



Organic Tomato Production

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This publication addresses practical questions on organic tomato production. It focuses on the specific production challenges, including site selection (soil and climate), variety selection, sources of organic seeds and organic annual transplants, organic grafting, planting and training/staking arrangements, soil fertility and fertilization, crop rotation, and pest (insect, disease, and weed) management. Harvest and yield/productivity are closely related to marketing possibilities. While market conditions are extremely region-specific, this publication also addresses a few general principles on marketing and economics of organic tomatoes.

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Organic local tomatoes are always in high demand. Growers can receive price premiums earlier and later in the season. Photo: NCAT

Introduction

Organic tomatoes are always in high demand in both local and wholesale markets. With proper production techniques, they can yield a high return on your investment. Returns are significantly higher when you sell earlier and later in the season.

Taste is in the mouth of the beholder, but consumers are generally willing to pay a premium price for organic tomatoes, depending on their specific region of the country, specific marketing techniques, and seasonal fluctuations. See Appendix 1 for information on tomato varieties and their characteristics.

This publication will address organic production

and marketing techniques for tomatoes. It focuses on soil, pest, and weed management as well as economic and marketing aspects that are specific to organic production. It also briefly discusses hoop house tomato production, which enables growers to extend their season with this crop. For more details on this topic, see ATTRA's *Organic Greenhouse Tomato Production*.

Soils and Organic Fertility for Tomato Production

A wide variety of soil textures can be used for tomato production. Ideal soil textures range from sandy to fine-textured clays as long as the soil is well drained (tomato roots will not tolerate being

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waterlogged), has good structure, and is well aerated. Planting dates can be determined by the type of soil a grower has. For example, sandy soils are preferred for early plantings in California due to adequate drainage during wet weather and rapid increase in soil temperature in the spring, which, in turn, can lead to early growth (Strange et al., 2000). However, loam and clay loam soils are the most productive soils for production. A mixture of one-quarter to one-half sand, one-quarter to one-half silt, and no more than 27% clay gives loam soils the best possible properties for plant growth. These mixtures supply adequate drainage and good soil structure. Conversely, heavier clays can be a serious problem due to poor soil drainage and excess soil moisture for extended periods, making tomatoes more prone to disease.

One of the foundations of organic farming is maintaining and building a microbial-active soil enriched with organic matter and a balanced mineral diet. Humus-building practices and addition of minerals not only supply plant nutrients but also increase tolerance to insects and diseases, help control weeds, retain soil moisture, and ensure produce quality.

A typical organic fertility system revolves around a combination of practices such as using crop rotation, forage legumes, cover crops, green manures, composted livestock manures, and lime, rock phosphate, and other rock minerals, as well as supplemental organic fertilizers. Depending on the soil type, soils with no history of organic management will probably need additional fertilization to be incorporated during field preparation and bedding operations or banded to the side of the row at planting.

Soil tests provide a baseline for your soil. Most state Extension services provide tests for a nomi-

nal fee. For information that is specific to organic production, see the ATTRA database on *Organic Soil Testing Laboratories*. In general, tomato plants have a high requirement for the macro elements potassium (K) and calcium (Ca) and the micro-nutrients iron (Fe), manganese (Mn), and zinc (Zn). Without a good supply of both K and Ca for plant uptake and utilization, the fruits will lack the recommended soluble solids content (sugars) and will be more susceptible to physiological disorders such as blossom end rot. Smaller requirements of the elements nitrogen (N), magnesium (Mg), phosphorus (P), boron (B), and copper (Cu) also are needed for proper plant development (Jones, 2008).

As shown in Table 1, tomatoes need moderate to high levels of P and K. On deficient soils, most needs can be met by applying rock powders such as rock phosphate, colloidal phosphate, untreated (mined) potassium sulfate, and sulfate of potash-magnesia in advance of planting. Supplementary P and K may be added as indicated by the soil test results. Always conduct a soil test to determine the proper amount of nutrients to apply. See Appendix 4 for additional information on plant nutrient recommendations based on soil tests from Rutgers University.

Depending on the soil type, fresh market tomatoes also require about 75 to 100 pounds per acre of N. Most, if not all, can be supplied by legumes in rotation; composts or manures can also fill in the balance. If manure is chosen as the supplemental fertilizer, the USDA National Organic Program (NOP) regulations require that the manure be incorporated into the soil at least 120 days prior to harvest [NOP standard 205.203 (c)1]. Some farmers provide additional supplemental N at transplanting; a mixture of

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Table 1: Desirable Soil Nutrient Levels for Tomatoes

The amounts are in pounds per acre and are tested in Missouri.

	Phosphorus (P)	Exchangeable potassium (K)	Exchangeable magnesium (Mg)	Exchangeable calcium (Ca)
Sandy or gravelly loam	100 to 125	225 to 325	150 to 300	2,000 to 3,000
Medium silt loam	125 to 150	325 to 425	300 to 450	3,000 to 4,500
Heavy loam and clays	150 to 175	425 to 500	450 to 600	4,500 to 7,000

Source: Gaus et al. 1993.

animal meal by-products, rock phosphate, and kelp meal is commonly used. If reliance is based primarily on supplemental fertilizers, about 50 pounds of actual N should be applied pre-plant and the remainder side-dressed when fruits are about nickel-size.

Tomato plants grow best when the soil pH is between 6.0 and 6.5. Liming to this range improves plant growth and optimizes fertilizer efficiency. If the pH is less than 5.5, Mg availability decreases significantly. Consequently, this increases the level of available Mn and aluminum (Al). Unless a deficiency of magnesium is noted, application of high-calcium (nondolomitic without magnesium) lime is advised. In addition, when a low pH is coupled with low Ca, blossom

end rot is likely to occur. However, when soil tests are high in both P and pH levels, Zn will become insoluble, resulting in deficiency symptoms such as cupped leaves and splotchy chlorosis (Jones, 2008).

Irrigation

All processing and fresh-market tomatoes are irrigated. Water must be supplied uniformly from the time of first fruit set to harvest. Uneven moisture periods will give rise to disorders such as blossom end rot and fruit cracking.

Drip, furrow, and sprinkler irrigation methods are used for tomato production. Drip irrigation is increasing in usage each year. As of 2008, more than 20% of processing tomato acreage

Research and Field Experience in Tomato Fertility

- In a California study, soils well prepared with cover crops (legumes or legume-grass mixtures, grown during the winter preceding all other cash crops) and composted poultry manure showed no yield response over four years of replication as compared to conventionally based two-year rotation (tomato and wheat) and four-year rotation (tomato, safflower, corn, bean). Yields averaged 70 to 80 t/ha across the treatments. However, greater inputs were needed in the organic treatments, such as higher levels of irrigation because of greater infiltration rates, whereas the conventionally managed soils had poor infiltration rates. The total nitrogen inputs were also greater, applying twice the amount of nitrogen (N) to the organic as the conventional system in the last two years of treatment. High N input suggested N immobilization or insufficient decay by the microbial community. Many studies have shown that providing N via cover crops and/or composts can provide adequate fertility; however, this study demonstrates that total N inputs cannot rely on cover crops and/or composts alone. (Clark et al., 1999)
- In an Iowa study, two natural soil amendment/fertilizer products were used in an organic tomato production trial as a comparison to tomato plants that received no soil amendment. Chilean nitrate, also known as sodium nitrate, was applied at a rate of 40 pounds N/acre plus composted manure at 160 pounds N/acre. Cinagro™ was used as the other treatment at the application rate of 200 pounds N/acre. Results of the amendments were much the same: the tomato plants treated with the fertilizers were taller and had more leaves than the unfertilized soil. Flower, fruit number, and yield were numerically greater in the fertilized plots as compared to the untreated soil. No differences were statistically shown between the two amendments. (Delate et al., 2008)
- In a two-year Ohio study, fall-applied organic composted cannery waste (40% tomato processing byproducts, 20% duck manure, 20% municipal yard waste, and 20% reed canary grass straw) at a total of 26 t/ha in 1996 and 35 t/ha in 1997 produced 33% higher yields of ripe tomatoes than the nonamended conventional plots that were receiving supplemental nutrient fertilizers. In addition, the composted cannery waste incorporated into organic tomato plots reduced the incidence of anthracnose root rot when disease was severe in the conventional plots. The organic plots also seemed to have better water retention than the conventional plots during two unusually dry months of the year when they received no supplemental irrigation. (Abbasi et al., 2002)
- In a long-term field experiment set up in North Carolina, three tomato subplots were amended each May with synthetic fertilizers (for the conventional method), cotton-gin trash, and animal manure (poultry and swine manure) at a rate of 67 kg N/ha. A fourth subplot consisted of rye/vetch green manure at a rate of 45 kg N/ha. Results showed that microbial biomass and microbial activity were generally higher in organically, rather than conventionally, managed soils with cotton-gin trash being the most effective, followed by animal manure, rye/vetch, and the synthetic soil. Likewise, the highest extractable carbon (C) and N levels occurred in plots amended with cotton-gin trash, followed by animal manure, rye/vetch, with the conventional plot showing the least amount of extractable C and N. Cotton-gin trash, animal manure, and rye/vetch treatments increased soil moisture by 25% to 58%, 11% to 13%, and 8% to 12%, respectively, compared to the synthetic fertilizer treatment. In addition, data showed that mulching the plots enhanced the soil microbial biomass N and potential N supply by 45% compared to the amended organic plots not mulched. (Tu et al., 2005)

was under drip irrigation. Generally, drip irrigation enhances yield and promotes efficient irrigation methods even in situations with challenging slopes and soil properties.

In California, drip irrigation maintains productivity by keeping the root zone relatively salt-free and limits excess water runoff (Hartz et al., 2008). Drip irrigation also improves irrigation efficiency and permits the grower to harvest at regular intervals by hand. A typical drip-irrigation system includes a single drip tape that is either buried two to 12 inches deep in the center of the bed or placed on top of the soil surface and secured with pins.

Using weather-based reference evapotranspiration (ET) data and crop growth stages, proper drip irrigation requirements should be determined by the site-location requirements. ET is a calculation of the water lost from soil and plants and is measured in inches. The effects of ET are

increased by solar radiation, wind, low relative humidity, and high temperatures. The number of inches measured is the amount of irrigation water that needs to be delivered to the root zone of the plant in the field. To find state-based ET data, see www.cpc.ncep.noaa.gov/products/GIS/GIS_DATA/JAWF/.

Furrow irrigation is sometimes used in collaboration with drip irrigation. In furrow irrigation, rates vary by soil type and crop growth stage. In most instances, seven- to 14-day intervals are used.

Sprinkle irrigation often is used to establish newly transplanted seedlings up to the time of first bloom. Drip irrigation, however, is used thereafter. Continued sprinkler use after establishment may increase susceptibility to bacterial diseases such as bacterial speck (*Pseudomonas syringae*), bacterial spot (*Xanthomonas campestris*), both early and late blight (*Alternaria solani* and *Phytophthora infestans*), and molds (*Pythium* and *Sclerotinia* spp.) (Strange et al., 2000).

Generally, tomatoes require one inch of water from rain or irrigation once a week for optimal growth. Tomatoes have a deep root system and therefore thrive on deep, infrequent irrigation methods. Watering less frequently decreases the susceptibility to root-rot diseases and increases efficient weed management.

Compared with field-grown tomatoes, high-tunnel tomatoes have several advantages:

- Earlier harvests in summer
- Later harvests in fall
- Better fruit quality
- Less foliar disease

Most growers transplant tomatoes into tunnels nearly one month ahead of field tomatoes. For zones 4 to 5 (see the USDA hardiness zones map at <http://planthardiness.ars.usda.gov/PHZMWeb/>), late April to early May transplanting would be appropriate, with adjustments for warmer conditions in the South and colder conditions in the North, at higher elevations, and in other cold pockets.

To reduce risk of plant-killing frosts inside the tunnel, it's good to have a backup heat source (Cornell University Department of Horticulture, 2012).



Gallatin Valley Botanical hoop house tomatoes. Many growers have started growing tomatoes in hoop houses (also called high tunnels) to moderate temperatures and plant earlier for earlier harvests in the summer and later harvests in the fall. Photo: NCAT.

Processing Tomatoes

Most, but not all, processing tomatoes are grown in California. Of the 331,000 acres planted to processing tomatoes in the United States, 312,000 (94%) were in California (USDA/ERS, 2009). According to the California Department of Food and Agriculture Organic Program, organic processing tomato acreage in California was just under 7,400 acres in 2007, worth \$10.6 million. Compare this number with fresh market tomatoes, which were planted on only about 1,000 acres but worth \$33.8 million. The difference in value reflects the fact that processing tomatoes are mechanically harvested and, because these tomatoes are processed, cosmetic damage is much less important compared to fresh market tomatoes. Other states with significant processing tomato acreage (nonorganic) include Indiana with 9,800 acres in 2009, Ohio with 6,600 acres, and Michigan with 3,500 acres. Over the last several years, acreage of processing tomatoes in the United States has been in the neighborhood of 300,000 acres. In the last decade or so, almost all processing tomatoes have been transplants.

Twenty years ago, most processing tomatoes were direct seeded. Transplanting gives the grower a one- to two-week head start against weed competition and reduces the likelihood of major “skips” in the planting process. There is a second major change in the way processing tomatoes are being grown. Buried drip tape is increasingly common, compared to furrow irrigation, and it’s estimated that over 60% of processing tomatoes in California are grown using buried drip (Johnson, 2010). One of the major advantages of buried drip is that since the water and fertilizer are applied directly in the root zone, very few weed seeds germinate on the surface, reducing competition from weeds and also reducing the costs associated with weed management. Buried drip requires substantial investment, as well as substantial maintenance to prevent the drip emitters from becoming plugged by bacteria. Conventional growers have reported yield increases after switching to buried drip, and water requirements generally are reduced.

Good soil management is critical to supporting production of organic processing tomatoes. Part of this comes from using diverse rotations, which can include alfalfa, wheat, corn, and dry beans, and can also include winter cover crops of vetch or oat-vetch mixes. Cover crops of vetch can be planted in the fall (October/November) on beds



Nowadays, most processing tomatoes are planted as seedlings. Photo: Rex Dufour, NCAT



Vetch cover mowed in preparation for tomato transplants. Photo: Rex Dufour, NCAT



Photo: Rex Dufour, NCAT

prepared for tomato production. The vetch is mowed in March and allowed to dry down, and it can be disked lightly with a Lilliston cultivator to incorporate, with transplanting being done one to two weeks later. Good soil management will allow for processing tomato yields in excess of 40 tons per acre.

Training

Healthier plants, more bountiful harvests, and earlier harvests are three reasons why training tomato plants is beneficial. Since training allows foliage to dry quickly, it limits several factors that encourage harmful fungal spores to reach fruits and leaves, such as wet leaves, poor air circulation, and soil splashed up by rain. Training also allows for faster identification of a pest problem. It also is a preventative management tool used to keep pests such as burrowing insects, snails, or slugs away from the fruit. Fruits can ripen faster as a result of more light penetration from training, in turn lengthening the harvest season.

Depending on the plant type—determinate or indeterminate—plant densities per acre may range from 4,860 to 14,760 plants (Jones, 2008). Determinate plant types are typically short and stout, stop growing at 3 feet, and set fruit all at once. Determinate tomatoes require less support and can be planted at greater densities, which is why they are favored by large commercial growers (Evans, 2004). Determinate varieties can be spaced 24 inches apart in the row and 3.5 feet apart between rows. Indeterminate varieties

require a stronger support system, such as T-posts or heavy-duty wooden stakes, because they grow much taller and wider than their counterparts and they fruit until frost. They are often favored by producers who sell at farmers markets (Joslin, 2004). Indeterminate varieties should be 5 to 6 feet apart between rows and 30 to 36 inches apart within the row (Jones, 2008). See Appendix 1 for a list of determinate and indeterminate varieties.

Several training systems can be used in tomato culture. These include unsupported, either on bare ground or grown on plastic or organic mulch; the basic stake approach that can also be supported by wire cages, trellis/tunnels on either bare or mulched ground; and stake-and-weave systems.

Staked Systems

The *basic stake* approach is best for both indeterminate and determinate tomatoes. It provides support to the seedling during development and will prevent the tomato stem from snapping during moderate winds. Using a naturally rot-resistant wood stake such as cedar will help prevent the stakes from rotting and toppling over. Treated wood stakes are prohibited under the USDA organic regulations. For more information on alternatives to treated wood, see the ATTRA publication *Pressure-Treated Wood: Organic and Natural Alternatives*.



Photo: NCAT

Wire cages are best for indeterminate plant types on smaller farms. This system is most common among home and market gardeners because the added support assures optimal growth, but it is often expensive and time consuming. Threading two stakes through the wires assures optimal sturdiness.

Staking on plastic mulch, used for both determinate and indeterminate types, is typically accompanied by drip irrigation and tensiometers to monitor soil moisture. Floating row covers and tunnels are used in some instances to provide frost protection and to enhance early production.

Staking on organic mulch is similar to using plastic mulch, but unlike plastic, organic straw mulch has soil-enhancing benefits that are often preferred by the organic grower. These mulches cool the soil, as compared to plastic mulches, which can be a disadvantage in the spring when plastic mulches are promoting more plant growth. However, later in the season when temperatures are higher, organic mulches have an advantage over plastics.

A *trellis system* is best used to train indeterminate tomatoes. Plants usually produce fewer fruits with this system as compared to others, but the fruits are larger and typically ripen earlier. Sunburned fruit may be a problem, however, due to the decreased leaf canopy.

The *stake-and-weave* method can be used for both plant types. Weaving the string in and out of the plants ensures support when the plants are loaded with fruit. This method is easy to maintain, supports a large number of tomatoes in a small space, is inexpensive, and requires little storage space (Evans, 2004).

Unsupported Systems

Raising plants on bare soil and allowing them to sprawl—also known as *ground culture*—is still a commercial method in some regions. Low input costs are the chief advantage of this system. However, lower yields, lower fruit quality, and a higher incidence of fruit and foliage diseases may be expected when compared to supported systems.

Transplanting tomatoes through plastic mulch and allowing them to sprawl out on the plastic is an alternative to ground culture. Plastic mulch reduces soil splashing onto the leaves and fruit, thus reducing disease. Either determinate or indeterminate types can be grown this way. Straw mulch can also be used in ground culture.



The weave staking system at Clover Leaf Farm. Photo: Courtesy of Cloverleaf Farm

A Comparison of Systems to Train Tomatoes

Researchers at Oklahoma State University examined the economics and performance of tomato training systems. They compared four different training systems in Table 2. Ultimately, the vulnerability of tomatoes to disease and the limited efficacy of organically certified materials to control them, especially in humid climates, weighs heavily in favor of supported culture systems for organic production.

Table 2: A Comparison of Tomato-Training Systems

Factor	Ground ¹	Cage ²	Stake & Weave ³	Trellis ⁴
Earliness	3 rd	4 th	2 nd	Best
Fruit size	4 th	3 rd	2 nd	Largest
Marketable yield	4 th	Largest	2 nd	3 rd
Fruit cracking	3 rd	4 th	2 nd	Worst
Fruit rotting	Worst	2 nd	2 nd	2 nd
Fruit quality	Worst	2 nd	2 nd	2 nd
Fruit sunburn	Worst	4 th	3 rd	2 nd
Cost per acre	4 th	2 nd	Largest	3 rd
Pest control	4 th	3 rd	2 nd	Best

¹ **Ground** – No support system.

² **Cage** – Two-foot-tall wire cage 14 inches in diameter made from No. 10 mesh on 6-inch by 6-inch spacing.

³ **Stake & Weave** – Stake is driven between every other plant and twine woven between and around stakes four to six times. All suckers but one below the first fruit cluster are removed. No other suckers are removed above the first cluster.

⁴ **Trellis** – Post support No. 10 wire. Strings are dropped from wire and tied to base of plant. Plants are twined around string. The main stem and one sucker are allowed to develop and all other suckers are removed as they develop.

Managing Weeds: Basic Concepts

Organic farmers use a wide variety of approaches to control weeds without the use of synthetic chemicals. Crop rotations in combination with cover crops have proven to be the foundation of organic farming. Crop rotation not only enhances the competitiveness of the crop plant, but it also inhibits weed growth and breaks the life cycles of insects and diseases in the field.

Complementary to crop rotations is the use of mulching for adequate weed control. Both natural mulches and synthetic mulches, including polyethylene film and polypropylene landscape fabrics, are used in organic production. However, according to USDA organic regulations, synthetic mulches must remain intact during the growing season and must be removed from the field at the end of the season. Still, synthetic mulches have demonstrated their durability for multiple years in organic vegetable production systems.

Natural mulches such as leaf matter, straw, hay, or switchgrass have multiple benefits for the organic farmer. First, they are capable of regulating soil surface temperatures and moisture. Second, natural mulches improve overall soil quality by adding organic matter to the soil, increasing nutrient availability, soil porosity, cation exchange capacity, water-holding capacity, and microbial organisms while controlling the weed pressure (Delate and Hartzler, 2003).

To prevent stimulation of weed growth, mulches should be maintained at a depth of six inches. With that depth, weed emergence is greatly decreased by the reductions of both light transmittance and soil temperatures.

In a two-year Iowa study, researchers compared three no-till cover cropping systems for organic tomatoes: control (no cover), hairy vetch/rye treatment, and winter pea/wheat treatment. The results showed that cover crops such as a hairy vetch/rye treatment provided greater management of broadleaf weeds earlier in the season, when weed management is most critical, as compared to the pea/wheat treatment, because of the pea/wheat treatment's faster decomposition rate. Grass weeds were also lower in the hairy vetch/rye treatment at the end of the season. Likewise, a trend of greater fruit harvest and a greater number of No. 1 grade tomatoes were seen with the hairy vetch/rye treatment. Equal yields were found in the control and winter pea/wheat treatments (Delate et al., 2007).

Managing Insects, Pests, and Diseases: Basic Concepts

Cover crops play a vital role in the management of pests and diseases in an organic production system. Cover crops are any crop grown to provide soil cover. Generally speaking, cover crops are used to prevent soil erosion on soils with a slope

Biorationals: Ecological Pest Management Database

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Refer to the **instructions** below for search usage.

Select a Pest Type

Select a Pest Name

Active Ingredient or Beneficial Organism

OR

Pesticide Trade Name

 **Reset Search**

From each of the drop down menus, select either a pest type or pest name, or both. You may then select an active ingredient or beneficial organism or pesticide trade name. Please note that not all of these fields need to be filled in to get results. Be sure to click on "submit search" when you have filled in the desired criteria.

The ATTRA Ecological Pest Management Database lists organic pesticides with minimal environmental impact by disease, insect, and type of pesticide. It is a useful tool for finding management methods if you know which pest you have. Find it online at: www.attra.ncat.org/attra-pub/biorationals/.

that would otherwise be eroded by wind or water in any production system. However, in an organic system, cover crops also provide nitrogen. If the cover crop is a legume, it will suppress weeds, prevent nutrient leaching, and reduce insect pests and diseases. The ATTRA publication *Overview of Cover Crops and Green Manures* provides extensive information on the types of cover crops used today.

Cover crops also attract beneficial insects, a method known as *farmscaping*. Beneficial insects such as lacewings, parasitic wasps, and ladybird beetles need shelter, pollen, nectar, and food prey to survive. Plants that act as a host for these beneficial predators include sweet clover, buckwheat, fava beans, vetch, red clover, white clover, mustards, cowpeas, and species in the carrot (*Umbelliferae*), sunflower (*Compositae*), and mint (*Lamiaceae*) families. The ATTRA publication *Farmscaping to Enhance Biological Control* provides extensive resources for establishing beneficial insect habitats.

Prevention and sanitation procedures are also important. Practices such as removal of dead or diseased plants, frequent cleaning of tools, using disease-free stock, planting resistant varieties, and post-season cleanup of vines via tillage, burning, or composting are some preventative measures of contamination of pests and diseases between fields.

Other cultural practices include giving the plants adequate spacing to allow air circulation through the rows, in order to help the foliage dry rapidly. Watering at the base of plants via drip or trickle irrigation reduces the amount of moisture on the leaves, thus minimizing foliar disease occurrence. Watering in the morning, rather than the evening, minimizes the length of time that the leaves are wet. Allow foliage to dry before working with it again to avoid spreading disease-causing microorganisms such as *Septoria lycopersici*, tomato leaf spot, and other foliar diseases (Gleason and Edmunds, 2006).

Perhaps the most important method of cultural control for tomatoes is rotating the crops between soils every three or four years to reduce populations of the fungus *Fusarium oxysporum* f. sp. *lycopersici* in the soil. This includes rotation of crops within the tomato family (*Solanaceae*), including pepper, potato, eggplant, and husk tomatoes.

Insects

There are numerous insect pests that affect tomato crops. Control of pests requires continual monitoring and integration of biological and cultural practices. Refer to Appendix 2 for more detailed information about the major insect pests of tomatoes and their control methods.

The best pest-management system is based on prevention rather than control. Consistent monitoring of your tomatoes along with determining fast and correct prognosis is the key to managing pests before they get out of hand. Doing so will also help save time and money in the future. As the grower, you have a number of control options.

One option is to use natural repellants. Garlic, onions, zinnia, marigolds, and nasturtium are used as natural repellants to repel insects such as aphids or whitefly, a method known as companion planting. For more information on companion planting, refer to the ATTRA publication *Companion Planting: Basic Concepts and Resources*.

Another control procedure available to organic producers is using insecticidal soaps or sprays. Neem oil is an insecticidal soap that is advertised to control a wide range of insects that are commonly found in the greenhouse, such as aphids, mealybugs, whiteflies, and mites. For it to be effective, plants need to be completely saturated with the soap and may need repeated applications to control an infestation. To avoid repeated applications, inspect your field daily to prevent an infestation from occurring.

Other natural pesticides such as biopesticides and botanical extracts, which are generally made from plants, are also available as a means of gaining control of an infestation. Pyrethrum, a botanical extract from chrysanthemums, is one example that is effective in controlling aphids. Most botanical insecticides tend to degrade quickly in the environment but are generally toxic to humans, bees, and beneficial insects. These should be used when the insect pest population is reaching economically damaging levels.

Microbial insecticides, derived from insect-pathogenic microorganisms, tend to be more specific and are safe to most nontarget organisms (Capinera, 2001). The most common microbial insecticide used today is *Bacillus thuringiensis* (Bt); it controls a variety of crop pests, mainly caterpillars and some beetles, depending on the strain used. However, no matter what strain it is, Bt must be

Perhaps the most important method of cultural control for tomatoes is rotating the crops between soils every three or four years.

used on the pests when they are immature, thus causing disease to the immature insect and eventually death. Bt is not effective when the pests are in the adult stage.

Biological control—using predator insects to control various insect pests—is another option to control pest populations. For example, *Aphelinus abdominalis*, a parasitic wasp, and *Chrysoperla rufilabris*, a lacewing species, can be introduced to the area to control aphids (Jones, 2008). Keep in mind that using the beneficial insects when pest populations are exceedingly high probably won't provide enough control to eradicate the problem. Careful monitoring of the predators and maintaining optimum humidity and temperature levels are also important factors that can influence the effectiveness on both the target insect and the predators. Refer to the ATTRA publication *Farmscaping to Enhance Biological Control*, for things to keep in mind when using biological control procedures.

Most recommended tomato cultivars and varieties in the market today have a wide range of

resistance to diseases, including some resistance to nematodes. Therefore, choosing resistant cultivars and varieties could help prevent the damage of root knot, stubby root, and sting nematodes to your tomato roots.

Organically approved pesticides are also available to keep pests below damaging levels. Refer to Appendix 2 for more details on approved, nonsynthetic pesticides. As with any pest problem, using a combination of controls is essential for success in keeping insect populations from reaching detrimental levels.

Diseases

Tomatoes are injured by pathogenic diseases caused by fungi, bacteria, and viruses, as well as abiotic diseases, such as catfacing and blossom end rot, which are caused by environmental and physiological disorders. Pathogenic diseases develop through soil-borne and above-ground infections and, in some instances, are transmitted through insect feeding.

Grafting is a new, innovative way that tomato growers are managing tomato diseases. Since grafting is a time-intensive process, it is typically used for higher value tomatoes in hoop houses or greenhouses. Grafting tomatoes is similar to grafting trees—the desirable fruit trait is used as the top portion (scion), and the disease resistance and hardiness is used for the bottom portion, or root stock. See Table 3 for a list of common rootstocks and their disease resistance.

Table 3: Disease Resistance and Vigor of Commercial Tomato Rootstock Cultivars

Seed Supplier Root stock variety	Disease							
	Tomato Mosaic	Corky Root	Fusarium (Both races)	Verticillium wilt	Bacterial wilt	Nematodes	Vigor	
Deruyter Seeds								
Maxifort	High	High	Mod	high	high	Susceptible	high	5
Beufort	High	High	Mod	high	high	Susceptible	high	3
Takii Seeds								
Anchor- T	High	Susc	High	High	High	Moderate	High	5
Survivor	High	Susc	High	High	High	Moderate	High	5
Aegis	High	Mod	High	High	High	Moderate	High	4
Bruinsma Seeds								
Body	High	High	Susc	High	High	Susc	High	5
Robusta	High	High	Susc	High	High	Susc	Susc	3

Ratings are based on seed supplier information. Vigor is measured on a scale of 1 to 5, where 1 represents poor and 5 represents excellent. This table is used with permission from the North Carolina State University publication *Grafting for Disease Resistance in Heirloom Tomatoes*. Rivard and Louws. North Carolina State University Department of Plant Pathology. www4.ncsu.edu/~clrivard/TubeGraftingTechnique.pdf

Major tomato diseases include those that attack the root system (fusarium wilt, verticillium wilt, bacterial wilt, nematodes, rhizoctonia), above-ground stems and foliage (early blight, late blight, septoria leaf spot, bacterial canker), and fruit (bacterial spot, bacterial speck, anthracnose). Thus, a disease-control program is important at each stage of growth. Verticillium wilt, one of the most damaging soilborne diseases of tomatoes, also attacks more than 200 other plant species, including potato, pepper, eggplant, strawberry, watermelon, and radish (Gleason and Edmonds, 2006).

A considerable amount of progress has been made in breeding disease resistance or tolerance to naturally occurring tomato plant diseases and viruses. Such resistance is found in cultivars such as Venus, Saturn, Kewato, and Rosita for bacterial wilt disease; the Mountain series (Mountain Pride, Mountain Supreme, Mountain Gold, Mountain Fresh, and Mountain Belle) for resistance of early blight; and verticillium wilt, root knot, tobacco mosaic virus, gray leaf spot, and Alternaria stem canker resistance found in common tomato hybrids (Jones, 2008). See Appendix 1 for tomato variety disease resistance. An organic grower cannot base his or her success on variety selection alone, however—site selection, cultural control, the use of biological control agents, and nonsynthetic fungicides are other factors to consider. While the use of pesticides is generally restricted in certified systems, the NOP permits various products under its organic regulations.

Johnny's Selected Seeds has developed a useful video on grafting. It is available online at www.johnnyseeds.com/t-video_tomato_grafting.aspx

Copper-based products have been widely used in organic vegetable and fruit production. Used to control anthracnose, bacterial speck, bacterial spot, early and late blight, gray leaf mold, powdery mildew, and septoria leaf spot, copper has been used as a routine disease control practice in organic tomato production. Copper is, however, classified as a “restricted” substance by the NOP. A certified organic farm must document application time and rates and show a documented history of the disease organism. Most formulations of copper fungicides such as Bordeaux, basic sulfates, hydroxides, oxychlorides, and oxides are allowable, with restrictions, in organic certifica-

tion systems. However, they pose a problem with potential soil toxicity, contamination of water run-off, and toxicity to nontarget organisms, particularly earthworms and some soil microbes.

The use of copper fungicides also increases the potential risk of injuring the leaves and fruit of most crops. Using excessive amounts of copper coupled with slow drying conditions after a rain and hot weather conditions (above 85 degrees Fahrenheit) may be the cause of injury. Thus, organic growers often monitor soil copper applications and do not rely on copper alone for disease management. Integrated control methods might include choosing disease-resistant varieties, disinfecting seeds with heat treatments, rotating crops, applying compost, managing weeds, and, when necessary, using other effective, approved products for disease management. Garlic and neem oils, *Bacillus subtilis*, and seaweed extract significantly reduced foliar disease on tomatoes compared to the control in one study (Wszelaki and Miller, 2005).

Elemental sulfur has been used in the organic vegetable industry as a preventative fungicide against powdery mildew and as an insecticide for mite control. The key to its fungicide success is that it prevents spore germination and, for this reason, is only effective when applied prior to disease development. However, like copper, sulfur has also shown phytotoxic effects. Avoid applications in hot temperatures to reduce injury to plants.

Bicarbonate salts, essential oils, plant and soil extracts, and biological control organisms are other materials allowed under the NOP regulations for disease control. Essential oils such as garlic and neem oils (*Bacillus subtilis*), and seaweed extract were shown to significantly reduce foliar disease injury in one study by Ohio State University in 2002 and 2003. The results, however, were variable in other years.

Potassium bicarbonate, more commonly known as baking soda, has been found to possess fungicidal properties as well. It is used as prevention or as treatment at the first signs of infection caused by anthracnose, early blight, leaf blight, leaf spot, and powdery mildew.

Harvesting and Handling

Production practices have a tremendous effect on the quality of fruit at harvest, postharvest, and during shelf life. For example, some cultivars are

An organic grower cannot base his or her success on variety selection alone, however—site selection, cultural control, the use of biological control agents, and nonsynthetic fungicides are other factors to consider.

Research and Field Experience in Tomato Diseases

- A two-year study in North Carolina found that organic soil fertility amendments (composted cotton-gin trash, swine manure, or a rye-vetch green manure) applied to bare ground resulted in limited southern blight disease incidence as compared to greater disease incidence in bare soil that received synthetic fertilizers. The composted cotton-gin trash ranked first on reducing the incidence of southern blight on processing tomatoes and also best enhanced the populations of beneficial soil microbes (Bulluck and Ristaino, 2002).
- In Florida, interplanting with Chinese chive (*Allium tuberosum*) in tomato production has been shown to drop the population of the organism responsible for bacterial wilt (*Pseudomonas solanacearum*) in the soil (Berkelaar, 2002).

known to have a longer shelf life and to ship better than others. Because of this, you should consider your market before considering which varieties to plant. In addition, environmental factors such as soil type, temperature, frost, and rainy weather also have unfavorable effects on the crop's harvest quality. For example, some tomato varieties have a tendency to crack after a rain. Therefore, choosing varieties such as Sapho and Mountain Fresh, which are resistant to cracking, may help alleviate the problem of poor fruit quality at the time of harvest. Management practices such as too little or too much water, mechanical injury, or high fertilizer rates can also affect postharvest quality.

Tomatoes should be harvested during the coolest time of the day, which is typically in the morning, and produce should be kept shaded in the field. Harvesting tomatoes requires extensive labor; harvesting may be done every day during the peak

of the season along with continuous discarding of culled fruit from the field to prevent the spread of diseases and pests. Harvesting is done either by hand or with a harvesting aid; only processing tomatoes are harvested by machine due to increased bruising of the produce. Produce should be graded, separating the marketable tomatoes from the cull tomatoes that show signs of bruises, cracking, spots, rots, or decay. Damage such as this can be prevented if tomatoes are handled with care at the time of harvest, harvested at proper maturity, harvested during dry weather, and handled minimally. Tomatoes should be harvested with no more than two to three stacked deep into strong cardboard or stackable flat boxes. Growers have used bread racks in the past with great success. Check with a local bakery to see if they would be willing to sell some to you.

Tomatoes are very susceptible to chilling injury; therefore, maintaining precise storage temperature is critical for postharvest storage quality. Storage temperatures differ with the maturity of the fruit. Tomatoes picked with a slight pink color all the way up to a mature red color should be stored at temperatures between 48°F to 50°F. These fruits will have a maximum shelf life of two weeks. Tomatoes that are picked green are best stored at temperatures between 58°F to 60°F and have a three- to four-week shelf life.

Proper sanitation is of great importance in preventing postharvest diseases and the spread of foodborne illnesses. Thus, strict regulations of sanitary facilities and the use of disinfectants in wash water are used to help prevent both the spread of postharvest diseases and foodborne illnesses. Disinfectants such as chlorine, at a residual of 4 ppm, or hydrogen peroxide, at a concentration of 0.5%, have been effective disinfectants in organic programs. Always check with your certifying agent to see what concentrations are allowed under the regulations.

The publication *Wholesale Success: A Farmers Guide to Selling, Post Harvest Handling, and Packing Produce* offers useful information on cleaning and grading specifics as well as harvest maturity indicators. See the Further Resources section for more information. The ATTRA publication *Post-harvest Handling of Fruits and Vegetables* is also an excellent source for additional information on postharvest and storage considerations.



Cherry tomatoes make a bright display at the farmers market. Photo: NCAT

Marketing and Economics

ATTRA has various resources available for beginning market farmers. Refer to the ATTRA publication *Marketing Gardening: A Start-Up Guide* for more information.

The outlook for organic tomatoes is strong. According to the USDA Economic Research Service, the top three organic vegetables grown in

How to Assess Your Markets

Market research is one of the most important parts of developing a marketing plan. This may sound intimidating, but market research is really just gathering information from the sources that you would like to sell to.

To find out who your potential customers might be, and what they want, talk to people in the markets that you are most interested in selling to. These include restaurant chefs, grocery store managers, local produce distributors, and farmers market managers.

Some questions to ask these businesses and important things to observe are:

- What products are missing that they would like to stock, sell, serve, or buy?
- What new products do they think are emerging trends?
- Are they interested in getting more local products?

the United States are tomatoes, lettuce, and carrots (Economic Research Service, 2008). Direct markets for organic tomatoes include farmers markets, roadside stands, subscription marketing arrangements (CSAs), and restaurants. Local wholesale markets, such as grocery stores and restaurants, can also fetch price premiums. Wholesale markets will require packing and grade standards. The perishability of organic tomatoes is an important consideration in wholesale markets. If you anticipate growing tomatoes for market, it is always a good idea to find markets and develop a marketing plan before you even plant the tomatoes in the ground. Organically grown tomatoes can command premium prices, especially for early- and late-season sales. Growing tomatoes in hoop houses is the best way to assure early and late season tomatoes.

ATTRA has a series of marketing tip sheets that outline advantages, considerations, tips, and ques-

tions to ask yourself for 13 different marketing channels. The tip sheets are available online at <https://attra.ncat.org/marketing.html>

Organic Tomato Costs of Production

According to a recent organic tomato publication by the University of Kentucky Extension, production costs for drip irrigated, staked tomatoes are estimated at \$2,630 per acre, with harvest and marketing costs for 1,200 boxes at \$6,705 per acre. Total costs are estimated at approximately \$10,200 to \$12,000 per acre.

A Northeast Organic Network study on organic costs and returns per acre estimated the revenue for tomatoes at New Leaf Farm in Durham, Maine. Table 4 shows the results.

Table 4: Organic Tomato Costs and Income per Acre

Year	Amount sold (lbs per acre)	Average price per pound	Revenue	Total costs of production per acre	Profit per acre
2002	24,900	\$2.57	\$63,900	\$18,900	\$45,000
2003	22,600	\$2.20	\$49,700	\$22,100	\$27,700

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Agricultural Marketing Resource Center. www.agmrc.org/commodities__products/vegetables/tomatoes.cfm

Organic Production

U.S. Department of Agriculture Economic Research Service. www.ers.usda.gov/Data/Organic

Organic Premiums of US Fresh Produce
 Renewable Agriculture and Food Systems
<http://journals.cambridge.org/action/displayFulltext?type=6&fid=2003604&jid=&volumeId=&issueId=03&aid=2003600&bodyId=&membershipNumber=&societyETOCSession=&fulltextType=RA&fileId=S1742170508002238>

United States Standards for Grades of Fresh Tomatoes
 USDA-Agricultural Marketing Service
www.ams.usda.gov/standards/tomatfrh.pdf

Wholesale Success: A Farmers Guide to Selling, Post Harvest Handling, and Packing Produce.

This useful manual includes harvesting, cooling, storing, and packing information for 103 different fruits and vegetables.

Request a copy from:

Family Farmed

Phone 708-763-9920

www.familyfarmed.org/wholesale-success

Appendix 1: Recommended Tomato Varieties

Variety	Season	Plant Type	Resistance/tolerance	Comments
Sapho	Early-Mid	Indeterminate	Cracking at harvest, crown rot, root rot	Tangy and sweet, cherry, meaty, best for containers
Celebrity	Early	Determinate	Blight tolerance, verticillium and fusarium wilts	One of the more flavorful hybrids
Sweet Baby Girl	Early-Mid	Indeterminate	Tobacco mosaic virus	Cherry, juicy, firm, prone to splitting
Venus	Mid	Semi-determinate	Bacterial wilt, fusarium wilt	Used for fresh or canned
Saturn	Mid	Determinate	Bacterial wilt, fusarium wilt	Used for fresh or canned
Mountain Fresh	Early-Mid	Determinate	Verticillium wilt, fusarium wilt, nematodes, cracking	Firm, large heirloom
Sunbeam	Early-Mid	Determinate	Verticillium and fusarium wilt	Firm
Carnival	Mid	Determinate	Verticillium and fusarium wilt	Firm
Better Boy	Early-Mid	Indeterminate	Fusarium and verticillium wilt, nematodes	Firm
Jet Star	Early-Mid	Indeterminate	Verticillium and fusarium wilt, cracking	Somewhat firm
Mountain Spring	Early-Mid	Determinate	Early blight, verticillium wilt, fusarium wilt, nematodes, cracking	Firm
Daybreak	Very Early	Determinate	Early blight, verticillium wilt, fusarium wilt, nematodes, cracking	Firm
Tango	Mid-Late	Lg. Determinate	Early blight, verticillium wilt, fusarium wilt, nematodes, cracking	Firm
Mountain Gold	Mid	Determinate	Early blight, verticillium wilt, fusarium wilt, nematodes, cracking	Yellow, firm fruit
Sun Leaper	Early-Mid	Determinate	Early blight, verticillium wilt, fusarium wilt, nematodes, cracking	Heat tolerant, firm

Source: Commercial Vegetable Production. Kansas State University

Appendix 2: Major Insects that Attack Tomatoes and Their Control

Common Name	Damage	Control/Management
Aphids		
Green Peach aphid Potato aphid	Sucks sap; vectors disease; creates honeydew, which attracts sooty mold	Insecticidal soaps; Beneficial insects (ladybugs, lacewings, etc.); <i>Beauvaria bassiana</i> ; Pyrethrum
Whitefly		
Silverleaf whitefly Greenhouse whitefly	Distorted yellow leaves; creates honeydew, which attracts sooty mold	Insecticidal soap; yellow sticky traps; garlic oil; biological control; Pyrethrum; <i>Beauvaria bassiana</i>
Tomato psyllid		
Paratrioza cockerelli	Toxin that disrupts plant growth	Insecticidal soaps; avoid early planting; sanitation
Thrips		
Western Flower thrips Tobacco thrips Onion thrips	Piercing of cells and removal of cell contents; transmits tomato spotted wilt virus	Insecticidal soaps; biological control with predatory mites; aluminum-surfaced mulches; sanitation; companion planting
Leafminers		
Vegetable leafminer Serpentine leafminer	Extensive leaf mining; premature leaf drop; damage allows entry of diseases	Placement of row covers; parasitoids; Neem; Bt
Spider mites		
Two-spotted spider mite Tomato russet mites	Yellowing speckled leaves; wilting; leaf deformity; stunting of growth	Biological control (dusty-wings, lady beetles, some plant bugs, thrips); insecticidal soaps and oils
Large caterpillars		
Tomato pinworm	Mining of fruit and leaves; feeding of fruit	Biological control (parasitic wasps); sanitation; till at the end of season
Tomato fruitworm	Feeds on foliage, flower, and fruit	Sanitation; Bt; row covers; Neem; Ryania
Tomato hornworm	Defoliates leaves; attack green fruit	Biological control (<i>Phytoseilus persimilis</i> , lacewing, parasitic wasps); Bt.; tillage, kill adults before they lay eggs

Source: J.L. Capinera. Handbook of Vegetable Pests. 2001

Appendix 3: Guide to Common Tomato Diseases and Disorders

Tomato Diseases		
Name	Damage	Control
Early Blight (Alternaria blight)	Premature loss of lower leaves; leaves have brown to black spots with concentric rings and yellow "halos"; large sunken areas with concentric rings appears on fruit occasionally; incidence increases in warm, humid weather	Choose resistant cultivars; rotation; sanitation at season end; mulching; air circulation; avoid water on leaves; rotation; copper
Late Blight	Leaves have greenish black blotches that appear to be frost damaged; undersides of leaves have a downy white growth; fruits have dark brown, corky spots; fruits become foul smelling; incidence increases with wet weather, warm days and cool nights	Choose resistant cultivars; sanitation; avoid water on leaves; adequate spacing; grow in poly hoop houses; copper
Leaf spot (Septoria leaf spot)	Numerous small brown spots with grayish white or black centers; leaves turn yellow and drop; lower leaves are infected first	Sanitation; rotation; avoid water on leaves; adequate spacing; anti-transpiration; copper, potassium bicarbonate
Anthracnose	Fruit has small, slightly sunken circular spots that spread and crack open; spots develop dark centers that can appear cream to salmon pink when spores exude in moist conditions	Resistant cultivars; sanitation at season end; rotation; cover crop; harvest frequently; physical support of plant; copper; potassium bicarbonate
Tobacco Mosaic Virus (TMV)	Distorted, small leaves and plants	Don't grow around tobacco; don't handle if tobacco is on hands; destroy infested plants
Bacterial spot; Bacterial speck	Small, dark spots on leaves and stems; spots often become surrounded by yellow halo; small brown to black, raised spots on fruits; as lesions enlarge, they become sunken	Copper; remove and destroy infested plants if severe; disease-free transplants; weeding
Bacterial canker	Leaves have brown edges; sudden wilted leaves; fruit has very small, raised, dark brown spots with white edges	Remove and destroy infested plants; copper sprays have minor impact
Powdery Mildew	White patches on the upper surface of leaves; defoliation as spots develop into brown lesions	Copper; potassium bicarbonate; air circulation; avoid water on leaves; Activoate® AG

For verticillium, fusarium, and nematode resistance, cultivars labeled VFN should be used. Rotating away from all crops in the tomato family (Solanaceae) for at least four years also will be a preventative to the above diseases. Source: NCAT

Physiological Disorders of Tomatoes			
Name	Cause	Effect	Control
Blossom end rot	Lack of calcium	Sunken brown spot on blossom end of fruit; admittance of secondary organisms to fruit	Supply consistent and ample moisture to help maintain steady flow of calcium; add Ca to soil; choose resistant cultivars; mulch; spray with seaweed extract
Fruit cracking	Rapid fruit development; dry weather followed by warm, rainy weather	Radial and concentric fruit cracking	Choose resistant cultivars; mulch to keep moisture levels constant; avoid heavy N applications
Cat-faced fruit	Cold weather at the time of blossom set	Misshapen fruit with irregular bulges at blossom ends	Row covers; poly hoop houses
Sunscald	Overexposure to sun caused by defoliation	Whitish, shiny area that appears blistered; yellow and wrinkled fruit	Control foliar diseases; avoid heavy pruning or shoot removal
Failure to set fruit	High day and night temperatures; night temps above 70°F and below 55°F; drought conditions	Blossom drops before pollination occurs	Choose resistant varieties
N deficiency	Lack of nitrogen	Yellowing of oldest leaves; stunted growth	Compost/manure; soybean meal; legume cover crop; dried blood; fish emulsion
P deficiency	Lack of phosphorus	Reddish-purple leaves	Compost; leaf mold; bonemeal; rock phosphate
K deficiency	Lack of potassium	Bronze spots between veins of leaves; underdeveloped roots	Compost; kelp meal; granite dust; greensand; wood ashes

Source: NCAT

Appendix 4: Plant Nutrient Recommendations Based on Soil Tests

Plant Nutrient Recommendations for Tomatoes Based on Soil Tests							
Crop and Application Method	N Pounds per Acre	Soil P Level			Soil K Level		
		Pounds of P ₂ O ₅ per Acre			Pounds of K ₂ O ₂ per Acre		
Fresh Market Tomatoes							
		Low	Medium	High	Low	Medium	High
<i>Sandy loams and loamy sand soils</i>							
Total recommended	80-90	200	150	100	300	200	100
Broadcast and plow down	40-45	200	150	100	300	200	100
Sidedress when first fruits are set	40-45	0	0	0	0	0	0
<i>Loam and silt loam soils</i>							
Total recommended	50-80	200	150	100	250	150	100
Broadcast and plow down	50	200	150	100	250	150	100
Sidedress when first fruits are set	25-30	0	0	0	0	0	0
Processing Tomatoes-Transplants for Multiple Harvests							
<i>Sandy loams and loamy sand soils</i>							
Total recommended	130	250	150	100	300	200	100
Broadcast and plow down	50	250	150	100	300	200	100
Sidedress at first cultivation	50	0	0	0	0	0	0
Sidedress when first fruits are 1" in diameter	30	0	0	0	0	0	0
<i>Loam and silt loam soils</i>							
Total recommended	100-125	250	150	100	300	200	100
Broadcast and plow down	50-75	250	150	100	300	200	100
Sidedress when first fruits are 1" in diameter	25-50	0	0	0	0	0	0

Notes

Organic Tomato Production

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