



ORGANIC TOMATO PRODUCTION

HORTICULTURE PRODUCTION GUIDE

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Abstract: A market exists for organically grown, fresh- and processing-market tomatoes. Although information on conventional tomato practices is available from many sources, comprehensive information on organic cultivation practices is difficult to find. Organic tomato production differs from conventional production primarily in soil fertility, weed, insect, and disease management. These are the focus of this publication, with special emphasis on fresh market tomatoes.

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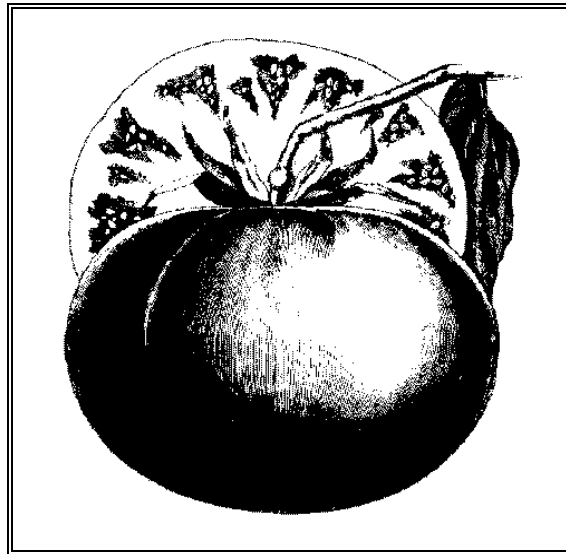
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Organic certification emerged as a marketing tool during the 1970s and 80s to ensure foods produced organically met specified standards of production. The Organic Foods Production Act, a section of the 1990 Farm Bill, enabled the USDA to develop a national program of

Organic Farming and Certification Programs

As defined by the USDA in 1980 (1), organic farming is a system that excludes the use of synthetic fertilizers, pesticides, and growth regulators. Organic farmers rely heavily on crop rotations, crop residues, animal manures, legumes, green manures, organic wastes, and mineral-bearing rocks to feed the soil and supply plant nutrients.

Insects, weeds, and other pests are managed by mechanical cultivation and cultural, biological, and biorational controls.



universal standards, certification accreditation, and food labeling. In early 1998, the USDA released a draft of the new standards for public comment. Public opposition to these proposed standards was vocal, sending a message to the USDA that more work was necessary. While revisions to the draft are underway, it may take another year or two before the national program actually materializes.

A new definition of "Organic agriculture," as proposed by the National Organic Standards Board, is:

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Organic agriculture is an ecological production management system that promotes and enhances biodiversity, biological cycles and soil biological activity. It is based on minimal use of off-farm inputs and management practices that restore, maintain and enhance ecological harmony. Organic is a labeling term which denotes products produced under the requirements of the Organic Foods Production Act.

The primary goal of Organic agriculture is to optimize the health and productivity of interdependent communities of soil life, plants, animals and people. The principal guidelines for organic production are to use materials and practices that enhance the ecological balance of natural systems and that integrate the parts of the farming system into an ecological whole. Organic agriculture practices cannot ensure that products are completely free of residues; however, methods are used to minimize pollution from the air, soil and water. Organic food handlers, processors and retailers adhere to standards that maintain the integrity of Organic agriculture products.

Growers choose organic methods for a variety of reasons. One of the attractions of organic produce is that it sometimes brings a 10–30% premium in the marketplace. As organically-grown produce becomes commonplace, however, these premiums may be the exception rather than the rule, and motivation beyond market premiums should be considered. Incentives may include the possibility of reduced input costs, improved farm safety, reduced environmental impact, and a better-functioning agroecosystem.

In addition to organic production, IPM certification has emerged as a marketing tool for growers for whom organic production is impractical or otherwise unsuitable. Though such programs do not restrict pesticide use, produce is raised within a comprehensive IPM framework, and total pesticide usage is often reduced. For example, Responsible Choice™ is an IPM-label for apples raised in a growers' cooperative in Washington State.

The Cooperative Extension Service at the University of Massachusetts developed IPM standards for tomatoes. The standards are based on a set of best management practices that emphasize sound nutrient management, crop rotation, legume cover cropping, sanitation procedures, field scouting, pesticide record keeping, and so on. Growers earn a set number of points for each practice utilized in their production program. To be certified, each field must accumulate 311 out of a possible 445 IPM Practice Points—70% of the total (2).

Tomato Acreages, Yields, Economics, and Harvest

The tomato is one of the most commonly grown fresh market vegetables. Yet, since tomatoes are both high yielding and labor intensive, 1/4-acre, 1/2-acre, and 1-acre production units are common with market gardeners. In Massachusetts, for example, there are approximately 500 acres of tomatoes, and approximately 500 vegetable farms. Since some of the larger farms produce 10–15 acres of tomatoes, quite a few farms grow less than one acre (3).

Tomato yields of 650 to 850 boxes (30 pounds each) per acre are common in the South Central U.S. (e.g., Oklahoma) (4). This is equivalent to 19,000 to 25,000 pounds or about 10 to 13 tons per acre. Comparable fresh market yields of 23,000 to 27,000 pounds per acre are listed in *Knott's Handbook for Vegetable Growers* (5). In 1990, the average fresh market tomato yield nationwide was 25,100 pounds per acre (6).

Production and marketing costs for intensively cultured tomatoes can be over \$4,000 per acre with an expected gross return of \$4,000 to \$8,000 per acre (7). Gross returns of \$18,000 are not uncommon (8). One organic farmer in New Jersey netted \$10,000 an acre, with 10 acres in production (9).

Efficient harvesting, handling, and marketing techniques are extremely important in the production of this highly perishable crop. Harvesting tomatoes is very labor intensive. One source (10) estimates 350 hours for each staked acre. For storage and shipping, fruit can first be

picked at the "breaker" stage of maturity, when the blossom end turns pink. Post-harvest temperature management is critical to maintain quality. Tomatoes may become damaged when stored below 55°F. The optimum temperature range for longest shelf life is between 55°F and 70°F (5).

In general, the tomato market fluctuates with the growing season, starting high and dropping as the summer season progresses. That is why plasticulture and hoop house production — techniques which increase earliness or extend the season — have become popular.

Figure 1. 1997 Seasonal Price Variation, Organic Fresh-Market Tomatoes*



* Prices are average of each month's weekly prices from the *Organic Food and Business News Weekly Fax Bulletin*. Note that prices are farmgate and represent only West and East Coast markets.

Variety Selection

Factors influencing selection of tomato varieties include market demands, disease resistance, suitability to production systems, and regional adaptability.

Market demands: Wholesale markets that involve handling and packaging of the fruit require firm varieties suitable for shipping. This is less critical in farmers' markets, roadside

stands, and U-pick sales. In these cases, local consumer preference dictates which varieties to choose and may provide opportunities for specialty tomatoes (e.g., yellow, pink, low-acid, cherry, pear-shaped, and heirloom varieties).

Disease resistance: Diseases are the Achilles heel of organic tomato production. The use of resistant and tolerant varieties can give the farmer a "leg up" on pest management. Consider varieties such as the Mountain series developed

at North Carolina State University (e.g., Mountain Pride, Supreme, Gold, Fresh, and Belle), which are tolerant to early blight.

Suitability to production systems: Tomatoes have growth habits ranging from determinate (bush) to indeterminate (vining). Growth habit affects staking methods, pruning, length of harvest season, and other aspects of management.

Regional adaptability: Cooperative Extension Service publications and commercial seed catalogs provide information on varieties adapted to local conditions.

Crop Rotation

Crop rotation is a major component of organic farming, affecting both soil conditions and pest cycles. Tomatoes belong to the nightshade family (Solanaceae), which includes potatoes, eggplant, peppers, and garden huckleberry. Rotation to non-solanaceous crops for three years is usually recommended to avoid pest problems common to this group of vegetables (11).

For market gardeners and farmers with limited growing space, long rotations may be impractical. In these instances, soil building practices such as green manuring and composting — practices that support abundant soil microflora — are doubly important to create natural disease suppressive conditions.

Sod crops preceding tomatoes — such as grass pasture and small grains crops — often result in heavy cutworm and/or wireworm damage to tomatoes. When soil building crops such as these are grown in rotation to increase soil structure and organic matter, they should be plowed down several months in advance of planting.

Soil Fertility

The foundation of organic farming is a microbially active soil enriched with organic matter and a balanced mineral diet. Humus building practices and additions of rock minerals not only supply plant nutrients, but increase tolerance to insects and diseases, help control

weeds, retain soil moisture, and finally, ensure produce quality.

The organic fertility system revolves around a combination of practices such as crop rotation; forage legumes, cover crops, and green manures; livestock manures (preferably composted); lime, rock phosphate, and other rock minerals; and lastly, supplemental organic fertilizers.

On soils managed biologically for several years, tomatoes yield well from legume and compost treatments alone. While 5–10 tons/acre/year is a typical rate of compost application for vegetables, organic growers in New Jersey have been scaling back on compost rates for tomatoes, especially on established fields. Rates as low as 1–2 tons/acre/year are performing well.

Applications of well-rotted barnyard manures at 10–15 tons/acre/year have been recommended for tomato production. These are typically soil-incorporated in fall or early spring before planting. Raw manures are restricted in organic certification. They should be fall-applied, preferably to cover crops, well in advance of the crop.

"Hot manures" such as poultry litter are often limited to 4 tons/acre in the Ozark region; and less than 1 ton/acre in spring, well-incorporated at least two weeks prior to transplanting. Research from Alabama suggests higher rates of fall-applied poultry litter (9–18 tons/acre) can also yield good results (12). Poultry litter may be restricted in some organic certification programs.

Soils with no history of organic management will probably need additional fertilization. Fertilizer can be incorporated during field preparation and bedding operations, or banded to the side of the row at planting.

Fresh market tomatoes require about 75 to 100 pounds of nitrogen (N) per acre. Most, if not all, can be supplied by legumes in rotation; composts or manures can fill in the balance. Some farmers provide additional supplemental nitrogen at transplanting; a mixture of animal meal by-products, rock phosphate, and kelp meal is commonly used.

If reliance is primarily on supplemental fertilizers, about 50 pounds of actual nitrogen should be applied pre-plant, and the remainder side-dressed when fruits are about nickel-size. Old tomato publications recommended drilling or banding cottonseed meal, blood meal, or similar medium-to-fast acting organics at the time of planting (13).

Tomatoes need moderate to high levels of phosphorus (P) and potassium (K). On deficient soils, most needs can be met by advance applications of rock powders such as rock phosphate, colloidal phosphate, untreated (mined) potassium sulfate, and sulfate of potash-magnesia. Supplementary P and K may be added as indicated by soil test results compared to guidelines provided by Cooperative Extension; for example, see Table 1 “Plant Nutrient Recommendations Based on Soil Tests” from Rutgers University in the Appendix.

Tomatoes do best with a pH of 6.0 to 6.8. Liming to this range improves plant growth and optimizes fertilizer efficiency. Unless a deficiency of magnesium is noted, hi-calcium (non-dolomitic) lime is advised.

In addition to soil management practices, foliar feeding with fish emulsion, seaweed, biostimulants, and compost or weed teas is frequently done. A specific foliar spray — the application of apple-cider vinegar at a ratio of 1:100 in the spray solution — may stimulate flowering if delayed by weather or soil conditions (14). Field results of foliar fertilization are not consistent, however. Poor performance is often the result of failure to follow application procedures correctly. ATTRA has detailed information on foliar feeding available on request.

Major factors that influence fertility decisions on an organic farm include: crop rotation; the presence or absence of livestock on the farm; nearby manure sources; availability of equipment (compost turners, manure spreaders, fertilizer drills); and the availability and cost of commercial organic fertilizers in the region.

Research and Field Experience in Tomato Fertility

- In an Alabama study, fall-applied broiler litter at 18 T/A (tons/acre) produced 20% higher yields of earlier and larger tomatoes than commercial fertilizers (12). The litter was tilled in and rye was used as a winter cover crop.
- In Nigeria, tomatoes yielded 44 and 42 T/A when swine manure or poultry manure was applied at 9 T/A. Tomatoes yielded 37 and 42 T/A on fields treated with sewage sludge or rabbit manure applied at 18 T/A. Organic manures performed better than NPK treatments, which yielded only 31 T/A (15).
- In a New Jersey tomato study, soils well prepared with green manures and compost showed no yield response over two years to applications of supplemental blood meal and alfalfa meal at N rates as high as 200 lbs/A, suggesting that organic growers can save money by not purchasing pricey inputs (16).
- In California, yields of processing tomatoes grown following winter legume cover crops (Austrian winter peas, bell beans, lana wooly-pod vetch, berseem clover) were comparable to chemical N fertilizer treatments. Legume cover crops can provide N inputs sufficient to support 40 to 45 T/A of tomatoes (17).
- The Siegfried Luebke family, which operates one of the best known organic farms in Austria, uses Controlled Microbial Compost™ at 8 T/A for field and greenhouse tomatoes alike (18).

- Bob Hofstetter, formerly on-farm researcher at the Rodale Institute Research Center, plows down strawy manure and cover crops to produce tomatoes and peppers (19).
- Researchers in Georgia, South Carolina, and North Carolina investigated a vegetable production system using winter cover crops and various rates of nitrogen over a four year period. In all locations, cover crops produced higher yields and better quality tomatoes and other vegetables than applied nitrogen (20).
- In Arkansas, researchers recommended 9-13 T/A of poultry manure applied in winter (December) for spring (April) tomato production (21).
- Australian researchers determined that compost, inoculated with several species of beneficial fungi, greatly enhanced the growth of tomatoes (22).
- Treating organically grown tomato crops with kelp and fish powder sprays yielded inconclusive results in a California study. The researchers concluded—as had others before them—that the efficacy of foliar treatments is ultimately dependent on multiple plant, soil, and environmental factors (23).
- Well-rotted manures applied in the spring or fresh manure applied in the fall tends to enhance production beyond what the use of only commercial fertilizers can achieve. The best tomato crops follow crops of clover, sweet clover or alfalfa in a three- or four- year rotation. Non-legume green manuring crops, such

as rye or oats, may be used as an alternative to the previously mentioned crops but yields will be less than those for legumes. Whatever the rotation, the aim is to ensure the presence of an abundance of organic matter in the soil. Adequate supplies of rotting or decaying organic matter will increase crop yield and improve fruit quality (24).

Weed Management

Effective, non-chemical weed management begins with planned, diverse crop rotations, especially those including competitive cover (*smother*) crops. Attention is also given to careful site selection and sanitation procedures that avoid the introduction of weed seeds and other propagules.

The critical weed-free period for tomatoes is about 4–5 weeks after transplanting (or longer if the crop is direct-seeded) (25). It is during this period that weed competition must be suppressed to avoid a reduction in yield.

Weeds growing *between crop rows* are the easiest to control. They are usually handled either by shallow tillage or the use of a living mulch. Living mulches are cover crops (like white clover, subclover, or ryegrass) established to suppress weeds. Living mulches usually require some suppression also—either through partial-tillage or mowing—to avoid competition with the crop.

There are several ways to control weeds *within tomato rows*. The method(s) used will depend to a large degree on whether the tomato crop is mulched or raised on bare ground. Additional factors include scale of production, equipment, materials, labor, and grower preference.

In-row mulches control weeds by excluding light and forming a physical barrier to growth. These can be either organic mulches or some form of plastic sheeting.

Opaque plastic mulches (black and infrared transmitting—IRT) increase earliness and overall yields, and have become a standard practice in modern tomato production. Plastic mulch

systems are popular with entry level growers because production on plastic mulch is reliable. However, a few organic certification programs restrict the use of plastics. Plasticulture is rarely done without supplemental irrigation; drip is most commonly used but flood irrigation works, too. Fertigation, the injection of soluble fertilizers through drip lines, is feasible with specially formulated organic fertilizers.

Further information and resources on plasticulture can be found in the ATTRA publication *Season Extension Techniques for Market Gardeners* < <http://www.attra.org/attra-pub/seasext.html>>.

Organic mulches are an ideal organic treatment because they add nutrients and feed soil organisms as they decompose. They also enhance the presence of predatory beetles and spiders. Mulches containing weed or grass seeds, rhizomes and other propagules should be avoided to prevent the introduction of further weed problems. Straw-bale spreaders—commonly used in strawberry production—are available to mechanize organic mulching operations. Forage wagons, like those used on dairy farms, are sometimes used to deliver freshly cut pasture-mulch.

No-till cover crop mulches, which suppress weeds both within and between the rows, work well in some locations. One such system, devised by USDA researchers (26), employs a winter cover crop of hairy vetch. The vetch is killed with a flail mower leaving a 1–2 inch stubble and the cut vegetation as a surface mulch. Tomatoes—transplanted into the residue—benefit from excellent weed suppression, soil moisture retention, and the slow-release of nitrogen as the vetch decomposes.

On large acreages, mechanical cultivation is a common method of weed control within and between rows. Shallow cultivation, 1–2 inches deep, controls weeds and loosens soil that has crusted or become compacted. Loosening the soil helps in the absorption of rainfall and supplies soil microorganisms with oxygen. In turn, microorganisms decompose organic matter and

liberate plant food for the tomato crop. Hilling the soil towards the plant row (using rolling cultivators or disc hillers) has at least three benefits:

- 1) small weeds close to the plant row are smothered;
- 2) tomato plants develop roots farther up the stem; and
- 3) surplus moisture does not collect under tomato plants where it encourages disease, but instead runs away from the plants and collects between the rows (27).

The first cultivation may be done fairly close to newly established plants; later cultivations should be shallower and farther from the stems to avoid plant damage and reduced yields. Non-chemical weed control is further enhanced through the use of crop rotation, especially when competitive cover crops (smother crops) are included.

Research and Field Experience in Tomato Weed Management

- USDA researchers in Beltsville, MD, using hairy vetch as a no-till mulch crop for tomatoes, obtained yields averaging more than 45 tons/acre. This was trailed by yields of 35 tons using plastic mulch, and 34 tons using paper mulch. Control plots with no mulch averaged 19 tons/acre (28-29).
- Ohio State researchers designed an implement that mechanically undercuts and kills cover crops, thus providing a no-till surface mulch for tomatoes and other crops. Undercutting suppressed weeds better than either a flail mower or sicklebar mower. When not mowed into little pieces, the mulch is thicker and its ability to prevent light from penetrating to the soil surface is enhanced. The

residue also remains on the soil surface longer (30).

- USDA researchers in Mississippi set disc coulters at an angle to mechanically kill hairy vetch—a technique known as "rolling." They learned that the most effective time to do this operation was when the legume reached seed formation, or when stem lengths along the ground exceeded 15 inches (31).
- In Ohio, researchers compared yields of tomatoes and sweet corn on plots with no mulch to those in plots with 4–6" of straw or 6–8" of newspaper mulch. Highest yields for both crops were found on plots receiving shredded newspaper. Both mulches suppressed annual weeds but gave poor control of perennial weeds like Canada thistle and yellow nutsedge (32).
- In Virginia, on-farm researchers compared the efficacy of plastic, hay, and oiled paper plus hay mulch. The paper mulch was 40-lb recycled kraft paper, similar in color, texture, and thickness to paper shopping bags. Oiled paper was prepared by submerging rolls of kraft paper in waste cooking oil for 12 hours. The two organic mulch treatments had lower summer soil temperatures, higher summer moisture, and higher earthworm populations than the plastic mulch. Early marketable yields were higher on plastic, but total marketable yields were not significantly different. Spreading hay on top of the paper mulch, or use of a heavier 65-lb kraft paper, gave better weed control than 40-lb kraft paper alone (33).
- In New York State, wheat straw-mulched plots of 'Sunrise' tomatoes yielded almost

twice as much as unmulched plots. The researchers also noted reduced incidence of anthracnose, early blight, blossom end rot, and weeds on mulched plots (34).

- The use of colored plastic and paper mulches is a recent development in vegetable production. Different colors affect the wavelengths of light reflected back up into the crop canopy. This affects the amount of heat available to the crop and appears to have repellent effects on some insect pests. Mike Orzolek, of Penn State University, believes red is the most effective mulch color for tomatoes (35). In a Florida tomato study (36), where foliar horticultural oil sprays were also applied as part of the experiment, the largest number of whiteflies and the greatest incidence of virus symptoms were observed on white and yellow-mulched plots. Plants were tallest on aluminum and yellow plus oil-sprayed plots. Fruit size and marketable yields were best on plots with yellow mulch plus oil treatment.

Tomato Training Systems

Several training systems are used in tomato culture. These include unsupported on bare ground; unsupported on plastic or organic mulch; and supported (staked) by wire cages, stake and weave, or trellises—either on bare ground or plastic mulch.

Staked Culture Systems

The two systems in widespread commercial use are: stake and weave, and cage culture. A third system, more common in market gardens than in field-scale production, is the trellis system.

Staked on plastic mulch: This 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. Production costs associated with such intensive culture systems are high, but yield and quality are excellent.

Staked on organic mulch: This is similar to the system described above, but instead of plastic, an organic mulch is used. Organic growers may prefer the soil-enhancing benefits of an organic mulch over plastic, but there are still costs associated with materials and labor.

Unsupported Culture Systems

Sprawl culture: 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. Lower yields, lower fruit quality, and a higher incidence of fruit and foliage diseases may be expected when compared to supported systems. However, with lower establishment and labor costs, economic returns to the grower may be quite satisfactory.

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

Sprawl culture on organic mulch: Similar to plastic sprawl culture but organic mulches are used. Laying a thick mulch with farm equipment prior to setting out transplants is the easiest way to mulch a large area. Unlike plastic mulches which warm the soil, organic mulches cool the soil. This results in slower plant growth in the early part of the season. However, later in the season, when temperatures are higher, organic mulches have an advantage over plastics.

A Comparison of Tomato Training Systems

Researchers at Oklahoma State University examined the economics and performance of tomato training systems (37). They compare four different tomato training systems in the table below.

Comparison of Tomato Training Systems				
Factor	Ground ¹	Cage ²	Stake & Weave ³	Trellis ⁴
Earliness	3rd	4th	2nd	Best
Fruit Size	4th	3rd	2nd	Largest
Marketable Yld	4th	Largest	2nd	3rd
Fruit Cracking	3rd	4th	2nd	Worst
Fruit Rotting	Worst	2nd	2nd	2nd
Fruit Quality	Worst	2nd	2nd	2nd
Fruit Sunburn	Worst	4th	3rd	2nd
Cost/Acre	4th	2nd	Largest	3rd
Pest Control	4th	3rd	2nd	Best

¹Ground

No support system

²Cage

2 foot tall wire cage 14 inches in diameter made from No. 10 mesh on 6"x 6" spacing

³Stake and weave

Stake is driven between every other plant and twine woven between and around stakes 4–6 times. All suckers but one below the first fruit cluster are removed. No other suckers are removed above the first cluster.

⁴Trellis

Posts 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.

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.

A Rutgers study, for example, determined that fruit grown on staked plants suffers less post-harvest fruit rot (10%) than do ground-cultured fruit (34%) (38). An Oklahoma study found that a stake and weave trellis system delayed early blight by about seven days and decreased rate of infection, thus reducing disease incidence and severity at the end of the growing period (39). Results from a study in Massachusetts — where stake and weave trellising is encouraged for organic production due to reduced incidence of disease — were similar to those in Oklahoma (40).

Managing Insect Pests And Diseases: Basic Concepts

It is a long-held principle of organiculture that insect pests and diseases strike primarily at weak and improperly nourished plants. The objective of organic methods, then, is to grow crops which naturally resist the onslaught of pests. Management of soil tilth, moisture, and nutrient status is the first step in effective pest management.

Crop rotations, planted with the intention of breaking life cycles of insects and diseases, is a traditional means of pest control.

Complementary to crop rotations is the layout of fields with selected cover crops and flowering plants to attract beneficial insects, a technique known as *farmscaping*. Natural enemies of crop pests (e.g., ladybird beetles, lacewings, syrphid flies, and *Trichogramma* wasps) need shelter, pollen, nectar, and food prey to survive. Plants especially useful as refuge for beneficials include most legumes, mints, buckwheat, and members of the umbelliferae and compositae families. ATTRA's *Farmscaping to Enhance Biological Control* <<http://www.attra.org/attra-pub/farmscape.html>> publication provides extensive resources and seed sources for establishing beneficial insect habitats.

Strip cropping and interplanting are other forms of farmscaping. Sweet corn attracts the tomato fruitworm (also known as corn earworm) and may be an effective trap crop for this pest (41). Likewise, when field corn and tomatoes are grown in the same production area, fruitworm infestations on tomatoes are reduced (42).

Adjacent vegetation can also worsen pest problems, however. Bull nettle and other weedy nightshades may harbor diseases and insects of tomato, especially flea beetles. Weedy nightshades, jimsonweed, and plantain also harbor tobacco mosaic virus, a common viral disease of tomatoes.

Prevention and sanitation procedures are also important. These include post-season destruction of vines via tillage, burning, or composting; removal of diseased tomato plants and solanaceous weeds; sterilization of plant stakes prior to re-use; prohibiting tobacco use in the field; and frequent cleaning of tools and implements to prevent transporting problems between fields.

Other cultural practices also play a role. Orientation of rows to maximize air circulation helps reduce fungal problems. Suspending field activities when vegetation is wet with dew or rain limits the spread of disease (27), as does mulching to reduce direct soil contact and rain splash. Drip irrigation is preferred over sprinkler irrigation to reduce moisture and splash onto leaves and thus foliar disease occurrence.

Solarization, or heating soils by tarping with clear plastic prior to planting, is a non-chemical soil treatment for suppression of diseases, nematodes, and other pests. As a practical matter, however, its use is limited to small-scale operations.

Insects

Control of tomato insect pests requires careful monitoring and integration of cultural practices and biological controls. A wide range of biorational pesticides are available to keep pests below damaging levels. The table entitled "Major Insect Pests of Tomatoes" in the Appendix summarizes tomato insect pests and control

options. See the ATTRA publications titled *Sustainable Vegetable Production and Integrated Pest Management* <<http://www.attra.org/attra-pub/ipm.html>> for further concepts and practices associated with insect pest management.

Diseases

Despite good management practices, diseases usually occur, presenting one of the greatest challenges to organic tomato growers. The degree of occurrence is regionally based and largely dependent on environmental conditions.

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.

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, septoria leaf spot, bacterial canker, late blight), and fruit (bacterial spot, bacterial speck, anthracnose). Thus, a disease control program is important at each stage of growth. Early blight, one of the most damaging diseases in the eastern United States, is the focus of many control programs.

Organic tomato disease control programs are based on a combination of organic soil management practices, IPM practices, natural remedies, and limited fungicide use.

Application of composts, crop rotations including legumes, and supplemental fertilization with organic materials and rock powders are soil management practices that form the basis of biological disease control of soil-borne pathogens (43, 44). Indications of a systemic (whole plant) response to composts that are disease suppressive have been reported for several vegetables (45, 46).

Fungicide options are limited in organic production; copper- and sulfur-based products

are the only labeled fungicides allowed in certification programs. Coppers are labeled for anthracnose, bacterial speck, bacterial spot, early and late blight, gray leaf mold, and septoria leaf spot. Sulfur is labeled for control of powdery mildew.

Sulfur by itself is a minor fungicide in tomato production. Sulfur can easily burn the plant as air temperatures rise. It also has mild insecticidal and miticidal properties which may reduce the predator/parasite complex keeping pest insects in check.

Application of copper is a routine disease control practice in organic tomato production in the eastern United States. Copper functions both as a fungicide and bactericide. Most formulations are allowable in organic certification. These include bordeaux, basic sulfates, hydroxides, oxychlorides, and oxides.

Commercial products like Kocide 101™ are used in both conventional and organic tomato production for the control of septoria leaf spot, bacterial spot, bacterial speck, anthracnose, and early blight. The efficacy of copper in the control of early blight is limited, though, especially when disease pressure is high. Since applications are made on a 7–10 day schedule, the result may be 8–12 sprays per growing season.

The use of copper fungicides in organic production is somewhat controversial. It is directly toxic at applied rates to some beneficial organisms, particularly earthworms and some soil microbes such as blue-green algae — an important nitrogen-fixer in many soils. Excessive use can also result in the buildup to phytotoxic (crop damaging) levels of copper in the soil. Thus, organic growers often monitor soil copper levels through regular soil testing.

Disease forecasting is an IPM practice used to predict the probability of disease incidence. Weather monitoring instruments are placed in the field to collect data on canopy temperature, leaf wetness periods, and other factors that affect the likelihood of disease occurrence. The data collected from these monitoring stations are used to time fungicidal sprays for their optimum

effect, generally resulting in fewer spray applications each growing season.

TOM-CAST, CU-FAST, and FAST are three of several different disease forecasting systems developed for processing tomatoes (47). In Ohio, 100% of the tomato paste and ketchup industry, and about two-thirds of the whole-pack industry have adopted the TOM-CAST system (48). A recent expansion of TOMCAST services in this region now includes BLITECAST, a related program used to predict late blight (49).

Researchers are now looking at TOM-CAST as a tool for fresh market tomato production.

Whereas the standard schedule for conventional fresh market tomatoes includes 8–12 sprays per growing season, TOM-CAST users have reported reductions in fungicide applications of 25–30% in Ohio (48), and up to 70–80% in New York (50).

There are four ways that tomato growers can gain access to weather data and/or TOM-CAST forecasts:

1. Growers in the Midwest can call the TOM-CAST hotline and hear a recording of the latest disease severity index. The forecast is provided by Ohio State University and is updated six days a week. Weather data is collected from several monitoring sites in the Ohio-Indiana-Michigan region. The phone number is 1-800-228-2905.
2. Growers can purchase and install weather monitoring equipment on their own farm. As an example, one vendor sells field weather monitoring equipment as a tool for use in IPM programs for \$1,200–3,000. Several growers, or a growers' cooperative, may need to band together to split the cost.
3. Growers can obtain data from state-wide agriculture weather systems. A few states operate web-based agricultural weather sites (e.g., MesoNet in Oklahoma, AWIS in Alabama-Florida-Georgia, PAWS in Washington, Texas A&M Meteorology).

4. Growers can purchase agriculture weather data from a commercial vendor like SkyBit. SkyBit offers an agriculture weather service for \$50 a month. Contact SkyBit at 1-800-454-2266 for more information.

Any of the three latter systems can be used in combination with TOM-CAST. For detailed information on how to use the TOM-CAST disease severity index, contact Jim Jasinski at Ohio State University or view the TOM-CAST website at: <<http://www.ag.ohio-state.edu/~vegnet/tomcats/tomfrm.htm>>
Contact:

Jim Jasinski, Tom-Cast Coordinator
SW District Agent, IPM
303 Corporate Center Drive, Suite 208
Vandalia, OH 45377
513-454-5002
513-454-1237 Fax
jasinski.4@osu.edu

Several natural remedies may be employed by organic farmers for foliar disease management. These include a wide range of products and practices including: compost watery extracts; hydrogen peroxide; sodium bicarbonate; foliar fertilizers; plant extracts (fermented nettle tea, equisetum tea, comfrey tea); and biostimulants (seaweed, humates). The precise mode of action for many of these materials remains to be discovered.

Of these, compost watery extracts and hydrogen peroxide look promising for the control of tomato diseases like early blight. Compost extracts have proven effective for several vegetable diseases, including late blight of tomatoes (51). See the ATTRA publication *Compost Teas for Plant Disease Control* <<http://www.attra.org/attra-pub/comptea.html>> for references and resources.

Little information is available on the use and efficacy of hydrogen peroxide. Growers in New Jersey are using 35% hydrogen peroxide and diluting it to a 0.5%–1% foliar spray solution, though lower rates are also common. Rates of 2% and 4% are being used as a post-harvest wash. A

1% solution is equivalent to 3.7 oz in 124.3 oz of water, while a 0.5% solution is equivalent to 1.8 oz in 126.2 oz of water (52).

Biological fungicides are a relatively new tool available to organic growers. Biological fungicides contain beneficial bacteria or fungi (microbial antagonists) which help suppress pathogens that cause plant disease. For example, F-Stop™, registered as a seed treatment for tomatoes, contains a biocontrol agent called *Trichoderma viride sensu*. T-22G Biological Plant Protectant Granules™, registered as an in-furrow soil treatment on tomatoes and other vegetables, contains *Trichoderma harzianum*, strain KRL-AG2.

See the Microbial Pesticides table in Appendix A of the ATTRA publication *Integrated Pest Management* <<http://www.attra.org/attra-pub/ipm.html#appendixa>> for a comprehensive summary of microbial pesticides used for insect and disease control.

See the USDA web site *Commercial Biocontrol Products for Use Against Soilborne Crop Diseases* <<http://www.barc.usda.gov/psi/bpdl/bioprod.htm>> for a comprehensive list of biocontrols for soilborne plant pathogen.

Resources

For standard information on tomato production (planting, staking and pruning, variety recommendations, irrigation, harvest, and marketing), we suggest the excellent resources already compiled by the Cooperative Extension Service. See the attached resource list titled *Tomato Web Links* for a listing of tomato literature.

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Appendix:

Table 1: Plant Nutrient Recommendations for Tomatoes Based on Soil Tests

Table 2: Number of Plants per Acre at Several Between-row and In-row Plant Spacings

Appendix: (continued)

Table 3: Major Insect Pests of Tomatoes

Table 4: Tomato Diseases

Table 5: Other Problems of Tomatoes

Enclosures:

ATTRA Resource List: Tomato Web Links

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Table 1

Plant Nutrient Recommendations for Tomatoes Based on Soil Tests									
Crop and Application Method	N Lbs/A	Soil Phosphorus Level				Soil Potassium Level			
		<u>Low</u>	<u>Med</u>	<u>High</u>	<u>V. High</u>	<u>Low</u>	<u>Med</u>	<u>High</u>	<u>V. High</u>
Pounds P₂O₅ per Acre									
Pounds K₂O per Acre									
Fresh market tomatoes									
<u>Sandy loams and loamy sands</u>									
Total recommended	80-90	200	150	100	0	300	200	100	0
Broadcast and plow down	40-45	200	150	100	0	300	200	100	0
Sidedress when first fruits are set	40-45	0	0	0	0	0	0	0	0
<u>Loams and silt loams</u>									
Total recommended	50-80	200	150	100	0	250	150	100	0
Broadcast and plow down	50	200	150	100	0	250	150	100	0
Sidedress at first fruit if needed	25-30	0	0	0	0	0	0	0	0
Processing tomatoes – transplants for multiple harvests									
<u>Sandy loams and loamy sands</u>									
Total recommended	130	250	150	100	0	300	200	100	0
Broadcast and disk in	50	250	150	100	0	300	200	100	0
Sidedress at first cultivation	50	0	0	0	0	0	0	0	0
Sidedress when 1st fruits 1" diam.	30	0	0	0	0	0	0	0	0
<u>Loams and silt loams</u>									
Total recommended	100-125	250	150	100	0	300	200	100	0
Broadcast and plow down	50-75	250	150	100	0	300	200	100	0
Sidedress when 1st fruits 1" diam.	25-50	0	0	0	0	0	0	0	0

Source: Rutgers University. 1998. 1998 Commercial Vegetable Production Recommendations. Publication No. E001N-W2. Rutgers Cooperative Extension, New Jersey Agricultural Experiment Station.

Table 2

Number of Tomato Plants* per Acre at Several Between-row and In-row Spacings

Between Rows (feet)	Between Plants in the Row (inches)		
	18	21	24
5	5,808	4,978	4,356
5½	5,280	4,526	3,960
6	4,840	4,148	3,630

* Number of stakes required per acre is exactly half the number of plants required, for any spacing.

Source: Neary, Philip E. 1992. Commercial Staked Tomato Production in New Jersey. E-163. Rutgers Cooperative Extension Service, New Jersey Agricultural Experiment Station. 7 p.

Table 3

Major Insect Pests of Tomatoes		
Name	Damage	Control
Aphid	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
Armyworm	Feeds on foliage and fruit	Beneficial insects; Bt on larvae; Superior oil
Blister beetle	Feeds on foliage and fruit	Larvae are beneficial. For severe infestations, use pyrethrum, rotenone, or sabadilla
Colorado potato beetle	Feeds on foliage	Bt on larvae; Encourage beneficials; Neem; Pyrethrum; Rotenone
Cutworm	Cuts plant stem	Apply parasitic nematodes to soil; Wood ashes around stem; Moist bran mixed with Bt scattered on soil
Flea beetle	Many small holes in foliage	Row covers; Sanitation; Apply parasitic nematodes to soil; Neem; Pyrethrum; Rotenone; Sabadilla
Fruitworm	Feeds on foliage, flower, fruit	Destroy infested fruit; Bt; Row covers; Neem; Ryania
Hornworm	Feeds on foliage and fruit	Bt; Pyrethrum if severe
Pinworm	Fruit has narrow black tunnels	Destroy infested fruit; Till at season end to prevent overwintering; Sabadilla
Stink bug	Deformed fruit with whitish-yellow spots	Control weeds near plants; Trap crops; Planting late-maturing varieties; Attract beneficials by planting small-flowered plants; Sabadilla
Whitefly	Distorted, yellow leaves; Honeydew which attracts sooty mold	Insecticidal soap; Yellow sticky traps; Beneficial insects; Garlic oil; Pyrethrum; Rotenone; <i>Beauveria bassiana</i>

Table 4

Tomato Diseases		
Name	Damage	Control
Early blight (Alternaria blight)	Leaves have brown spots with concentric rings and yellow "halos"; Incidence increases in warm, humid weather	Resistant cultivars*; Sanitation at season end; Mulching; Air circulation; Avoid water on leaves; Rotation; Copper.
Late blight	Leaves have bluish-gray spots; Leaves turn brown and drop; Fruits have dark brown, corky spots; Incidence increases with wet weather, warm days and cool nights	Resistant cultivars; Sanitation; Avoid water on leaves; Grow in poly hoop houses; Copper
Leaf spot (Septoria leaf spot)	Numerous small brown spots with gray or black centers; Leaves turn yellow and drop	Sanitation; Rotation; Avoid water on leaves; Anti-transpirants; Copper
Anthracnose	Fruit has small, slightly sunken circular spots that spread and crack open	Resistant cultivars; Sanitation; Rotation; Physical support of plant; Copper; Sulfur; Remove severely infected plants
Tobacco Mosaic Virus (TMV)	Distorted, small leaves and plants	Don't grow around tobacco; Don't handle if tobacco is present on hands; Destroy infested plants
Bacterial spot; Bacterial speck	Small, dark spots on leaves; Brown, rough spots on fruit	Copper; Remove and destroy infested plants if severe
Bacterial canker	Leaves have brown edges; Wilted leaves; Fruit has very small, dark brown spots with white edges	Remove and destroy infested plants

*The Mountain series (Mountain Pride, Mountain Supreme, Mountain Gold, Mountain Fresh, and Mountain Belle) is early blight tolerant.

For Verticillium, Fusarium, and nematode resistance, cultivars labeled VFN should be used.

Table 5

Other Problems of Tomatoes			
Name	Cause	Effect	Control
Blossom end rot; Blackheart	Lack of calcium	Sunken spot on blossom end of fruit; Blackheart is internal condition	Resistant cultivars; Add Ca to soil; Spray with seaweed extract; Mulch to keep moisture level constant
Cracking	Warm, rainy weather after dry spell	Fruits split open	Resistant cultivars; Mulch to keep moisture level constant
Catfacing	Cool weather	Malformed fruit with scars near blossom end	Row covers
Blossom drop	Sudden temp. changes; Nights below 55°F; Hot weather; Too little light; Too much/Too little water; Too much fertilizer	Blossoms fall off before pollination occurs	Resistant varieties
Sunscald	Overexposure to sun caused by defoliation	Yellowish-white patches on fruit	Maintain plant vigor to avoid defoliation by insects and disease
N deficiency	Lack of nitrogen	Yellowing of oldest leaves; Stunted growth	Compost; Composted manure; Soybean meal; Dried blood; Fish emulsion; Legume cover crop
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



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Extension Fact Sheets on Tomato Production and Handling

Tomato Production in Florida

Florida Cooperative Extension Service

<http://hammock.ifas.ufl.edu/txt/fairs/CV137>

Tomato Production Guide for Florida

Cooperative Extension Service, University of Florida

<http://hammock.ifas.ufl.edu/txt/fairs/56332>

Processing Tomato Production in California

Cooperative Extension Service, University of California

<http://vric.ucdavis.edu/vrichome/html/selectnewcrop.tomproc.htm>

Mature-Green Tomatoes (Bush Grown)

Cooperative Extension Service, University of California

<http://vric.ucdavis.edu/vrichome/html/veginfo/commodity/tomato/matgrtomatoprod.html>

Tomatoes (Fresh Market) San Diego County

Cooperative Extension Service, University of California

<http://vric.ucdavis.edu/vrichome/html/veginfo/commodity/tomato/sdtomatoprod.html>

Fresh-Market Tomato Production

Ontario Agriculture, Agdex 257/20

<http://www.gov.on.ca/OMAFRA/english/crops/facts/94-019.htm>

Commercial Production of Fresh Market Tomatoes

Oklahoma Cooperative Extension Service, Oklahoma State University

http://www.okstate.edu/OSU_Ag/agedcm4h/pearl/hort/vegetble/f-6019.pdf

Agricultural Alternatives: Tomatoes

Pennsylvania Cooperative Extension Service, Pennsylvania State University

<http://agalternatives.cas.psu.edu/tomato.html>

Commercial Production of Tomatoes in Mississippi

Mississippi State Extension Service, Mississippi State University

<http://ext.msstate.edu/pubs/is1514.htm>

Pruning and Training Tomatoes

University of Missouri Extension Service

<http://muextension.missouri.edu/xplor/agguides/hort/g06460.htm>

Fresh Market Tomatoes
University of Missouri Extension Service
<http://muextension.missouri.edu/xplor/agguides/hort/g06370.htm>

Commercial Vegetable Production: Tomatoes
Kansas Cooperative Extension Service, Kansas State University
http://www.oznet.ksu.edu/_library/HORT2/MF1124.pdf

Tomatoes
Oregon State University Cooperative Extension Service
<http://www.orst.edu/Dept/NWREC/tomato.html>

Postharvest Cooling and Handling of Field- and Greenhouse-Grown Tomatoes
North Carolina Cooperative Extension Service
<http://www1.ncsu.edu/bae/programs/extension/publicat/postharvest.html>

Crop Budgets, Economics, and Marketing for Tomatoes

1994, University of California Cooperative Extension Sample Costs to Produce Organic Processing Tomatoes in the Sacramento Valley
<http://vric.ucdavis.edu/vrichome/html/veginfo/topics/prodcosts/organictom.html>

Table 77: Costs of Production for Fresh Market Tomato, Per Acre Organic Production Practices Northeastern United States, 1996. Rutgers Cooperative Extension.
<http://aesop.rutgers.edu:80/~farmmgmt/ne-budgets/organic/Tomatoes-FreshMarket.html>

Table 78: Costs of Production for Processing Tomato, Per Acre Organic Production Practices Northeastern United States, 1996. Rutgers Cooperative Extension.
<http://aesop.rutgers.edu:80/~farmmgmt/ne-budgets/organic/Tomatoes-Processing.html>

Processor Tomato Projected Production Costs, 1994-1995
Cooperative Extension Service , University of California
<http://vric.ucdavis.edu/vrichome/html/veginfo/commodity/tomato/proctomatocosts.html>

Mature Green Tomatoes, Bush Grown Projected Production Costs, 1994-1995
Cooperative Extension Service , University of California
<http://vric.ucdavis.edu/vrichome/html/veginfo/commodity/tomato/grtomatocosts.html>

Mature Green Tomatoes, Bush Grown Drip Irrigated Projected Production Costs, 1995-1995
Cooperative Extension Service, University of California
<http://vric.ucdavis.edu/vrichome/html/veginfo/commodity/tomato/grtomatodripcosts.html>

USDA-Economic Research Service: Fresh Market Tomato Production Statistics
<http://www.econ.ag.gov/briefing/tomato/>

Tomatoes: Fresh Market and Processing
1998 Ohio Vegetable Production Guide Bulletin 672
http://www.ag.ohio-state.edu/~ohioline/b672/b672_31.html

Statewide Statistics on Processing Tomato Acreage and Tonnage
California Tomato Growers Association, Inc.
<http://www.ctga.org/by%20state.htm>

Staked Tomatoes: Green Pack Budget
Ohio Cooperative Extension Service, Ohio State University
<http://www.hcs.ohio-state.edu/hcs/EM/budget/tom-gren.pdf>

Processing Tomatoes: Machine Harvest Budget
Ohio Cooperative Extension Service, Ohio State University
<http://www.hcs.ohio-state.edu/hcs/EM/budget/tom-mach.pdf>

Processing Tomatoes: Hand Harvest Budget
Ohio Cooperative Extension Service, Ohio State University
<http://www.hcs.ohio-state.edu/hcs/EM/budget/tom-hand.pdf>

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

The Farmer's Bookshelf: Tomato
University of Hawaii — College of Tropical Agriculture and Human Resources
<http://Agrss.sherman.Hawaii.Edu/bookshelf/tomato2/tomato2.htm>
This has a link to download a Tomato Cost Analysis spreadsheet for Lotus 1-2-3

Sustainable Production Practices for Tomatoes and Vegetables

Sustainable Practices for Vegetable Production in the South
North Carolina Cooperative Extension Service
<http://www.cals.ncsu.edu/sustainable/peet/>

A No-Tillage Tomato Production System Using Hairy Vetch and Subterranean Clover Mulches
UC-SAREP, University of California
<http://www.sarep.ucdavis.edu/sarep/newsltr/v7n1/sa-11.htm>

Role of Legume Cover Crops in Sustainable Tomato Production
Fort Valley State University (Fort Valley, Georgia)
<http://agschool.fvsc.peachnet.edu/html/Research/Projects/0164671.htm>
Abstract: The third year of yield experiments was conducted during 1996-97 to compare the efficacy of winter cover cropping with legumes for replacing synthetic N fertilization in tomato production. Legumes supplied significantly greater amounts of mineralized N to the soil during the tomato growing season than rye or control. There was no significant difference in plant dry weight and fruit yields between fertilizer and legume N sources. Both fertilizer and legume winter cover resulted in higher plant dry weight and tomato yields than control.

Current Research – Legume Cover Crops and Tomato Yields
Fort Valley State University (Fort Valley, Georgia)
<http://agschool.fvsc.peachnet.edu/html/Publications/CommoditySheets/fvsu014.htm>
Abstract: Alternative methods of tomato production is the focus of ongoing research at the Fort

Valley State University Agricultural Research Station. For the past three years, the overall tomato research objective has been the comparison of fall/winter cover crops (Abruzzi Rye, Hairy Vetch, and Crimson Clover) to different rates of commercial nitrogen for a possible nitrogen fertilizer substitute. The study did not use raised beds, plastic mulch, or drip irrigation. The state's median yield for tomato production on raised mulched beds is 20 tons/acre and 12.5 tons/acre for bare ground. Average tomato yield over three years in the station study were: Zero Nitrogen=19.0 tons/acre, Abruzzi rye=18.1 tons/acre, Hairy Vetch=28.7 tons/acre, Crimson Clover=27.5 tons/acre, Full Nitrogen=28.2 tons/acre, and Half Nitrogen=29.9 tons/acre. In general, it appears that Vetch and Clover are comparable to nitrogen fertilizer.

IPM for Tomatoes

Fact Sheets Related to Tomato Diseases and TOMCAST

Ohio State University

<http://www.ag.ohio-state.edu/~vegnet/tomcats/tomfrm.htm>

Crop Knowledge Master: Tomato IPM

University of Hawaii — College of Tropical Agriculture and Human Resources

<http://www.extento.hawaii.edu/kbase/crop/crops/tomato.htm>

UC Pest Management Guidelines: Pests of Tomatoes

<http://www.ipm.ucdavis.edu/PMG/selectnewpest.tomatoes.html>

Northeast Greenhouse IPM Notes (Field and Greenhouse Horticultural Crops)

Cornell & Rutgers Cooperative Extension

<http://www.cce.cornell.edu/suffolk/greenhouse-notes/>

Miscellaneous Web Links

Using Cold Frames in Eastern Oklahoma (Tomato Crop)

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