



# ORGANIC GREENHOUSE TOMATO PRODUCTION

HORTICULTURE PRODUCTION GUIDE

*Abstract: This publication offers an overview of organic greenhouse tomato production. To be successful, the small-scale producer needs to do thorough production and marketing research, find or create a niche market, and produce a consistently healthy crop. Maintaining optimum fertilization and moisture levels, practicing rigorous pest management, and ensuring good pollination can increase crop yields. Information in this publication includes organic management methods for major diseases and insect pests; organic fertilization recommendations; a list of organic fertilizer suppliers; and a directory of further resources available on the Internet.*

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## INTRODUCTION

Tomatoes are the leading greenhouse vegetable crop in the United States and Canada. In the U.S., the total acreage in greenhouse tomato production increased by 40 percent between 1996 and 1999. Statistics for 1999 show that the U.S. had about 800 acres in greenhouse vegetable production, with tomatoes accounting for 750 of those acres (1). The leading states in greenhouse vegetable production are California, Florida, Colorado, Arizona, Ohio, Texas, and Pennsylvania – each with more than one million square feet in production (2). The vast majority of greenhouse tomatoes are produced in greenhouses using conventional production systems. Conventional and organic greenhouse production differ in the types of potting media, fertilization practices, and pest control methods they use.

## EDUCATION IS KEY

Education is the first step toward a successful greenhouse tomato crop, and there is a lot of

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information available on growing greenhouse tomatoes. Your local extension agent is an excellent source of information for your area. Extension publications from all U.S. states are available on the Internet. Most publications can be downloaded and printed at no charge. California, Colorado, Florida, North Carolina, Georgia, and Mississippi all have excellent information on growing greenhouse tomatoes. *Dr. Mary Peet's Greenhouse Vegetable Production Website* is an especially good resource with links to many related websites (see the Web Resources section for the website address). This website offers valuable information on sustainable production and integrated pest management, with specific information on individual crops. Mississippi State Extension Service has many publications and articles on greenhouse tomato production written by Dr. Rick Snyder (see the Web Resources section for the website addresses). This website focuses mainly on conventional greenhouse production; however, much of the information is valuable to both organic and conventional growers.

## MARKETING

Sell your tomato crop before you plant it. It is important for small growers to explore niche markets such as selling directly to the public via roadside stands or at farmers' markets. Marketing your products as "locally grown" is a possible strategy to explore. It may also be feasible to wholesale your product directly to local and regional retailers that sell organic produce.

Direct market sales are affected by competition among local greenhouses and by cut-rate wholesale organic produce. The market can change rapidly, and greenhouse producers must be adaptable to change. The popular press and advertising can have a powerful influence on consumers. Niche markets can fade overnight with the arrival of large wholesale operations or simply by a change in consumer demand (3). For more information, request the ATTRA publications *Direct Marketing* and *Organic Marketing Resources*.

## SCHEDULING THE CROP

Greenhouse tomatoes bring the highest price from December through April, when it is too cool for local field-grown tomatoes. Winter growers may choose between a

### Days to Maturity:

Very Early 45-50

Early 50-60

Midseason 70-80

one- or two-crop system. With the one-crop system, plants are set in September and grow through the winter and spring until late June. This system works best in the cooler and less humid northern regions and is also used by most Florida growers. In a two-crop system, the fall crop is succeeded by a spring crop. Tomato plants that have been growing since September do not have the same vigor as the younger transplants. The older plants tend to have a denser growth by winter, which reduces airflow and aggravates problems with humidity. Plants held over winter are more likely to be infected with diseases that thrive on high humidity and cooler temperatures, such as Gray Mold (caused by *Botrytis cinerea*) and Leaf Mold (caused by *Cladosporium fulvum*).

In a two crop system, the fall crop is seeded between July and September. Check with your local extension agent for planting times in your area. If the crop is planted too early, high summer heat can stunt the young plants and delay harvest. For premium prices, try to schedule the first harvest to coincide with the first frost in your area. In some southern states, first frost may come as late as mid-November to early December.

Seed the spring crop in mid- to late November. If possible, the seedlings should be started in a separate house, in case there is a disease or insect problem with the fall crop. The seedlings will be ready to transplant about six weeks after seeding. Expect to see the first harvest in late March or early April. The spring crop is usually grown until the summer crop of field tomatoes is ready to harvest.

## SOIL AND SOILLESS MEDIA

Greenhouse tomatoes can be grown in soil or in soilless media. In soil culture, crops are grown at ground level or in raised beds. The soil is usually amended with approved compost and other approved organic additives. The potential for disease and nematode build-up in organic soil-based greenhouses is quite high in many areas. Tomatoes, in particular, are vulnerable to many soil-borne diseases, including *Verticillium* and *Fusarium* wilts. Nematodes that can cause root knot galling can also be a problem in some soils. Many growers go to the added expense of grafting onto disease and nematode resistant rootstock. (Additional information about grafting is available at <http://www.agnet.org/library/article/eb480.html#1>.) Steam pasteurization and solarization in the summer are approved pest control methods for nematodes, *Verticillium*, *Fusarium*, and other soil-borne pathogens.

For general information about greenhouse organics, see the ATTRA publication *Organic Greenhouse Vegetable Production*.

Soilless cultivation methods—sometimes collectively (and loosely) known as hydroponics—are covered in the ATTRA publications *Greenhouse and Hydroponic Vegetable Resources on the Internet* and *Aquaponics: Integration of Hydroponics with Aquaculture*.

## PEST MANAGEMENT

One key to a successful organic greenhouse operation is maintaining rigorous pest management. A pesticide-free greenhouse means that growers *must* practice good sanitation and pest management methods from the beginning. Pathogens or insects can become epidemic in a greenhouse environment in a very short time.

Once a pest problem has set in, there are few options available to organic greenhouse producers. For detailed information on specific greenhouse tomato pests and controls, see Appendix One. Integrated Pest Management (IPM) is a strategy that can be used in organic production as well as in conventional production systems.

IPM promotes a variety of tactics, including the use of pest resistant varieties and biological, cultural, and physical controls. Pesticides are a control tactic used in IPM, but they are used only when needed. Pesticide use is thus minimized without jeopardizing crop quality or yield. Organic production systems use all of these, with the exception of chemical pesticides. Other pesticides, such as insecticidal soaps, biopesticides, botanicals, and mineral-based pesticides, are allowed. For more detailed information on greenhouse IPM, refer to the ATTRA publication, *Integrated Pest Management for Greenhouse Crops*.

### *Cultural Control Methods*

In a closed environment, some diseases can literally spread overnight. Pathogens come in contact with the plants in many ways. Infested soil or plant debris, air movement, water, and contaminated hands, tools, or clothing can all spread disease. Good ventilation and air circulation, rigorous sanitation practices, and maintaining optimum temperatures and humidity levels are effective methods of disease control in the greenhouse.

### *Sanitation*

Rigorous sanitation practices are essential for healthy and productive crops. Before a crop is planted, it is important to thoroughly inspect the greenhouse. Screens, doors, and walls should be checked periodically for any tears or other openings. Mulching around the plants and using landscape fabric on walkways helps to reduce weeds and soilborne pathogens. It is not advisable to store houseplants in vegetable production greenhouses. A seemingly healthy

houseplant can be a vector for many diseases that attack vegetable crops (4).

During tomato production, debris and cull piles are a prime source of many plant diseases. Promptly remove all plant debris from the greenhouse areas *before* an infection can take place. Work surfaces should be made of non-porous material, such as stainless steel, and sterilized after each use. Laundry bleach is an acceptable disinfectant, providing the residual chlorine levels in the bleach-water do not exceed those set by the Safe Drinking Water Act (4 ppm).

Proper sterilization of hands, feet, and clothing when moving from house to house greatly reduces cross-contamination. Before entering the greenhouse, hands should be washed in hot soapy water. For tobacco users (both smokers and chewers), a rinse of 1– 3% trisodium phosphate prior to washing in hot soapy water is recommended to avoid the introduction of Tobacco Mosaic Virus (TMV) into the greenhouse. Because TMV can survive on clothing for long periods of time (up to 3 years in a darkened closet), it is important that clothing and overalls be changed daily and washed and dried at high temperatures. A shoe wash with a disinfectant-soaked mat at the entrance to the greenhouse will help eliminate pathogens brought in on shoes. Adding a small enclosed entry porch to the greenhouse provides a place to decontaminate shoes, tools, and equipment, and also helps keep out pests. In situations where there is a contagious disease such as bacterial canker, all tools, machinery, and electromechanical pollinators should be sterilized at the end of *every row* with ethanol or 0.5% sodium hypochlorite (5).



### Good (Green)housekeeping

- ✓ Keep doors closed and make sure all screens are in good working order.
- ✓ Make sure all plant debris and cull piles are removed promptly.
- ✓ Sanitize hands, tools, and machinery when moving from house to house.
- ✓ Have a shoe wash at each entrance.
- ✓ Wash clothing regularly in hot water.
- ✓ Do not store houseplants in production greenhouses.

### *Ventilation, temperature control, and humidity reduction*

Temperature control and humidity reduction play a major role in maintaining greenhouse crop health. During the fall, winter, and spring, when the majority of greenhouse tomatoes are grown, high humidity and limited air circulation give many diseases an ideal growing environment. Moisture condensation creates humid conditions within the foliage, encouraging fungal and bacterial infection (6).

Good ventilation and proper temperature control are critical for reducing humidity and controlling airborne fungal diseases. To ensure good ventilation, allow several feet of airspace above the plants and use proper spacing between them. Pruning the suckers just below the first fruit set also helps to maintain good air circulation within the canopy. To increase ventilation, Mike Collins of Old Athens Farm in Westminster, Vermont, culls the bottom leaves once his plants are four feet tall. Collins cuts the leaves off an inch away from the stem and snaps off the stubs at the next pruning to minimize *Botrytis* infection sites (7). Some greenhouse producers also “lower” their crop—move the plants on their supports, so the sections ready for harvest are always at the same level, enjoying the same temperature.

**Optimum air temperature for sustained tomato growth:**

Day: 75–85°F

Night: 60–70°F

Temperature control can be maintained in several ways. Polyethylene tubing works best for maintaining even temperatures throughout the greenhouse. With this system, fresh air from the outside can be warmed with fan-type heaters to maintain optimum temperatures. Fans inside the greenhouse, mounted above the crop, help keep temperature uniform. With a pad and fan system, the air can be too cool at the cooling-pad end and too warm at the fan end. Temperature differences of 10–15°F can occur within the same greenhouse, which can cause catfacing, uneven growth, failures in fruit set, and devastating foliage disease (6). And the higher the humidity, the less efficient evaporative systems are. For even heating from the ground up, heating pipes can be placed between alternating rows. The heated air rises and pushes the cooler air to the floor, helping to maintain good airflow. In hot climates, greenhouses need higher roofs to keep hot air away from the plants.

## RESISTANT VARIETIES

Using disease-resistant seeds and transplants whenever possible is one of the organic greenhouse producer’s best lines of defense. For best results, use good-quality seed from a reputable source. Organic growers must use organically grown seed if it is commercially available, or untreated seed from a conventional source if it is not. For a list of organic and untreated seed and transplant suppliers, see ATTRA’s [Suppliers of Organic and/or Non-GE Seeds and Plants](#).

**Table 1. Common Disease Abbreviations\*.**

Disease	Abbreviation
Bacterial Speck	BSK-O
Early Blight ( <i>Alternaria</i> )	EB
Fusarium Crown & Root Rot	FCRR or FrWi
Verticillium Wilt Race 1	V
Fusarium Wilt Race 1	F1
Race 2	F2
Race 3	F3
Leaf Mold ( <i>Cladosporium</i> )	C2, C5, C7
Nematode	N
Powdery Mildew ( <i>Oidium</i> )	Oi
Gray Leaf Spot ( <i>Stemphylium</i> )	St
Tobacco Mosaic Virus	TMV
Tomato Spotted Wilt	TSW or TmSw
Tomato Mosaic Virus	ToMV

\*These are examples of common abbreviations. Suppliers may differ in abbreviation styles.

To indicate disease resistance, a series of abbreviations is usually listed with the description of the cultivar. Each abbreviation stands for a specific pathogen. For instance, Tobacco Mosaic Virus is TMV; Fusarium Wilt race 1 is F1, etc. (8). Fusarium Crown and Root Rot may be printed as FCRR or FrWi depending on the distributor. See Table 1 for examples of major greenhouse tomato diseases and their abbreviations. See Table 2 for a list of resistant greenhouse tomato varieties.

Once a variety of tomato has been selected, the next task is to decide whether to grow transplants from seed or to purchase plugs. Either way, all transplants must be grown using approved organic methods and inputs. The advantages of producing plugs in-house include an efficient use of greenhouse space and rapid production. The disadvantages include extra labor cost for seeding and transplant production and increased heating costs in winter (plugs

**Table 2. Disease-resistant Greenhouse Tomato Varieties\*.**

Disease	Resistant Varieties	Tolerant Varieties
Fusarium Crown and Root Rot	Trust	
Fusarium Wilt Race 1	Caruso, Trust	Vendor
Race 2	Caruso, Trust	Vendor
Race 3		
Leaf Mold ( <i>Cladosporium</i> )	Buffalo, Capello, Caruso (races A thru E), Cobra, Dombito, Jumbo, Match, Pink KR15 and Pink CR-864 with gene <i>Cf-5</i> , Trend, Trust (races A thru E), Ultra Sweet & Ultra Pink with <i>Cf-7</i> , Vision, Furon and Vetomold with <i>Cf-2</i>	
Powdery Mildew ( <i>Oidium</i> )	DRW 4409, Belliro (DRW 4369)	Grace, Milano
Gray Leaf Spot ( <i>Stemphylium</i> )		
Tobacco Mosaic Virus	Boa, Caruso, Cobra, Trust	Vendor
Tomato Spotted Wilt	DRW 5719	

\*Remember, you must use organically grown seed if it is available commercially, or untreated seed if it is not.

are very sensitive to temperature fluctuations). There are many issues to consider when deciding whether to use seed or transplants. The size of the operation, available labor, and cost of production are just a few considerations. According to Kessler and Behe (9):

The decision should be based partially on market considerations, labor availability and expertise, the number of plants to be produced, the cost per plug, and the specialized equipment and facilities required. This investment is often not economically practical unless production is large or plugs are marketed to other growers. For most small to medium sized growers, especially [beginners], it is often more economical to purchase...plugs from specialized growers and concentrate on producing finished containers. The issue of grow versus purchase should be reviewed periodically as the needs and facilities of the grower change.

For more-detailed information on plug production, see the ATTRA publication [Organic Plug and Transplant Production](#).

## NUTRITION

A well-fed plant is a healthy plant. Maintaining optimum nutrient, light, and moisture levels will result in healthier plants that are better able to fend off diseases and insect pests. Tomatoes are heavy feeders because of their rapid growth and long production season. Tomatoes need 75 to 100 pounds of nitrogen (N) per acre and moderate to high levels of phosphorus (P) and potassium (K) for maximum yields. Soil tests can establish what nutrients soil needs. Some growers add a mixture of animal meal by-products, rock phosphate, and kelp meal to provide needed nutrients. Fertilizer efficiency is highest at a pH of 6.0 to 6.8. To help maintain proper nutrition and pH levels, a pH meter is a handy tool. For more information on organic fertilizers and the nutritional needs of tomatoes, see the ATTRA publication, [Organic Tomato Production](#).

According to the National Organic Standards, it appears that organic greenhouse crops may be grown either in soil or in soilless media. Build-

ing nutrient-rich soil in a greenhouse environment takes extra time and effort, but the results are well worth it. Compost is the main nutrient ingredient used in soil beds. One grower in Canada applies compost at a rate of one or two cubic meters per 100 square meters of bed space (1.2 to 2.4 cubic yards per 1,000 square feet). The beds are then covered with straw mulch. Five to six applications were added to the beds at five- to six-week intervals in the first year. The compost was applied in smaller amounts and less frequently through the fourth year. A rich, healthy soil was the result. Soil organic matter usually ranges from 10 to 12% and can

even reach a remarkable 25 to 30% after several years. For more information on large-scale composting, see ATTRA's [Farm-Scale Composting Resource List](#).

Soilless technology shows promise for increasing yields and reducing economic losses to soil-borne diseases. Dr. Mary Peet and Janet Miles of North Carolina State University have recently concluded a study to develop organic fertilization regimes specifically for greenhouse tomatoes using soilless media. See Appendix Two for a copy of the article, "Recommended Fertilization Practices for Producing Organic Green-

## GROWER PROFILE

Six years ago, Mike Duda, a market gardener from Victor, Montana, was just sick about his tomatoes: The high winds and cool nights around Victor were costing him two-thirds of his crop. That was when he decided to try greenhouse production. He bought a 30' x 90' metal-frame greenhouse kit, erected it himself, and installed an inflatable poly cover. A second-hand oil-fired furnace supplied the heat. An old attic fan furnished ventilation exhaust, and some used house fans moved air around inside the greenhouse. And not much has changed since then, except that Mike's tomato harvest has tripled.

Duda grows in soil, on raised beds. As he describes it: "We live in cattle country, so manure is easy to find. I use aged (three years) cow manure about two inches deep, dolomite lime, rock phosphate, and a little homemade wood ash. I use a soil test to gauge the amounts and hand-dig the beds. . . . I also fertilize with seabird guano every couple of weeks. I use drip tape for irrigation and tie the tomatoes to twine attached to the greenhouse for support.

"I start the tomatoes from seed on December 26. . . . Harvest starts the last week in May and continues through October. It peaks mid-June to mid-August, when we get 250 pounds a week.

"I use garden variety tomatoes, not greenhouse varieties. They're bred for shipping, not taste. I use Brandywine with good results, Oregon Spring with excellent results (they don't need pollination), and Sungold with excellent results (they produce until Thanksgiving).

"I spray with kelp weekly until the fruit set. It works well. You eventually get some disease, but it's near the end of the crop, so you tolerate it as long as you can, then remove [the diseased plants]. We do see a few aphids. I use soap spray when they get too bad. This year I'm going to try some beneficial insects; it's hard to spray effectively when the plants are big.

"We sell all of our tomatoes at the farmers' market, all at retail prices. It's good for us, and the customers love fresh tomatoes. This will be our sixth year for greenhouse tomatoes, and I can't imagine not having them. It's fun to be able to start gardening in the middle of winter, and tomatoes always sell well."

house Tomatoes” by Janet Miles. This article includes detailed recipes for each stage of maturity.

## POLLINATION

Tomato plants have both male and female reproductive organs on the same flower, so with a little help, each flower can self-pollinate. In the natural environment, wind and insects pollinate tomatoes. In a greenhouse environment, more attention must be paid to the pollination process to ensure maximum fruit set. Today, tomatoes are pollinated in greenhouses either by bumblebees or by mechanical pollinators.

Mechanical pollination is done with a battery-powered, hand-held pollinator or by electric vibrating benches. The hand-held pollinators are labor-intensive. Workers have to hand pollinate each plant two or three days each week during flowering. Vibration benches work on an automatic timer and do not require much labor after installation, but they are expensive and not cost-effective for small- to medium-scale growers.

Mechanical pollination of tomatoes was predominant in U.S. and Canadian greenhouses until the mid-90s, when the use of bumblebees was adopted from European growers. Today, most greenhouse tomato growers in North America are using bumblebees, which work every day of the week, selecting only the flowers that are ready to pollinate. Bumblebees can pollinate up to 30 flowers a minute. It is not unusual to have 100% pollination, which results in higher yields than are achieved with mechanical methods (10).

Bumblebees are mild-mannered and easy to work with; they rarely sting without provocation. They start a new colony each year, with only a single queen hibernating over the winter. This queen then starts a new colony in the spring. By mid-summer the colony can number in the hundreds. At the end of the summer

the bees begin to die out and the process starts over again. However, due to breakthroughs in bumblebee breeding, full-strength colonies of bumblebees are now available year round.

For commercial production, the bees are shipped by airfreight and placed in the greenhouse as the first flowers begin to open. Stocking rate varies from one hive for a small greenhouse to two to four hives per acre for larger facilities. The hives are usually replaced every 8 to 12 weeks as the colony begins to die out. There are two primary species of bees produced in Canada and the United States: *Bombus occidentalis* for the west and *B. impatiens* for the east. According to the USDA and AgCanada, the dividing line is at the 100th meridian, which runs through the middle of Texas, Oklahoma, Kansas, Nebraska, and the Dakotas. To avoid confusion, the USDA has classified these states as “eastern” states in the case of bees. Bees West, Inc., supplies western species, and Koppert Biological Systems, Inc., supplies eastern species (10).

## SUMMARY

A successful organic greenhouse tomato operation will require research into all aspects of the business. Before planting the first seed, it is important to locate a niche market in your area and schedule harvests to coincide with times of high market value. Soil systems have many advantages compared to soilless systems; however, they can be sources for soil-borne diseases such as *Verticilium* and *Fusarium* wilts. Maintaining rigorous pest control is key to maintaining a healthy, productive greenhouse operation. Successful pest control includes incorporating Integrated Pest Management practices, including cultural control methods, and the planting of disease resistant varieties. Organically grown seed must be used if available. If not, commercially available untreated seed may be used. All transplants, whether purchased or grown on the farm, must be grown using approved organic methods and inputs. Maintaining proper

pH and fertilization levels improves disease resistance and increases yields. Using bumblebees for pollination can also increase yields and reduce labor costs.

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<<http://msucares.com/pubs/pub1828.htm>>.
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- 10) Kueneman, Tom. 1995. The pollinator. Greenhouse Product News. Vol. 5, No. 9. p. 8, 10.

## RESOURCES

### *Organic Fertilizer Distributors*

Agri-Growth International, Inc.  
<http://www.agriorganics.com>  
*Agri-Growth International, Inc. is a manufacturer of organic plant nutrients and stimulants. This website offers information on their products. Send e-mail to [herb@agriorganics.com](mailto:herb@agriorganics.com), or contact them at 1-780-484-0102 for a distributor listing in your area.*

Alternative Garden Supply  
<http://www.alternativegarden.com/>  
*Alternative Garden Supply offers a complete online store and a listing of retailers in your area. They carry a variety of liquid organic fertilizers such as Earth Juice, Fox Farm, Pure Blend, Maxicrop, and Age Old Organics.*

Atlantis Hydroponics  
1035 Baxter Street  
Athens, GA 30603  
(706) 543-9980  
Toll Free: (888) 305-4450  
Fax: (706) 543-9919  
[info@atlantishydroponics.com](mailto:info@atlantishydroponics.com)  
<http://www.atlantishydroponics.com>  
*Atlantis Hydroponics offers a wide range of organic fertilizers and stimulants: Alaska Start-up, Earth Juice, Fox Farm, Neptune's Harvest, Pure Blend, and others.*

Greenfire  
347 Nord Ave. #1  
Chico, CA 95926  
(916) 895-8301  
Fax: (916) 895-8317  
<http://www.greenfire.net/>

*Greenfire offers a wide range of organic fertilizers for both soil and soilless media. Greenfire is an Earth Juice distributor.*

Growlight.com  
sales@growlight.com

<http://www.growlight.com/>

*Online catalog with a distributor list for retailers in your area. Organic products include B'Cuzz Growth, Root, and Bloom Stimulators; Nitrozime; and Age Old Organics Liquid Grow, Bloom, and Kelp.*

Harvest Moon Hydroponics

<http://www.hmoonhydro.com/>

*Harvest Moon Hydroponics offers a complete online store with a wide range of organic fertilizers and stimulants: including B'Cuzz, Earth Juice, Pure Blend, Superthrive, Nitron A-35, Grow Big, and Big Bloom. The website includes a list of Harvest Moon retailers in your area.*

Home Harvest® Garden Supply, Inc.

3807 Bank Street

Baltimore, Maryland 21224

1-800-348-4769

Voice: (410) 327-8403

Fax: (410) 327-8411

[ugrow@homeharvest.com](mailto:ugrow@homeharvest.com)

<http://homeharvest.com/storeinfo.htm>

*Earth Juice, Fox Farm, and others.*

HydroMall™

[http://www.hydrmall.com/infocart/Organic\\_Fertilizer/](http://www.hydrmall.com/infocart/Organic_Fertilizer/)

*HydroMall™ offers organic fertilizers from Agri-Growth International, Inc., such as: Myco-Net Biological Inoculum, Nutri-Max, and others. Order online from HydroMall™ or see their Stores Directory for a retail store near you.*

### **Information on the Web**

#### **Budget for Greenhouse Tomatoes**

Mississippi State University, Cooperative Extension Service

<http://msucares.com/pubs/p2257.html>

#### **Commercial Greenhouse Tomato Production**

Colorado State University; Cooperative Extension Service

<http://www.ext.colostate.edu/pubs/garden/07606.pdf>

#### **Dr. Mary Peet's Greenhouse Vegetable Production Website**

North Carolina State University

[http://www.ces.ncsu.edu/depts/hort/greenhouse\\_veg/resources/](http://www.ces.ncsu.edu/depts/hort/greenhouse_veg/resources/)

*Resource page with links to conversion tools, print information, and related Websites.*

#### **Environmental Control for Greenhouse Tomatoes**

Mississippi State University, Cooperative Extension Service

<http://msucares.com/pubs/pub1879.htm>

#### **Florida Greenhouse Design**

University of Florida, Cooperative Extension Service

[http://edis.ifas.ufl.edu/scripts/htmlgen.exe?DOCUMENT\\_AE016](http://edis.ifas.ufl.edu/scripts/htmlgen.exe?DOCUMENT_AE016)

#### **Grafting, De Ruiters Seeds Inc.**

<http://www.deruitersusa.com/guide.html>

*(Guidelines for Grafting)*

<http://www.deruitersusa.com/root.html>

*(Rootstock Germination)*

#### **Greenhouse Tomato Handbook**

Mississippi State University, Cooperative Extension Service

<http://msucares.com/pubs/pub1828.htm>

#### **Greenhouse Tomato Production**

Oregon State University, College of Agricultural Sciences

<http://www.orst.edu/Dept/NWREC/tomatogh.html>

#### **Growing Hydroponic Tomatoes**

The University of Arizona, College of Agriculture

<http://ag.arizona.edu/hydroponictomatoes/index.htm>

**Insect and Disease Problems of Tomato**  
Texas A&M University, Aggie Horticulture  
[http://aggie-horticulture.tamu.edu/  
imagemap/mgmaps/mgprob.html](http://aggie-horticulture.tamu.edu/imagemap/mgmaps/mgprob.html)

**North Carolina State's Greenhouse Food Production Website**

North Carolina State University  
[http://www.ces.ncsu.edu/depts/hort/  
greenhouse\\_veg/index.htm](http://www.ces.ncsu.edu/depts/hort/greenhouse_veg/index.htm)  
*Topics include cultural control, biological control, and organic production.*

**Single Truss Tomato Production System**

Bioresource Engineering Department  
Rutgers University - Cook College, New Jersey  
[http://nj-nscort.rutgers.edu/visitor/tps/  
index.html](http://nj-nscort.rutgers.edu/visitor/tps/index.html)

**Starting A Greenhouse Business**

Mississippi State University, Cooperative Extension Service  
<http://msucares.com/pubs/pub1957.htm>

**Starting Vegetable Transplants**

Mississippi State University, Cooperative Extension Service  
<http://msucares.com/pubs/pub1995.htm>

**Texas Greenhouse Management Handbook**

Texas A&M University, Aggie Horticulture  
[http://aggie-horticulture.tamu.edu/green-  
house/guides/green/green.html](http://aggie-horticulture.tamu.edu/greenhouse/guides/green/green.html)

**Tomato Plant Problems FAQ, by Kay Klier**

<http://is.rice.edu/~shel/tomato.html>  
*An overview of tomato plant problems and organic cures.*

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The electronic version of **Organic Greenhouse Tomato Production** is located at:

HTML

<http://www.attra.org/attra-pub/ghtomato.html>

PDF

<http://www.attra.org/attra-pub/PDF/ghtomato.pdf>

## APPENDIX ONE

### PROBLEMS IN THE GREENHOUSE

1. Major Fungal Diseases of Greenhouse Tomatoes		
Name	Damage	Control
<b>Early blight</b> <i>Alternaria solani</i>	Leaves have brown spots with concentric rings and yellow "halos"; Increases in warm, humid weather.	Use resistant cultivar; Sanitation at season end; Mulching; Air circulation; Avoid water on leaves; Rotation; Copper spray.
<b>Fusarium Crown &amp; Root Rot</b> <i>Fusarium oxysporum</i> sp. <i>radicis-lycopersici</i>	Tops of plants wilt; Dark brown colored root rot at soil level; Stems may have red-brown vascular discoloration; Symptoms appear just before first pick.	Use resistant varieties; Transplant when soil or media is 68°F or above; Remove first fruit to allow plant to recover.
<b>Fusarium Wilt</b> <i>Fusarium oxysporum</i> sp. <i>lycopersici</i>	Clearing of veins and chlorosis of lower leaves; Wilting leaves and stems; Marginal necrosis of leaves and eventual defoliation; Roots may be stunted; Stems may have brown discoloration; Prefers warm greenhouses.	Use resistant varieties; Sterilize seed; Use of soilless media or hydroponics reduces incidence of disease; Use good sanitation practices; Avoid excessive warming of cultivation beds (keep below 82°F).
<b>Gray Leaf Spot</b> <i>Stemphylium solani</i>	Older leaves affected first. Small brown to black spots on leaves, enlarging to gray centers that drop out to make several tiny holes in leaf.	Use resistant varieties; Reduce humidity and increase air circulation; Keep canopy dry; Avoid water on leaves; Destroy infected plant material.
<b>Gray Mold</b> <i>Botrytis cinerea</i>	Gray, velvety coating of spores on fruit, stems, and petioles. Thrives at temperatures below 65°F. Begins on flowers and spreads to fruit.	Keep canopy dry; Avoid water on leaves; Reduce humidity (below 85%); Increase temperature and air circulation; Ventilate at night if possible.
<b>Leaf Mold</b> <i>Fulvia Fulva</i> (syn. <i>Cladosporium fulvum</i> )	Chlorotic (yellow-green) spots on upper surface of older leaves; Undersurface may have olive green spores; Spots merge to affect entire leaf; Prefers poorly ventilated, cool, humid conditions; Spreads by air, water, workers and insects; Affects soil or hydroponics.	Good sanitation practices; Use resistant varieties; Proper row and plant spacing; Avoid excessive Nitrogen; Reduce humidity (below 85%) and increase air circulation (heated air); Avoid water on leaves; Burn or bury infected plant material; At season's end, remove and destroy all crop residue and sanitize greenhouse.
<b>Powdery Mildew</b> <i>Oidium lycopersicum</i>	Leaves develop irregular, bright yellow blotches; Severe infections can kill leaves; Sunscald from leaf loss.	Avoid water on leaves; Humidity control; Sulfur sprays; Biofungicide AQ10 ( <i>Ampelomyces quisqualis</i> ); Baking Soda (see ATTRA pub <i>Use of Baking Soda as a Fungicide</i> ); Copper sprays.
<b>Septoria Leaf Spot</b> <i>Septoria lycopersici</i>	Numerous small brown water-soaked spots on leaves, petioles & stems with gray or black centers; Leaves turn yellow and drop; Sunscald may occur; Spreads by wind, water, hands, tools & aphids; Favors warm, dry days and damp nights (85%-100% relative humidity).	Rotation; Avoid water on leaves; Burn or bury infected plant material; Maintain optimum temperatures and humidity control; Aphid control (see ATTRA's <i>Greenhouse IPM: Sustainable Aphid Control</i> ); Copper sprays.

## 2. Major Bacterial Diseases of Greenhouse Tomatoes

Name	Damage	Control
<b>Bacterial Canker</b> <i>Clavibacter michiganensis</i> pv. <i>michiganensis</i>	Very contagious; Wilting lower leaflets; Older leaflets curl upwards and die from margin inward; Cankers may form on stems; Brown, dry, mealy pith in later stages; Small, raised white "bird's eye spots" on fruit; Spreads from infected seed (systemic) or tools, hands, insects, or splashing water (local); Infection is favored by warm, wet conditions.	Use disease-free seed or sterilize seed in 130°F water for 25 minutes; Use drip irrigation to reduce splash; Reduce humidity and increase air circulation; Maintain optimum temperatures; Use sterilized soil or potting mixes; Disinfect benches, hoses, tools, etc. between crops; Sterilize or discard wooden stakes; Destroy infected plant material; Copper sprays.
<b>Bacterial Speck</b> <i>Pseudomonas syringae</i> pv. <i>tomato</i>	Most severe in 3-5 leaf stage; Small, dark lesions with yellow rings on leaves; Superficial, brown, rough spots on fruit; Retards growth and delays fruit maturity; Spread by sprinkler irrigation; Infection is favored by cool, wet conditions.	Use resistant cultivar; Use disease-free seed or sterilize seed in 130°F water for 25 minutes; Reduce humidity and increase air circulation; Maintain optimum temperatures (Bacterial Speck disappears with warmer temperatures); Use drip irrigation or mulch to reduce splash; Remove and destroy infested plants if severe; Copper sprays.

## 3. Major Insect Pests of Greenhouse Tomatoes

Name	Damage	Control
<b>Aphid</b>	Sucks sap; Vectors disease; Creates honeydew which attracts sooty mold; Misshapen foliage, flowers, and fruit	Insecticidal soap; Beneficial insects (ladybugs, lacewings, etc.) <i>Beauveria bassiana</i> ; Pyrethrum; Rotenone
<b>*Fruitworm</b>	Feeds on foliage, flower, fruit	Destroy infested fruit; Bt; Row covers; Neem; Ryania
<b>*Pinworm</b>	Fruit has narrow black tunnels	Destroy infested fruit; Till at season end to prevent overwintering; Sabadilla
<b>Whitefly</b>	Distorted, yellow leaves; Honeydew which attracts sooty mold	Insecticidal soap; Yellow sticky traps; Beneficial insects; Garlic oil; Pyrethrum; Rotenone; <i>Beauveria bassiana</i>

\*Affects mostly field tomato crops but has also been known to infest greenhouse crops

## APPENDIX TWO

### RECOMMENDED FERTILIZATION PRACTICES FOR PRODUCING ORGANIC GREENHOUSE TOMATOES

BY JANET MILES

Janet Miles developed these recommendations as part of an M.S. thesis under the supervision of Dr. Mary Peet. The thesis is entitled: Organic, Biorational and Conventional Growing Systems for Greenhouse Tomatoes, 2000, North Carolina State University, Raleigh, NC.

For more information on this study and on organic production, visit the North Carolina Greenhouse Food Production website:  
<[http://www.ces.ncsu.edu/greenhouse\\_veg/](http://www.ces.ncsu.edu/greenhouse_veg/)>.

These recommendations were devised from studies performed on 'Grace' tomatoes—a variety bred specifically for greenhouse production, grown in 5 gallon upright plastic bags with soil-less substrates in polyethylene greenhouses.

For current requirements for organically certified greenhouse vegetable production, consult the National Organic Program website <<http://www.ams.usda.gov/nop/>>. Draft recommendations for greenhouses are available at: <[http://www.ams.usda.gov/nop/nop2000/nosb/recommendations/Crops\\_recommendations/greenhouse.pdf](http://www.ams.usda.gov/nop/nop2000/nosb/recommendations/Crops_recommendations/greenhouse.pdf)>. For additional commercial materials which may be allowable for organic growers, consult the Organic Material Review Institute website <<http://www.omri.org/>>. A list of suppliers of organic fertilizers and horticultural substrates is available from ATTRA <<http://www.attra.org/>>.

This study was begun in 1998, before the initiation of national standards and with few potentially certifiable materials available. It can be used as a guideline for selecting and using organic fertilizers for greenhouse tomato production, but growers are advised to check the ATTRA and OMRI sites for new materials and with their certifying agency to see if particular materials are allowable.

### Transplant Production:

- 1) Seeds: 4-7 days until first true leaves appear
  - a) sow in sterile seedling mix
  - b) Place seed trays in a mist bed with bottom heat
    - i) Temperature: 75-80°F
    - ii) 16 hours fluorescent light
  
- 2) Transplant Seedlings: 4-6 weeks depending on Fall or Spring crop
  - a) 4" pots with peat or coir-based substrate  
\*note: We used a special mix provided by Faford which is equivalent to their commercial 4-P, but without the starter nutrient charge or wetting agent, which would not be acceptable for organic certification. (See Substrate Recipe in the Greenhouse Production section).
  - b) Nutrients:
    - i) Constant feed of fertilizer/water solution
    - ii) **Earth Juice™ brand:** This product is comprised of three different formulations. They also have a source of K<sub>2</sub>O and a source of micronutrients.  
**Grow:** analysis 2-1-1. Ingredients: bat guano, Norwegian Sea Kelp, natural sulfate of potash, feather meal, oat bran, blood meal, and steamed bone meal.  
**Bloom:** analysis 0-3-1. Ingredients: bat guano, Chilean sea bird guano, Norwegian Sea Kelp, natural sulfate of potash, steamed bone meal, oat bran, and rock phosphate.  
**Catalyst:** analysis 0.03-0.01-0.10. Ingredients: oat bran, kelp, wheat malt, molasses, and yeast.  
*Earth Juice Recipe*  
Mixed in 2 gal. water for direct fertilization:  
(Not concentrated for injectors)  
3 tbsp. Bloom

3 tbsp. Catalyst  
5 tbsp. Grow  
2 tbsp. K<sub>2</sub>O  
\* To provide 90 ppm N, 45 ppm P, and 195 ppm K.

- iii) **Magna Gro™ brand:**  
HydroponicBase Mix analysis 2-3-6. Ingredients: poultry compost tea, pasteurized blood meal, calcium phosphate, and seaweed. This also contains trace minerals with fermented molasses in the form of Zn SO<sub>4</sub>, Mg SO<sub>4</sub>, and Fe SO<sub>4</sub>. 19% N from poultry compost tea and pasteurized blood meal. K-9: 9% K<sub>2</sub>O from seaweed. Organic forms of trace minerals supplied as 6% B, 6% Fe, 6% Mg, and 6% Ca.

**Magna Gro Recipe**

Mixed in 2 gal. water for direct fertilization:

(Not concentrated for injectors)

2 tbsp. Hydroponic Base Mix

1/8 tsp. 19% N

1/3 tsp. 9% K

\*To provide 90 ppm N, 45 ppm P, and 195 ppm K.

**Greenhouse Production:**

- 1) Transplant when seedlings have 5-7 true leaves – BEFORE any flowers have opened.
- 2) 5 gal. plastic “grow bags” filled with peat or coir-based substrate that has not been amended with a starter nutrient charge or wetting agent, as these products are most likely from inorganic sources and not acceptable for use in organic production. We blended our own mix from commercial blend specially formulated to omit the wetting agent and starter charge.

- 85% Fafard’s Special Organic Mix<sup>1</sup>: Ingredients: Canadian sphagnum peat moss, vermiculite, perlite, gypsum, dolomitic lime, pine bark
- 15% Vermicycle (commercial worm compost)
- J.H. Biotech<sup>2</sup> “Natural Wet” 2T./gal.
- 1.25 lbs./cu.yd. each, blood meal, bone meal, and potassium sulfate
- ½ lb/cu. yd. elemental sulfur

Several commercial organic mixes are now available, but were not tested in this project. Sun Gro Horticulture, Inc., has a retail and professional line of soilless mixes which is OMRI approved. They can be used for transplanting or in containers. Sun Gro produces retail potting mixes under the Sunshine and other brands (Phone 888-896-1222). McEnroe Organic Farm, 194 Coleman Station Road, Millertown, NY 12546 (518-789-3252) offers both a light growing mix and a potting soil, which they suggest combining with vermiculite for a seed starting mix. You can also search for organic and OMRI-certified supplies at Peaceful Valley Farm Supply (<http://www.groworganic.com/>).

3) Nutrition:

\*Note – **Stage 1** = From transplant to the first fruit set

**Stage 2** = From first fruit set to “topping” the plants – when they are about 6’ tall

**Stage 3** = From topping to the end of the crop

- a) Fertigation using ½ gph emitters is ideal:

**Stage 1:** 6 minutes/cycle, 4 cycles/day, to supply 0.89 liters/plant/day

**Stage 2:** 8 minutes/cycle, 4 cycles/day, to supply 1.20 liters/plant/day

**Stage 3:** 13 minutes/cycle, 4 cycles/day to supply 1.77 liters/plant/day

- b) Commercial fertilizers should be for-

<sup>1</sup>Fafard’s Special Organic Mixture: Contact Hugh Poole, Fafard, 6406 Carmel Road, Suite 30, Charlotte, NC 28226, SC 29622 Phone: 1-800-845-1664 or 1-800-722-7645 email: [sales@fafard.com](mailto:sales@fafard.com); <http://www.Fafard.com/>

<sup>2</sup>Wetting agent: Harold Uradomo, 805-650-8942, J.H. Biotech, Inc., 4951 Olivias Park Drive, Ventura, California 93003

mulated to provide the following N-P-K concentrations:

Stage 1	Stage 2	Stage 3
90 ppm N	125 ppm N	165 ppm N
45 ppm P	45 ppm P	45 ppm P
195 ppm K	195 ppm K	310 ppm K

- i) **Earth Juice™**. In addition to products listed under the Organic Transplant Production section, they also have a product called:

“**Microburst Three**” – derived from sulfates of Magnesium, Cupric, Ferrous Manganese, Zinc, Borate, and Kelp to provide micronutrients. K<sub>2</sub>O is a 10% K source.

**Recipe – Earth Juice™: Stage 1**

To make 1 gal. of stock to be injected at a rate of 50:1

1 qt. Grow  
1 qt. Catalyst  
2 c. Bloom  
1½ c. 10% K<sub>2</sub>O

**Recipe – Earth Juice™: Stage 2**

To make 1 gal. of stock to be injected at a rate of 50:1

1 qt. + 1¼ c. Grow  
1 qt. + 1¼ c. Catalyst  
1¼ c. Bloom  
1¼ c. 10% K<sub>2</sub>O  
½ c. Microburst Three

**Recipe – Earth Juice™: Stage 3**

To make 1 gal. of stock to be injected at a rate of 50:1

1 qt. + 3 c. Grow  
1 qt. + 3 c. Catalyst  
¾ c. Bloom  
2¼ c. 10% K<sub>2</sub>O  
½ c. Microburst Three

- ii) **Magna Gro™**

**Recipe for Magna Gro™: Stage 1**

To make 1 gal. of stock to be injected at a rate of 50:1

1 qt. + ¼ c. Hydroponic Base Mix (HBM)  
½ Tbsp. 19% N  
¼ c. 9% K

**Recipe for Magna Gro™: Stage 2**

To make 1 gal. of stock to be injected at a rate of 50:1

1 qt. + ¼ c. Hydroponic Base Mix (HBM)  
1/3 c. 19% N  
¼ c. 9% K

**Recipe for Magna Gro™: Stage 3**

To make 1 gal. of stock to be injected at a rate of 50:1

1 qt. + ¼ c. Hydroponic Base Mix (HBM)  
1 c. 19% N  
2 c. 9% K

- c) The start-up nutrient charge that was added to the growing medium will provide enough nutrients to last 2-3 weeks after transplanting. At this time, plants will probably have progressed to Stage 2 of development.