhouse. Make sure to mark the location where you plan to put the growing bags and dig drain trenches and fill them with gravel before you cover the greenhouse ground.

Heating the greenhouse

Night temperature should be at least 63°F and not higher than 68°F and day temperature should be between 75 and 80°F . Night temperature above 70°F impairs fruit set because it reduces pollen and ovule viability and day temperature above 85°F does the same thing and reduces fruit quality because of poor color and fruit cracking. Bottom heat (side photo) is more efficient than top heat. Warm air will rise between tomato plants leading to dry leaves (no condensation) and less disease problems. **Hint**: run a convection tube over the feeding pipe between every two rows of tomato bags to heat the growing medium, fertilizer solution, and the air surrounding the plants. Have the convection tube snugged in-between the bags as seen in the picture. It is important to have the growing bags touching the convection tube and the feeding pipe to heat the growing medium and nutrients inside the pipe. Heating the growing medium to 70°F is very important to activate the roots and improve yield. Use natural gas, butane, or heating oil. Check with the heater manufacturer, energy companies, and other growers before deciding on what size heater and the type of fuel to use.

Cooling and ventilating the greenhouse

Evaporative cooling pads installed on the north side of the greenhouse and exhaust fans of appropriate size and power installed on the opposite side are needed to cool the greenhouse Cooling pads should be kept clean of green algae. Reduce sunlight exposure of the pads using a porous black shade cloth and use a black sump tank with a black cover. Dry the pads completely on regular bases whenever possible. Use a T shaped dull object (see the picture on the side) to scrape salts and dry algae from the exposed surface of the pads. Be careful not to destroy the pads. Reverse the pads by turning them around once every two years. Keep your greenhouse full of plants whenever possible. On a sunny day, a full grown tomato plant will lose approximately one quart of water through transpiration. This loss of water can lower the temperature of the house by at least 10°F. Use small fans (20 in. diameter) operating continuously above the plants. Half the number of fans should push the air in one direction on one side of the house and the other half should do the same thing in the opposite direction on the other side. Run the small fans non-stop 24 hours a day. **Hint**: leave some vents opened at night to let some fresh outside air enter the greenhouse to reduce condensation. Closing all the vents at night to save energy may lead to the build up of ethylene gas as a by-product of heating and may lead to flower abscission and/or reduce the shelf-life of the fruit. Use anti-drip material sprayed on the interior surface of the plastic or use a plastic cover containing anti-drip properties as part of its formulation to help reduce dripping of moisture into the plant Eliminating condensation and reducing humidity should reduce the incidence of botrytis and reduce the need for fungicides. Condensation on the fruit may cause minute cracks to develop on the skin. Fruit moisture lost through the cracks will shorten fruit shelf life.

Using shade cloth to cool the greenhouse

Shade cloth (side photo) is not effective in providing significant reduction of air temperature inside the greenhouse. A 50% shade cloth may lower air temperature by 3 to 4°F. However, shade cloth will provide a significant reduction in sunlight entering the greenhouse. Most of the light absorbed by the fruit turns to heat leading to poor color and fruit cracking. Shade cloth should be used in Louisiana between May and September. Reducing light during summer will not retard plant growth because there is more than enough light for the photosynthesis process, but it can reduce leaf and fruit temperature leading to improved plant growth and fruit quality.

Growing medium

Except for the nutrient film technique (NFT), a growing medium consists of solids and pore space. Coarse medium is made up of larger particles with fewer, but larger spaces. A fine medium has many, but small pores. The size of particles and distribution of pores are important factors to determine the physical characteristics of the medium. Total pore space and size determines the rate of drainage and gas exchange. A portion of this space is occupied by air. Plant roots require oxygen for growth and adequate aeration of the medium is necessary. A good soilless medium should have a good retaining ability of water, enough space for air exchange, and good drainage rate. Following are examples of some growing medium:

- **Soil**

Soil media is the worst choice for growing greenhouse tomatoes because it does not provide the optimum moisture and aeration at the same time. Disease, salts, and waste buildup in greenhouse soil is a limiting factor for long-term profitable production. Repeated use of greenhouse soil to grow tomatoes will lead to significant losses because of diseases, insect, and salt build-up It is not easy to sterilize greenhouse soil and there is no occasional heavy rain to wash off excess salt and plant waste.

- **The Nutrient Film Technique (NFT)**

It is a water culture system where a shallow stream of nutrient solution covers the roots of growing plants to provide water, nutrients, and oxygen. At the present time we do not use this system to generate research data on any of our projects at the Red River Research Station facilities.

- **Soilless media**

Rockwool, polyurethane, pine bark, and perlite are examples of soilless media that are used for growing greenhouse tomatoes. In the southern United States especially in Louisiana and Mississippi, greenhouse tomato growers prefer pine bark and perlite over other media. Following are some highlights of the two growing media:

1. **Pine bark**

Bark is a by-product of the timber industry. Before it can be used as a growing medium, it has to be composted to balance its carbon/nitrogen content, get rid of the harmful compounds, and kill insects and disease. For successful composting, the bark must be throughly watered and conditioned with nitrogen, then left to compost for at least three months with occasional turn over. During decomposition, compounds which inhibit growth are reduced and temperature increases to about 150°F. Never use green pine bark to grow greenhouse tomatoes. In our test trials, we used, five gallon upright plastic bags filled with composted bark and planted two tomato seedlings in each bag. We found that it was a good growing medium if used for a maximum of two years. It was difficult to clean the bark with hot water and reuse it indefinitely. Also, it was obvious to us that controlling the pH in the root zone was not an easy task because of the continues decomposition of the bark.

2. **Perlite**

Perlite is a volcanic mineral crushed to small pieces and heated to 2000°F. The small quantity of water trapped inside the small pieces turns to vapor during heating and puffs out the perlite pieces . Expanded perlite is white, lightweight, and inert. It is capable of retaining water, air, and nutrients and it provides optimum air-water relationship. Research conducted at the Red River Research Station in Bossier City indicated that perlite was a good growing medium and it can be reused for many years. Following are some suggestions on using perlite as a growing medium for greenhouse tomatoes.

Buying Perlite

It is much cheaper to buy perlite in bulk. Growers should group together and buy a truck load of perlite. Get coarse or medium grade of screened horticultural perlite bagged in four cubic feet (30 gallon) bags, each weighs about 23 pounds and has enough perlite to fill 6 bags of five gallon capacity; i.e. enough for 12 tomato plants. Fine grade perlite may keep too much water leading to undesirable results.

Preparing perlite for use

Before dispensing the perlite from its original bag, stand the bag in a vertical position, open the top and sprinkle the perlite with water using a water breaker nozzle attached to a garden hose to get rid of the dust (harmful if inhaled by workers). Fill the 5 gallon plastic bags with the wet perlite. Before planting tomato seedlings in the new perlite, make sure to sprinkle it with diluted nutrient solution.

Cleaning and reusing perlite

If you grow two tomato crops a year (in the fall and spring), make sure to pull the tomato plants with the roots after terminating the fall crop in late December or early January. Shake the roots loose to return the hanging perlite to the bag and discard the tomato plants with the roots. It may be easier and more practical to cut tomato stems at the perlite surface in the bag. Remove all the vegetation from the greenhouse and then remove the crown roots by coring them out with a bulb planter.

After all the vegetation and crown roots are removed, treat the perlite in each bag with hot water (photo next page) using a steam cleaner (Water temperature should be at least160°F). Use about one to two gallons of hot water per bag. Use a water breaker attached to the hose to break the pressure and avoid splashing the perlite out of the bag. Use hot water to treat the outside of the bags and everything else in the greenhouse to eliminate insects and diseases. The standard recommendation for disinfecting greenhouses is to use bleach, but many greenhouse workers do not like to use it. Hot water treatment is more acceptable by workers and more effective because it can be used to treat the perlite in the bags. Using bleach to treat perlite inside the bags may lead to the killing of many tomato plants. Following the termination of the spring crop in July, cut the tomato plants just above the perlite surface and remove all the vegetation from the greenhouse. Use a perlite sifter similar to the one made at the Red River Research Station (photo shown on the previous page) to separate the tomato roots from the perlite and return the perlite back to the growing bags. Treat the perlite in the bags and every thing else in the greenhouse with hot water as described above. If you grow one crop per year, follow the steps mentioned for cleaning and sterilizing perlite after the termination of the spring crop.

Cleaning and sterilizing perlite should cost less than buying new perlite every year. If sifting perlite (removing old tomato roots) once a year is too much work, do it once every two years, but do the hot water treatment after the termination of each crop.

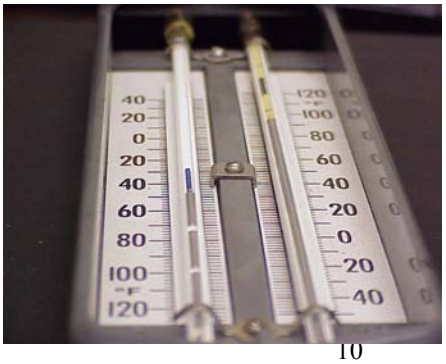
Advantages of cleaning and treating perlite with hot water

- Growers can buy perlite once and reuse it for many years. Our research indicated that the old perlite cleaned from tomato roots and treated with hot water is as productive as the new one.
- Treating perlite with hot water should remove excess salt and other undesirable material left in the bag after the termination of the last tomato crop.
- Hot water treatment should reduce insects, disease spores and green algae remaining in the bag after each crop. Our observations indicated that fungus gnats disappeared completely from the greenhouse after the regular use of hot water. We have reasons to believe that hot water treatment reduced thrips, white flies, spider mites, and botrytis disease in the greenhouse. This can lead to less pesticide use, saving money, and producing a more desired fruit to sell.
  Note: seeding tomatoes in July and transplanting in August using perlite medium may lead to some transplant losses. Transplants die because of injuries to the stem similar to those caused by damping off disease. However, our research indicated that the high temperature of the wet perlite in July and August can kill (cook) the stem of the young transplants buried in the hot perlite.
- More and more evidence suggests that hot water treatment eliminates crop failure and insures production consistency.
- It is possible to transplant the small tomato seedlings (8-10 days after germination) directly into the permanent perlite bags and skip the intermediate step of keeping the seedlings in small cell trays for 4-5 weeks . This approach can lead to a healthier and a more productive crop. Make sure that perlite temperature is between 60 and 80 °F and remain within this range. Note: We planted the seeds during the last week of September in1998, 1999, and 2000 and transplanted the small seedlings after germination directly into the permanent bags. This procedure saved time, money, and eliminated the trouble of keeping the transplants crowded in the small cell trays for five weeks.

Tools for Success

Greenhouse tomato growers should strive to maximize their production from a limited space area. To achieve their goal, growers have to purchase and know how to operate several tools to avoid making serious mistakes during the course of production.

- **Thermometers**



A minimum/ maximum thermometer is a must for greenhouse tomato growers. Temperature in the greenhouse has a great influence on nutrient uptake, plant growth, pollination, fruit set, fruit cracking, etc. Locate the thermometer at the center of the house and at the plant level not facing the sun. Every effort should be made to keep temperature within the acceptable range for maximum yield and quality (63-68°F at night and 75- 80°F during the day) . Night temperature above 68°F and day temperature above

85° F will lead to poor production of pollens and poor fruit set and fruit color. Growing medium with temperature above 85°F can kill the tender stem of the young seedlings especially when transplanted in August.

- **Humidity meters**

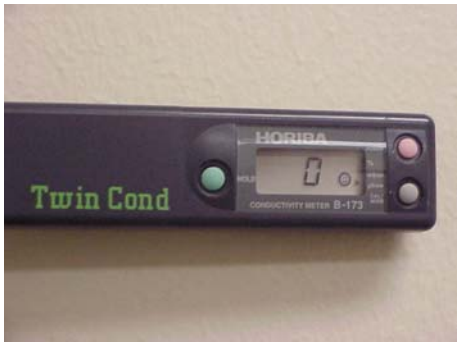
Best pollination can be achieved when humidity ranges between 60 and 80%. Less than 60% relative humidity can result in a dry stigma (the part of the flower which receives the pollen) and reduce germination of the pollen grains and fruit set. Condensed moisture on the leaves can have an impact on the spread of botrytis disease. High relative humidity in the greenhouse will result in less transpiration leading to less movement of calcium to the fruit and a higher incidence of blossom end rot . Growers should use these meters to adjust for the desired level of relative humidity. We were able to reduce the damage caused by botrytis with minimum or no use of fungicides by running the horizontal fans continuously, periodic running of the exhaust fans, allowing fresh air to enter the greenhouse even in rainy days. Good sanitation is a must.

- **pH meters**

Ideally the pH of the nutrient solution should be between 5.6 and 6.3 (many researchers recommend a pH of 5.6 to 5.8). Growers should invest in buying a good quality pH meter and regularly check the pH of the nutrient solution as well as the pH of the growing medium. Wait about one hour after irrigation and use a sampling tube to take a sample to a depth of 5 to 8 inches from 5 growing bags selected at random and gently squeeze the nutrients and measure the pH. Do this once a week or every two weeks at the most. The pH meter should be calibrated before use to assure accurate readings. Solubility of mineral nutrients, particularly micro-nutrients, is dramatically affected by media pH. Iron, manganese, boron, copper, and zinc are most soluble below pH 5.5 and may be available at toxic levels if the pH is below 5.0. At low pH, hydrogen ions saturate media exchange sites and increase the potential for leaching and losing nutrient cations such as calcium, magnesium, potassium, and ammonium. High media pH can cause micro nutrient deficiencies even when the micro nutrients are there. Chlorosis of the upper portion of the plant is often caused by high media pH. Optimum nutrient availability is achieved by maintaining media pH between 5.6 and 6.3.

- **Electrical conductivity (EC) meters**

These meters are used to estimate soluble salts in water which are usually measured by their electrical conductivity. EC meters express EC as millimhos per centimeter (mmhos/cm), deciSiemens per meter (dS/m), or milliSiemens per centimeter (mS/cm). They are equivalent units of measure.



Analysis should be made for the nutrient feed solution and for the root medium. The EC measurement alone does not indicate the types of fertilizer in the nutrient solution, but this measurement can provide a good indication of the total amount of fertilizer being applied. A root-zone EC of above 2.5 mS/cm should alert growers that salt buildup is becoming serious and flushing the growing medium may be necessary. It is important to know the water's EC before mixing the fertilizer and if it is high for the tomato crop, it may be necessary to find another source or to purify the water. An EC of 1.5 to 2.5 mS/cm is good for a mature tomato crop.

- **Specific ion meters**

Examples are Cardy Nitrate-N and K-meters. Using a drop of fresh sap placed in a continuous film over the electrodes of the meter can give the ion concentration of nitrate-N or K. Use the meters to check the N and K of the fertilizer solution, medium extract, and plant sap.

Starting a tomato crop

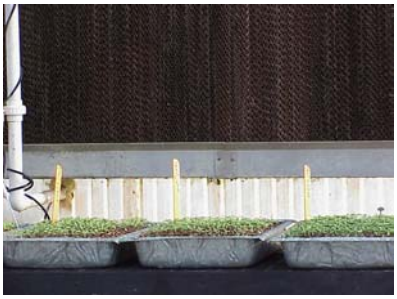
- **Selecting a variety**

Do not use varieties developed for field production in the greenhouse. The seeds are cheaper, but they are less adapted to greenhouse low light conditions and disease pressure. We have tested many greenhouse varieties at the Red River Research Station and concluded that 'Trust' was the most productive and disease-resistant variety so far and 'Grace' is a promising new one. For cluster production, we recommend 'Tradiro' at the present time.

- **How many crops to raise every year?**

At the Red River Research Station we raise a fall crop followed by a spring crop in three of our five greenhouses and raise one long season crop in the other two. This arrangement allows us to conduct our research under all weather conditions and harvest tomatoes for more than nine months every year. Fall production starts around mid-October and is terminated at the end of December. Spring harvest starts around mid-March and is terminated by mid- July. Harvest of the long season crop begins around the first week of January and ends in late June. Following are some notes on these production systems:

•The fall crop



Tomatoes were seeded around mid-July in 20" x 15" x 2.5" germination trays (maximum of 1000 seeds/tray) filled with Pro-mix BX soilless media and kept in a cool place at 78-80°F for four days (seeds do not need light to germinate). Trays were then moved next to the cool pads in the greenhouse (top photo) and kept for another eight days to continue germination. Selected seedlings with no defects were transplanted individually into multi-cell growing trays of size 12" x 20" x 2 3/8" and with 38 round cells of size 2 3/8" x 2 3/8" (center and bottom photos). Trays were kept in the cool zone of the greenhouse for four weeks and seedlings were irrigated as needed with Peter's 20-20-20 fertilizer @ one pound per 100 gallons of water. These seedlings were then transferred to the permanent bags around the end of August (two plants in five gallon bags filled with perlite). **Note**: it is possible to keep the five gallon bags in the cool zone of the greenhouse for another two weeks. Only transplants of equal height and free of visible defects were planted in the permanent bags. Plants were fed according to the schedule listed in Table 1. Pruning, tying, and pollination was performed as described later in this publication. Plants were harvested for eight to 10 weeks and produced an average of seven pounds per plant. The fall crop was the most difficult to grow and the least profitable.

Some of the problems encountered and possible solutions are:

- Low seed germination at temperature above 88. Germinate seeds at 78-80 F and use 25% more seeds.
- Seedlings were spindly. Cool irrigation water to 65-70°F with ice and keep the transplants at the cool side of the greenhouse (limited success).
- Nutrient deficiency, especially magnesium. Too much potassium will reduce the absorption of magnesium.
- Lower leaves curled upwards and plants grew very slow indicating medium EC was high and plants were not getting enough water to keep up with transpiration. Leach medium and use less fertilizer to lower the EC.
- Some transplants developed symptoms similar to damping-off disease and died following transfer to the five-gallon bags. The tender stem of these plants may have been damaged by temperature above 85°F. Keep the plants in the cool side of the greenhouse until the weather improves.
- Small insects such as thrips and white flies find their way to the greenhouse. Install screens on the vents and use sticky traps.

•The spring crop

Tomatoes were seeded during the last week of November in germination trays as indicated above and transplanted individually into the multi-cell trays after 12 days. The trays were kept in a small propagation greenhouse to allow the tomato seedlings to grow away from the fall tomato crop for 4 weeks. Day and night temperature were kept at 78 and 65°F, respectively. Seedlings were irrigated as needed with a nutrient solution prepared by mixing one pound of peter's 20-20-20 fertilizer in 100 gallons of water. Following the removal of the fall crop and cleaning the greenhouse, the 4 week old transplants were planted in the permanent five gallon bags filled with perlite around the first week of January and the feeding schedule listed in Table 1 was implemented. We screened the tomato seedlings before planting in the multi-cell trays and again before planting in the permanent bags. The two step screening approach was very effective to eliminate the undesirable seedlings. The spring crop was the most productive and profitable crop. Harvest started around mid-March and was terminated during the second week of July. Plants produced an average of 17 pounds/plant. The two-crop-per-year system allowed for maximum production per unit area per year. However, problems associated with the production of a good fall tomato crop and not being able to supply the market with tomatoes between January and mid-March may discourage some growers from following this system.

•The long season crop

Seeds were planted in germination trays in late September. Twelve days later, seedlings were transplanted directly into the five gallon bags filled with perlite. This approach saved money because no multi-cell trays were used to raise the transplants for four weeks prior to transplanting in the permanent bags. Other benefits include eliminating root jam and the competition of young seedlings for light in the multi-cell trays. The early presence of small tomato plants in the permanent bags allowed for feeding with more balanced formula resulting in healthier and stronger transplants. We have tried this approach for three years without losing any seedling to damping-off or any other disease. However, we cleaned and sterilized the perlite with hot water every year before reusing. Temperature of the perlite has to be below 80°F, otherwise you run the risk of losing the small seedlings to heat damage. One crop per year will let you harvest tomatoes continually between December and the end of June of the following year. Per plant production will drop in January and February because of the many cloudy days during these two months. Total plant production was less than the combined fall and spring crop production. Also, it should be noted that a long season crop becomes more susceptible to disease and insect problems as the plants get older. Pest management is more difficult and more expensive on older plants than younger plants.

Following are some hints to improve the long season crop production:

- Keep greenhouse cover clean to allow for more light to enter the greenhouse.
- Allow for more outside air to enter the greenhouse to reduce humidity and minimize the risk of botrytis disease.
- Handle plants with care because they grow very tall and can be easily damaged.
- Remove broken leaves and dead tissues because they attract botrytis spores.

Feeding greenhouse tomato plants

Tomatoes require at least 15 essential elements for maximum growth and yield. Potassium nitrogen, phosphorus, calcium, magnesium, and sulfur are needed in larger quantities. Minor elements such as boron, iron, manganese, copper, zinc, molybdenum are essential but needed in smaller quantities. The bulk of the tomato plant consists of carbon, hydrogen, and oxygen. These elements are obtained from the air and water. Greenhouse-grade fertilizers are generally preferred over standard grades because they have high purity and solubility. Small growers are encouraged to buy pre-mixed fertilizers to avoid making mistakes in preparing the mix themselves. There are many excellent fertilizer formulas available for greenhouse tomatoes in the marked to choose from and their prices are reasonable. The fertilizer schedule in Table 1. was developed at the Red River Research Station to feed greenhouse tomatoes using the bulk tank system. Gradual increase of fertilizer concentration based on the age of the tomato plant is preferred. If you have a large operation and you want to mix your own fertilizer, refer to the Mississippi greenhouse hand book or the Florida Greenhouse Vegetable Production Handbook for more information on using injectors and mixing fertilizers.

Table1.

Week # following transplanting	Days following seeding	Oz of 3-13-29/ 100 gl	Oz of calcium nitrate/100 gl	Times of* irrigation per day	N ppm	K ppm	EC mS/cm
1	35	6	4	3	56	100	1.00
2	42	7	5	4	77	110	1.20
3	49	8	6	5	90	130	1.35
4	56	9	7	6	99	150	1.65
5	63	10	8	7	113	170	1.75
6	70	11	9	8	129	190	1.80
7	77	12	9	9	129	200	1.90
8	84	13	9	10	129	220	2.05
9	91	14	9	11	131	240	2.10
10	98	14	9	12	135	260	2.20

*Use 125-150 ml (4-5 oz) per irrigation for each plant.

This table provides general guidelines. Growers should carefully monitor any undesirable changes in plant growth and take at least two leaf samples for tissue analysis, one after six weeks and a second sample after nine weeks of transplanting. Rates used in week #10 should be used for the remaining of the season. N,K,and EC determination may vary based on meter type and calibration.

Hints on feeding greenhouse tomato plants

•Tomato plants will use some of the fertilizer applied in the liquid feed and leave some in the growing medium. Left over fertilizer will lead to the build up of salts which can reduce plant growth and fruit production, especially during hot weather (fall crop). Many publications recommend irrigating with a higher volume to leach out 20% of the nutrient solution and prevent the build up of salts. We found that 20% is not enough to reduce salt buildup. To alleviate this problem, it may be necessary to flush the growing medium as needed with acidified plain water (pH of 5.5 - 6.0), especially when the EC of the growing medium is higher than 2.5 mS/cm.

•Do not use a high rate of N to feed your greenhouse tomatoes. In general, we used 100-120 ppm nitrate-N to feed our mature tomato plants with good success. Too much nitrogen can result from increasing the rate of application and/or increasing the volume of irrigation with low concentration of nitrogen. Apparently, there will be a build up of nitrogen regardless of its concentration in the fertilizer solution. Flushing the bags will be necessary to leach out the excess unusable fertilizer.

•The use of ammoniate nitrogen for greenhouse tomatoes has been correlated with a higher incidence of blossom-end rot. Ammonium can cause potassium and calcium deficiency leading to blossom-end rot.

•On hot days, plants will need more water to keep up with water loss through transpiration. Using a fertilizer solution with a high EC will reduce water uptake by the roots leading to more stressed tomato plants. High soluble salts impair the ability of roots to take up water and nutrients. Root injury from high salts can lead to root rot. Wilting or burning of leaves and a reduction in post-harvest quality are typical symptoms of high salts. Reducing the EC of the nutrient to1.0 mS/cm was good for feeding our tomatoes in hot weather and an EC of 1.5 to 2.5 mS/cm was good for feeding in cool weather.

•Some fertilizers contain salts like potassium chloride or sodium nitrate, which supply undesirable elements along with the nutrients. Tomato plants use very little sodium or chloride and too much of these elements can severely stress tomato plants, especially during hot weather. All the salts from water, fertilizer, and media that are not used by the plant will be left in the soilless medium. If they are not leached out regularly, they will accumulate and pose several problems including misinterpretation of the EC values. It is difficult to know whether the salts present are useful nutrients or undesirable elements.

Spacing greenhouse tomato plants

Each tomato plant should have at least four square feet of greenhouse space. Multiply the length by the width of the greenhouse and divide by four to get the number of tomato plants you can plant in a greenhouse. A 30x96 ft greenhouse should have enough space for 700 plants. We plant our tomatoes in five double-rows of bags leaving a walkway of three feet between every two pairs. Rows of bags are spaced at 1.5 feet within each pair and bags are spaced at 1.5 ft within the row (see picture on page 23). Plant two tomato plants per bag. Accurate spacing is essential

for uniform distribution of light. Space the supporting cable above the tomato rows the same way. North- south orientation of the rows is desirable in Louisiana.

Supporting and training greenhouse tomato plants

Single-stem tomato plants can grow up to 30 feet in height and can have a load of 10 pounds of fruit at any given time. The weak stem requires a strong support system to carry the heavy load. Normally, the fall crop plants are the easiest to support and train because they are terminated after 165 days of planting. The spring crop lasts for about 210 days and the long-season crop (one crop per year system) for about 300 days. A strong wire cable of 3/32 inch diameter should be stretched over each row of tomato plants at a height of 8 feet and supported by a strong greenhouse frame or metal posts. Hooks having at least 30 feet of wrapped string and plant clips are needed to complete the job. Hang one hook above each plant and release enough string to reach the base of the stem. Clamp the string in the hinge of the clip and snap the clip around the plant stem. As the tomato plant continues to grow wrap the string clockwise around it and snap a clip every two to three feet of height for extra support. Lean and drop each tomato plant in one direction when it reaches the cable by releasing some string from the hook. The fall crop may be leaned and dropped for two times, the spring crop for five times, and the long season crop for up to 10 times.

Pruning greenhouse tomato plants

•Suckers

Prune tomato plants to a single stem by removing all side shoots or suckers at least once a week. Remove the suckers early in the morning on sunny days when they are very small (one inch or smaller). The small wound resulting from removing the sucker will heal quickly leaving less chances for fungal invasion. Also, prune the suckers or leaves growing on the flower clusters.

•Leaves

A great percentage of assimilates are typically supplied to the fruit by the two or three leaves under the fruit cluster. Early removal of these leaves will hinder the growing fruit from reaching the desirable size. However, removal of the leaves under the fruit cluster will speed up the ripening process, improve air circulation, and reduce botrytis disease incidence. Make sure that the fruit is in the mature green stage before removing the leaves under it.

•Flowers

Normally you do not prune the flower cluster until you see 3 to 4 well-formed fruit on that cluster. However, abnormal flowers (the large fasciated flower shown near the stem on the side photo) have to be removed as soon as you recognize them. This flower will produce a cat-faced fruit.

•Fruits

Fruit pruning is very important to get the large size desired by the consumer. Leave 3-4 well-formed and defect free fruits per cluster. Do the pruning as early as possible to reduce competition between growing fruit. Remove all deformed fruit, excess fruit, and flowers by snapping and not pinching the holding stem. You may need to reduce the fruit load on stressed plants specially the early fall crop by leaving 2-3 fruit on the first two clusters. In general, greenhouse tomato plants should not carry any fruit other than the nice looking large size fruit.

- **Terminal points**

Remove the terminal growing point above the top flower cluster (last cluster to pollinate) approximately forty five days before the intended date of terminating the tomato crop to stop plants from continuing to grow. Leave 2-3 leaves above the top cluster to shade and feed the top fruits. This practice is desired for the fall crop which is normally terminated around the last week of December (remove the terminal point around November 10). It allows for more light which is especially needed in November and December and it reduces labor. We do not recommend removing the terminal point of any tomato crop which is terminated in late June or early July. Instead, we recommend the removal of flower clusters and cessation of pollination approximately 45 days before the intended termination date of the crop. Greenhouse temperature and light intensity are high in June and July in Louisiana and leaving as many leaves on the plant can provide good shade for the growing fruit and cool the greenhouse. It is estimated that each plant will transpire close to one quart of water a day and a house full of plants can lower the temperature of the greenhouse by at least 10°F. We reduced fruit cracking significantly in late June and early July by not topping the plants.

Pollination

The female organs of the tomato flower are enclosed inside the male organs (five anthers attached together to form a cone around the female organ). Anthers open to the inside releasing pollen as soon as they mature. At maturity, the anthers will have a bright yellow color and the flower will be receptive to pollination for about 48 hours. Pollen released without vibrating the flower will not be sufficient to produce high yield of good quality fruit. Field tomatoes are pollinated (vibrated) by natural wind. Because natural wind is absent in the greenhouse, tomato growers must pollinate their crop by several means including battery operated vibrators, air blowers, and bumblebees. Growers should also make every effort to transfer the maximum number of pollen to the stigma of the flower. The size and weight of the tomato fruit is positively correlated with the number of pollen transferred to the female part of the flower.

- **Battery operated vibrators**

Vibrators are small devices (top photo) which can be purchased from any greenhouse supply store and operated by a weak electrical current from a battery. Vibrate the flowers by touching the stem of the flower cluster for few seconds. The strong vibration created by this tool will release more than enough pollen to fertilize the majority of the eggs in the ovary. Pollinate the flowers every-other-day on sunny days when humidity in the greenhouse is between 60 and 80%. Touch the cluster stem and do not touch the flower itself otherwise you could create a hole in the developing fruit (bottom photo). Our research at the Red River Research Station indicates that it takes approximately 30 minutes three times a week to pollinate 700 plants in one greenhouse of size 30X96 feet. This method of pollination is good for a small-size operation and the best method to guarantee pollinating every flower you want to pollinate and produce maximum-size fruit. Some of the drawback include the fact that a grower has to be in the greenhouse at a certain time three times a week, it is a boring job, and the possibility of producing fruit with holes if you touch the flower.

- **Air blowers**

Greenhouse tomatoes can be pollinated by using a household leaf blower operated at normal speed with the air flow directed to the flower clusters. Use this device three times a week as mentioned earlier. Our research indicates that it takes half the time to pollinate the same number of plants compared to the electric vibrator. However, the number of seed per fruit was less and fruit size and weight were smaller than fruit produced by using the vibrator for pollination. In general, anticipate five percent reduction in yield if you use this device.

- **Bumblebees**

Using bees to pollinate one or two greenhouses of the size mentioned earlier will save you time to do something else but it will not save you money. Bumblebees are excellent pollinators for greenhouse tomatoes. Each bee will visit and vibrate the flower for few seconds to collect pollen for feeding. As a by product of this process, the stigma of the flower is showered with a large number of pollen leading to good pollination and fertilization of almost all the eggs in the ovary. Larger size and a heavier fruit is expected from bee pollination. Bees are active from sunrise to sun set, they do not take a long break or a day off. Using a hive (even the smallest mini-hive) can lead to over pollination and injuring many flowers in a small greenhouse. At any given time, each plant will have 2-4 mature flowers ready for pollination. A greenhouse having 700 plants should have 2000 to 2500 flowers ready for pollination. It is estimated that each bee can pollinate up to 350 flowers

a day. The smallest hive available now has more bees than a traditional greenhouse can sustain. We have used one mini-hive in each of our greenhouses to pollinate 640 plants and noticed appreciable number of destroyed flowers and injured fruits. The bottom line is to be very careful if you use bees to pollinate small number of plants.

Harvest and storage of tomatoes

Harvest greenhouse tomatoes every other day early in the morning when greenhouse temperatures are low and fruit quality is better. Do not leave the harvested tomato in the greenhouse in a sunny location even for a short time. Harvest the fruit as soon as you see some color developed on the blossom end (breakers or turning). Fruit harvested at any of these ripening stages has enough internal ethylene to continue the ripening process on it's own if stored at 68-72°F. Light is not needed to finish the ripening process. Fruit harvested at the red ripening stage will be subject to severe bruise without appreciable amount of extra quality. Leaving the fruit on the tomato plant to reach full color may result in higher percentage of cracked fruit and more fruit with yellowish color if the greenhouse temperatures were above 85°F. Do not store tomatoes at temperatures below 60°F. Vine-ripened tomatoes should not be refrigerated. Higher EC of the growing medium will enhance fruit quality and shelf life but may reduce fruit size. High humidity can lead to the production of transparent fruit and fruit with minute cracking leading to a significant reduction in fruit shelf life.

Marketing greenhouse tomatoes:

Do not grow greenhouse tomatoes unless you have a market ready for them. Vine-ripened tomatoes can be stored for a short period of time (4-5 days) before quality deteriorates. Only good quality fruit will keep the customers coming. When tomatoes are boxed, fruit at the bottom of the box should be as good as at the top. Separate the culls and sell them to an informed costumer at a discount price. Tomatoes produced in a higher EC medium will taste much better than tomatoes produced in a low EC medium but higher EC may reduce yield. Tomatoes produced in December, January, and February will taste much better than gassed tomatoes but fruit taste will be enhanced in March, April, and May. The quantity and quality of sun light available in the spring is responsible for better flavor (sugars, acids, aroma, etc.) produced by the plant during these months. Higher prices are common during the winter months, but total production per plant is reduced. Light is the limiting factor and if you clean the plastic to allow more light to enter the greenhouse you should be able to enhance production. Be creative in your marketing techniques; greenhouse tomatoes can be shipped in decorated boxes during occasions like Thanksgiving and Christmas. E-mail or phone your customers to get a feed back on their satisfaction.

Making a profit:

Failure to produce a good greenhouse tomato crop is not uncommon. Reasons include: planting at the wrong time, pest problems, too much nitrogen, salt buildup, heating problems, poor marketing, etc. To minimize losses and enhance profit, you need to pay attention to details.

Following is a summery of some hints mentioned in this manual:

- Select a good variety such as **'Trust'**.

Plant more than you need. Plant 25% more seeds for the fall crop and 15% more for the spring crop. Transplanting in August in wet and warm growing medium (temp. above 80°F) may kill some young transplants by injuring the tender stem buried in the hot and moist medium. If you use perlite as a growing medium, you may start the fall crop in peat pots and use them as a shield to protect the tender stem.

•Be selective. Plant equal size transplants in the same bag and in all the bags of the same greenhouse to maximize yield. Plant some extra transplants in big pots or five gallon bags to have matching size plants in case if you need to replace some later. (Photo on the side showing unequal size transplants in the same bag).

•Check the terminal bud. Carefully examine the tomato plants during the first few weeks after transplanting and replace the off type. Some genetically deformed plants will be easily recognized during the early stage of growth. The seedling on the right has no terminal bud

•Check the feeding tubes. Equal feed will help produce equal-size plants. All feeding tubes must have the same length and internal diameter. Many tubes will be completely or partially clogged after one year of use. You may need to replace all the feeding tubes once a year.

•Equal feed. Less feed resulting from stopped tubes can lead to less leachates and more salt buildup. Tomato plants may display toxic symptoms mistakenly diagnosed as nutrient deficiency. Check for equal feed and correct the problem if detected.

•Stop leaks. Check the main and sub-main lines periodically for leaks especially where feeding tubes are connected to the sub-main lines. The volume of nutrients released from the feeding tank may not be a good indicator of what the plants are getting.

•Plant age matters. Gradually increase the volume of fertilizer solution released for plants based on their stage of growth and weather conditions.

•**Watch the weather**. Reduce irrigation during cloudy and rainy days in the winter. Do not keep the greenhouse completely closed for a long period of time . Draw some fresh air from outside to reduce humidity, improve CO_2 rate, and activate the plants.

•**Reduce heat stress**. Allow tomato plants to take more water in hot weather to reduce heat stress. Lower the EC of the fertilizer solution especially during late July, August, and early September (fall crop). In cold weather, plants can tolerate higher EC.

•**Space plants accurately**. Equal spacing of plants at the ground level and at the horizontal cable is very important for equal distribution of sunlight. Grow bags have to be in a straight line if you look at them from the length and width of the greenhouse.

•**No early fall crop**. Do not try to beat the heat by planting the fall crop very early in July in hopes of harvesting an early crop. Remember that it takes 40-45 days from seeding to blooming. Unless the temperature at night is less than 70°F during flower initiation, plants will not have good fruit set. Keep in mind that it takes about two weeks to initiate the flowers before they become visible with their bright yellow color. Flowers are very sensitive to heat stress during the initiation period.

•**Bumblebee pollination may not be the best option.** The smallest hive you can buy has more bees than you need to pollinate the opened flowers in a single house of 700 plants Over pollination by bees can injure the flowers and reduce yield. Watch the flowers for severe injury (side photo at bottom shows damaged male and female organs, top indicates good pollination). Try to correct the problem as soon as possible by opening the hive every other day, use one mini-hive for two houses, or supply bees with pollen to decreas their activity.

•**Leave 3-4 fruit per cluster**. Most tomato varieties can set 5-8 fruit per cluster. Prune the fruit cluster to 3-4 fruits as soon as you can identify the best looking fruit (side photo). Do the pruning when fruits are small to direct plant energy to the remaining fruits on the cluster. Do not pinch the fruit stem, instead, snap the fruit at the joint.

•**Remove cat-faced fruit**. Do not leave a cat-faced fruit on the plant. It consumes plant energy at the expense of other growing fruit. Most likely the cat-faced fruit will be culled out after harvest and the other fruit on the same cluster will be small. With some training, you can detect and remove the flower which would produce a cat-faced fruit (fasciated flower).

•**Remove injured fruit**. Greenhouse tomato plants should not bear injured (side photo) or misshapen fruit. Each fruit should look nice and round. In fact, if you get more than 2-3% culls, you need to review your production practices.

•**Small suckers are easy to remove**. Pruning fruit clusters is not the only pruning a greenhouse tomato grower should do to produce a profitable crop. Make sure to prune the suckers when they are very small (side photo). Prune early in the morning on sunny days to allow the wounds to heal before exposure to high humidity at night. Snap and do not pinch the suckers.

•**Remove plant debris**. Daily activities may lead to broken leaves. The broken leaf shown on the side photo and other dead tissues attract botrytis spores. Always remove any broken leave and dead tissue. Botrytis gray mold is a disease of bad management and you may be able to control the disease and prevent serious crop losses by sanitation and continuous air movement in the greenhouse. Leave some open vents during the day and at night, especially during cloudy and rainy weather to improve air exchange.

•**Vent the greenhouse.** Tight closing of the greenhouse may lead to undesirable results (plants and heaters use a lot of oxygen at night). It may lead to the build-up of exhaust gases especially ethylene and also carbon monoxide. These gases can cause flower abscission (small flowers show on the side photo are ready to abort) and/or a complete loss of the crop. Vent your greenhouse and make sure that your heaters have plenty of fresh air. Check the flame in your heaters to make sure that it is burning clean (no yellow flame or soot). Yellow flame can contribute to the build-up of the ethylene gas. Tomato fruit on the plant emit ethylene gas and a very small amount of ethylene trapped in a tight closed greenhouse can lead to bloom drop and/or a complete loss of the tomato crop. Flower-drop also can occur under low light conditions which reduce the growth of the whole plant.

•**Keep humidity in check.** High humidity can lead to inactive tomato plants. Remember that leaves transpire and lose water if the air in the greenhouse is less humid than the leaf itself. Assuming that leaf humidity is at 100%, less humid air around the leaves will create a vapor pressure deficit and force the leaf to transpire more. The loss of plant water through transpiration and other activities is the key for absorbing water and nutrients. High humidity also can cause moisture condensation on the fruit, leading to the development of minute cracks and a drastic reduction in shelf life. Humidity higher than 80% can lead to poor pollination and more botrytis disease.

•**Leaf pruning.** Leaves under the fruit cluster provide most of the assimilates for the developing fruit. Pruning the leaves under the cluster should lead to fast ripening but possibly smaller fruit size. Removing too many leaves will leave big wounds and may lead to the spread of botrytis disease. If you want to prune leaves, snap and do not pinch the leaf. Do it early in the morning on a sunny day to allow time for the wounds to heal before night fall.

•**Topping the spring crop**. Topping the crop before termination may lead to more fruit split (side photo). Just remove the unwanted flowers and the suckers to keep the plant growing. Maximum vegetation is needed in June and July to cool the greenhouse. A house full of vegetation can be 10 to 15°F cooler. A cooler house can improve fruit color and reduce fruit cracking. Top the fall crop in November, i.e., 45 days before the intended date of termination in late December or early January. Leave 2-3 leaves above the top cluster to protect the fruit.

•**Fruit cracking**. This is a serious problem in October (fall crop) and again in June (spring crop). The main reason for fruit cracking is heat. Avoid planting an early fall crop in July. Do not top the spring crop as mentioned above. Irrigating with large volume of fertilizer solution having a low EC during hot weather may increase the incidence of cracked fruit. Avoid big differences between day and night temperature.

•**Be cautious with nitrogen fertilizer.** Excessive nitrogen can lead to more vegetative growth and less fruiting. Fruit shape, quality and shelf life can also be reduced. Always observe your plants and conduct tissue analysis. Use the NO_3 form of nitrogen and reduce NH_4 use. If the NH_4 rate is too high, toxic symptoms and/or more blossom end rot may be detected. Less irrigation can lead to wilted plants on sunny days and may lead to higher incidence of blossom-end rot (side photo).

•**Heat treatment.** Treat the growing medium with hot water (above 160°F) after each crop and screen the perlite at least once every two years to remove the roots and loosen the medium. This practice will reduce the risk of disease, insect, and salt build up, and improve air contents of the medium.

•**Use bottom heat**. It is the most efficient way to improve production with one heating system. Run conviction tubes between the double rows of bags above the feeding pipes. The warm air emitted from the ducts should warm the growing medium in the bags, the fertilizer solution in the pipes, and the whole plant from the bottom up. Make sure that the growing bags touch the convection tube.

•**Adjust temperature**. Formation of pollen grains and ovules in the tomato flower starts a long time before you see the yellow flower. Do not lower greenhouse temperature than 63°F at night or you may get cat-faced fruit.

•**Stress conditions.** Such as high temperature, high medium EC, and less irrigation may lead to more fruit with zipper track (anthers remain attached to the fruit as it continues to grow).

•**Improve light.** Remove fruitless plants to improve light and air circulation for the remaining plants. Clean the plastic cover of the greenhouse in late October and again in January to remove dust and improve light intensity in the greenhouse. Sunlight is the limiting factor for yield improvement in the winter.

•**Using the EC and pH meters**. Besides testing the fertilizer solution, always test the EC and the pH of the growing medium around the roots. It is the best indicator of the root environment. Correct the undesirable conditions around the roots to produce a profitable crop.

•**Reusing the growing medium.** If you are planning to reuse the medium, do not cut your plants after the last harvest. Let them grow for an additional one week on just plain water. Plants will absorb the excess salt and reduce the EC to a manageable level for the next crop.

•**The fall crop**. Plant the seeds of the fall crop near the cool side of the greenhouse and keep the transplants in the same area for 3-4 weeks. Cooling faucet water to 65°F with ice (side photo) before irrigation may reduce the production of spindle transplants. Keep the permanent bags in the cool side of the green house after transplanting for another two weeks if possible.

•**Harvest tomatoes early in the morning**. Do not leave harvested fruit in a sunny location in the greenhouse. Harvest as soon as you see some color (breakers) and store the fruit at 68 to 70°F to develop full color. A fruit harvested at the red ripe stage will be subject to more bruising without enhancing quality.

•**Media salt**. Higher media EC within an acceptable range will improve fruit quality and lower the yield. Reducing medium EC will improve yield on the expense of fruit quality. A growing medium EC of 1.5 to 2.5 mS/cm. for mature plants is a good compromise.

•**Flush the growing medium**. Sometimes you need to flush the growing medium to get rid of excess salt. Adjust the pH of the flushing water to 5.5-6.0 before use. If you use water with a pH of 7.5 to 8.0, it will take a long time to bring back the medium pH to 5.5 or 6.0.

•**Toxic effect**. Low-volume irrigation can lead to symptoms similar to nutrient deficiency. Leach out at least 20% of the fertilizer solution to reduce plant toxicity.

•**Improve the cooling efficiency**. Clean the cooling pads by scrubbing the salts and green algae at least twice a year when they are dry. Use a shop vacuum to get red of the debris. Reverse the pads position once every two years to increase their longevity.

•**Use shade cloth**. Shade the greenhouse to decrease fruit and leaf temperature and improve fruit color. The red color pigment is best developed at temperature less than 80°F. Yellow fruit color will develop at temperature above 85°F.

•**Carbon dioxide**. Low CO_2 in the greenhouse can reduce fruit production by as much as 20%. Draw more fresh air from outside to replace the depleted CO_2 and help the plant produce more assimilates.

•**Fruit shape**. Low temperature during flower development induce the formation of severely-fasciated flower. These flowers will produce cat-faced fruit. Fertilizing tomatoes with nitrogen rich formula may increase the number of cat- faced fruit (side photo). Some of the fruit set under low temperature conditions are puffy. Night temperature should be 63- 68°F and day temperature 75-80°F.

•**Water drip**. Too much condensation on the polyethylene cover can lead to water drip on the leaves and fruit. Wet plant parts can promote the spread of disease and reduce fruit quality. Poly cover is available with anti-condensation properties.

•**Screen vents**. To stop insects from entering the greenhouse, screen all the vents and install a screen door outside the main door to create zero vacuum entrance. Use sticky cards to monitor and control small insects. Make sure they do not stick to the plant or the fruit. Keep a grass-free parameter around the greenhouse and spray around the greenhouse with labeled insecticides if insects are found. It is much easer to control pests before they enter the greenhouse.

•**Night irrigation**. Plants need about 15% of their total consumption of water at night but night irrigation may increase disease problems. Schedule irrigation to start one hour before sunrise and to be terminated around sunset. To maximize photosynthesis on sunny days, make sure that plants have plenty of fertilizer solution and CO_2 which can be enhanced by drawing outside fresh air.

•**Magnesium deficiency**. Almost every greenhouse tomato grower will notice some magnesium deficiency symptoms on tomato plants. In rare cases these symptoms may lead to yield reduction. More potassium around the roots will reduce the uptake of magnesium and can cause deficiency. The problem can be corrected by spraying a 2% epsom salts solution (approximately 2 ounces per gallon of water).

•**Flowers mixed with leaves on the same cluster**. Too much fertilizer in the growing medium can lead to the formation of leaves or suckers on the flower cluster. They have to be removed as soon as they become visible.

References:

Horticultural Journals (HortScience, Acta Horticulture, etc.).
Trade Publications (Vegetable grower, greenhouse grower, etc.).
Extension Publications.