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ATTRA
National Sustainable Agriculture Information Service
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Tree Fruits: Organic Production Overview

HORTICULTURE SYSTEMS GUIDE

Abstract: *This guide is an overview of issues relevant to commercial organic production of temperate zone tree fruits and, to a lesser extent, tree nuts. It includes discussions of marketing and economics, orchard design, and cultural considerations, including crop varieties, site selection, site preparation, soil fertility, weed control, and pest management (insects, diseases, and vertebrates). It raises questions for the grower to consider in making decisions about orchard and enterprise design. Lists of electronic and print resources offer further, more detailed information.*

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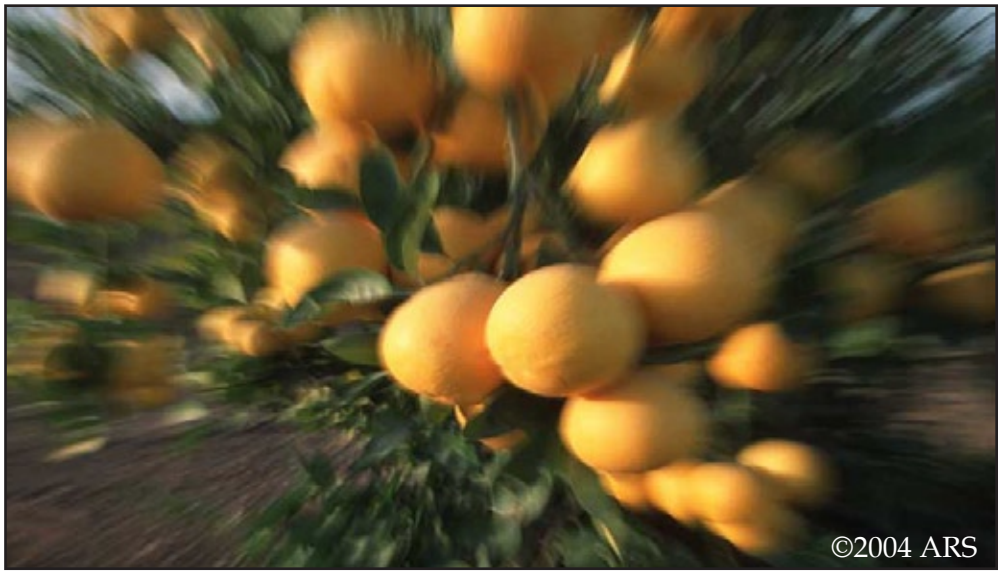

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A note about Organic Standards: Included in this publication are references to the organic standards authorized by the USDA's National Organic Program, www.ams.usda.gov/nop. Organic producers should verify with the appropriate certification bodies that their practices and any materials they intend to use are compliant with applicable standards for their intended markets. This is especially true if those markets are international, where there may be additional production and labeling requirements.

Introduction

This publication focuses on production and marketing of organic fruits and nuts, highlighting a systems approach to orchard production and farm management. Not intended as a comprehensive production guide for individual fruit crops, this publication introduces key production issues that merit consideration in any specific crop or production region. As noted below, ATTRA has other publications for specific fruit and nut crops. General information on cultural practices for fruit production (choosing varieties, spacing, pruning, training, irrigating, harvesting, postharvest handling, etc.) is relevant to both organic and conventionally managed operations, and it is widely available from the Cooperative Extension Service, nurseries, and in horticulture literature.

Organic Fruit Production

Organic production is defined by USDA's National Organic Program (NOP) as "A production system that is managed...to respond to site-specific conditions by integrating cultural, biological, and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity."

Organic fruit production involves more than simply excluding synthetic pesticides and fertilizers. Benign neglect does not meet NOP standards for production. Organic agriculture is an integrated approach to active and observant management of a farming system. It begins with good soil management for nutrient cycling, productivity, and tilth. It involves an integrated, preventative approach to pest management to protect the health and productivity of the orchard.

ATTRA has additional information on organic fruit production and organic agriculture. Please refer to the list below for guides to production of specific fruit crops. Many of these publications discuss the transition from conventional to organic farming, as well as how to become certified, write an organic systems plan, and develop markets or value-added enterprises. See the ATTRA Web site, www.attra.ncat.org, for a complete list of publications, or call 800-346-9140 to request a current Publications List.

ATTRA Publications on Organic and Low-Spray Fruit Production

- Organic and Low-Spray Apple Production
- Considerations in Organic Apple Production
- Organic Pear Production
- Organic Blueberry Production
- Organic Culture of Bramble Fruits
- Organic Grape Production
- Strawberries: Organic & IPM Options
- Pawpaw Production
- Persimmon Production
- Organic and Low-Spray Peach Production
- Low-Spray & Organic Plum Production
- Sustainable Pecan Production
- Overview of Cover Crops
- Farmscaping to Enhance Biological Control
- Biointensive IPM
- Sustainable Soil Management
- Alternative Soil Testing Laboratories
- Alternative Soil Amendments
- Foliar Fertilization
- Sources of Organic Fertilizers and Soil Amendments

Marketing and Economic Considerations

To plan for economically successful enterprises, farmers must design their fruit production systems to match their marketing strategies. Good fruit production alone does not lead to a successful enterprise. Profitability depends on a combination of production volume, quality, size, and a reliable marketing strategy. Marketing channels range from direct markets to wholesale shippers. Growers must understand what each of their customers wants and be prepared to meet the expectations of the markets they intend to reach. For example, at farmers' markets, customers seek good tasting fruit at or near the peak of ripeness for prompt consumption, but supermarket distributors demand that fruit be uniform and shippable. It is important to market in an appropriate niche, one where the production of your operation can consistently meet the buyers' expectations of volume, quality, and timing.

Good production and good quality do not guarantee good returns.

My late friend, farmer, and master machinist Grover Parsons recounted how he planted 10 acres of apricots in San Juan Bautista, California. He chose the best-tasting variety, Royal Blenheims. He cultivated them organically, but that was before there were organic standards for market differentiation and premium pricing. The variety was also well-suited to the climate and soil. They grew beautifully and began producing good yields of excellent fruit. He harvested the apricots at the appropriate time and sold them to a local buyer. With each successive season he found the price more and more discouraging; it did not adequately compensate him for his work. He got on his tractor and took out the orchard—all but a few trees along the fenceline. Those trees were still providing him with good fruit for home use decades later.

- Ann Baier

Premium pricing can be critical to the viability of organic fruit operations, because production costs are often higher than those for conventional orchards. Organic pest control, particularly labor costs for hand thinning and weed control, is generally more expensive than conventional practices. Yield and quality can vary widely, depending on the growing season and management practices. In the past it may have been true that organic yields and pack-out rates (the percent of marketable fruit) were lower than in conventional production. Today, however, those differences have narrowed, and yields in some organic production systems can match or exceed those of conventional systems. To achieve good yields, organic growers must be prepared to develop innovative production and marketing strategies. Many commercial organic fruit producers, especially family-scale farmers, minimize waste and losses of potential revenue by processing (drying, preserving, or juicing) fruit considered unsuitable for the fresh market. See ATTRA's publication *Adding Value to Farm Products: An Overview.*

Yield and quality can vary widely, depending on the growing season and management practices.

There are tradeoffs in every marketing strategy. A successful grower must develop markets in which the price for organic produce adequately compensates for all production costs. Additionally, the marketing process must be compatible with the grower's personality and business skills. The particular combination of components in any grower's marketing strategy will depend on local marketing opportunities as well as the grower's desire to be directly involved in marketing, tolerance for stress, and ability to balance a variety of risk factors. For more information, request the ATTRA publications *Evaluating a Rural Enterprise*, *Keys to Success in Value-Added Marketing*, and *Direct Marketing*.

Cost-Benefit Analysis of Markets

Several certified organic apple growers in the Central Coast region of California sell their culls to Martinelli's, a longstanding locally-based juice company. The company has a low-volume organic juice line that produces a limited number of runs each year, if farmers can time their harvest to match it. Even though the company does not give a premium for organic fruit that goes into their regular juice line, its proximity to the farms, fair payment practices, and good business relations make for a satisfying and cost-effective sale for many organic growers. Although there are organic processors in other parts of the state, the price premium for organic fruit does not always offset the increased transportation costs, volume requirements, hard bargaining, or worry about late payments from more distant organic processors. Being certified organic increases one's marketing flexibility. An organic certificate provides the option but not the obligation to use the organic claim. When it is advantageous, organic produce can be sold as conventional, but never vice-versa.

Cultural practices in fruit production begin with selection of an appropriate site, fruit crop, rootstock, and fruit variety, followed by site preparation (tillage and pre-plant soil amendments) and orchard layout (tree and row spacing). These considerations will largely determine the productivity, health, and efficiency of operations in your orchard over the long term, and they cannot easily be changed once the orchard is established. If you are managing an existing orchard, you will continually need to take stock of its assets and limitations in relation to current markets, and either work within those limits or make plans for some degree of orchard renewal. If you are considering the purchase of an existing orchard, ask the owners about their financial history (production costs and sales records), and research the market to assess the economic feasibility of continuing with the business as it is currently practiced. Once you have made the most realistic cost estimates possible, you can develop a plan to adjust the production system, revise the marketing plan, or walk away while you still have your shirt.

Planning and Planting an Organic Orchard

Site Selection

Fruit trees, like most crops, respond to good soil with vigor and productivity. Trees can successfully produce economic yields on hillsides, rocky soils, and other sites not suitable for frequent tillage. Look carefully at your site and take stock of its soil, slope, and aspect, water infiltration and drainage, frost patterns, maximum and minimum temperatures, length of growing season, distribution of annual precipitation, availability of water for irrigation, proximity of the water table, and wind and air circulation patterns. Most of these are beyond your control, and your planting plan must suit the natural conditions of the site. While farmers may be able to improve the soil over time, they cannot change the subsoil layers, influence the prevailing wind, or modify temperatures to any significant extent.

All the factors regarding site suitability for conventional fruit plantings apply—even more so—to organic operations. While conventional growers may fall back on chemical fertilizers and pesticides to compensate for some poor site decisions, organic growers cannot. Good drainage and air circulation are essential for disease control. The presence of certain weeds and forage species is of particular concern to the organic grower. Bermuda grass, Johnson grass, quack grass, and several other pernicious species can be serious problems to fruit growers and are difficult to control with organic methods once an orchard is established.

Depending on the crop, harvesting either early or late in the season can also provide a market advantage.

An assessment of physical and environmental factors will help the grower determine whether a crop can be grown easily, marginally, or not at all. While someone with a home orchard may consider it worthwhile to cover a lemon tree before each anticipated frost, or to nurse a few apricot trees through Midwestern winters in order to savor the delicious fruits two seasons out of seven, these would likely not be viable commercial enterprises. However, stretching the limits of production within reason can be worthwhile under certain circumstances. For example, subtropical fruits grown in the coastal valleys of California bring a premium for their freshness and novelty, offsetting the expense of the extra care they require. Depending on the crop, harvesting either early or late in the season can also provide a market advantage. While California's San Joaquin Valley is not known for apple production, its warmer spring and summer temperatures can bring the crop to maturity a few weeks ahead of coastal producers. The price premium for first-of-the-season organic fresh-market apples may offset the overall lower crop yields. Fruit grown in its primary growing region may be more difficult to distinguish from the rest of the fruit in the market, and so lose its competitive edge.

Pragmatism is critical in crop and variety selection. The fruit grower must take into account not only factors of yield, productivity, quality, and flavor, but also of marketability. Diversification of varieties and marketing channels is a prudent strategy. While one farm in California may receive a good return for the fruit from one lone jujube tree, there is no assurance that such a profit can be scaled up to an extensive orchard of specialty fruits. Conclusions: while the jujube is a tasty and unusual fruit, and the value of fruit from one tree may be substantive, the regional market for this novelty would not accommodate production from 200 trees. Similarly, in his book *Epitaph for a Peach*, Mas Masumoto describes the wonderful flavor and quality of the Suncrest peach. Yet his family farm substantially decreased their plantings of this variety. It was a practical business decision to plant more of the newer varieties that the current market demands, and keep a smaller block of the sumptuous Suncrests that are more difficult to ship and store. This seasoned fruit grower advises a production and marketing plan that includes a combination of mainstream and specialty varieties.

Fruit Crop and Variety Selection

Because fruit trees are perennial and represent a considerable investment of both time and money, it is important to start by planting your orchard with the optimum varieties for your location and intended markets. Research on the front end can pay the grower back many times over. Information on species and varieties is available from Cooperative Extension, nurseries, and other local growers. Many land grant universities have field stations where they have planted many varieties of fruit trees and gathered data and observations over several years. A visit to such a site can provide you with the invaluable opportunity to see the trees growing, talk with the manager of the experiment station about production challenges such as pests and diseases, and even taste the fruit.

Crop Species Selection

Clearly, the first decision is what species to plant. Is a tree orchard the best use of your land and talents? Or is your site and marketing plan better suited for a somewhat shorter-term investment in smaller plants such as blueberries, caneberries (raspberries, boysenberries, olallieberries, other blackberry varieties), grapes, kiwi, or even

strawberries? If you are sure that you are willing to manage tree fruits and nuts, will your focus be to produce almonds, apples, apricots, avocados, cherries, figs, grapefruit, jujubes, lemons, oranges, pawpaws, peaches, pecans, pears, persimmons, plums, pluots, or zapotes?

Careful consideration of environmental conditions, as well as the locations of markets and suppliers, is of tantamount importance. For example, organic peach production in the East is greatly complicated by the presence of the plum curculio and by greater disease pressure than in the drier climates of the West. In general, the West's arid climate is better for organic fruit production. The small fruits (blueberries, blackberries, raspberries) are easier to produce organically than tree fruits in almost all locations.

Photo by Scott Bauer. ©2004 ARS

The availability of production supplies and markets in your region can be a critical factor in crop selection. Being the only one growing a certain fruit may provide you with a local marketing niche; however, the value of readily available supplies and services should not be underestimated. While some supplies can be easily and cost-effectively shipped by mail, others cannot. Pest management materials such as codling moth pheromone traps can be efficiently shipped from a distant supply company. But how far do you have to drive to purchase boxes and bulky packaging supplies? How far to cold storage, a packing house, distributor, processor, or transportation terminal? Driving several hours to purchase appropriate boxes or to deliver fruit to a broker's cooler can make an otherwise viable enterprise unprofitable.

Careful consideration of environmental conditions, as well as the locations of markets and suppliers, is of tantamount importance.

Variety and Rootstock Selection

Once the question of crop species is settled, the next decision is what variety (or combination of varieties) to plant. Considerations include, but are not limited to:

- harvest season: early, mid, or late season, or a combination of these to achieve a more continuous supply or to ensure a crop during early or late marketing windows
- adaptability to the region: cold hardiness, temperature ranges for optimal growth, requirements for soil fertility or pH
- chill requirements for fruit set and flavor
- water requirements: need for irrigation or protection from waterlogging
- stature: dwarf, semi-dwarf, or standard
- resistance to diseases and pests

- marketability: color, flavor, nutritional value, storage requirements, shipability, uniformity, shelf life—any characteristics that define quality for your customer

- proximity to appropriate markets

You can select for desired characteristics, especially in grafted trees, with a combination of varieties of rootstock and fruiting wood.

Sources of Planting Stock

It is important to get clean planting stock. Buying from reputable nurseries that provide stock certified by state inspectors to be free of diseases and insect pests is best. Organic planting stock is required, if commercially available, for certified organic fruit production. If organic planting stock is not available, organic growers must document their search for organic stock and its lack of commercial availability. Most certifiers interpret the organic standards as requiring organic management of non-organic planting stock for at least 12 months before harvesting a crop that is to be represented or sold as certified organic. With newly planted tree crops, this is a non-issue, since they generally grow for at least three years before producing a marketable crop.

Type and Size of Planting Stock

The type of rootstock—standard, dwarf, or semi-dwarf—will determine the size of the tree at maturity. Tree size determines the spacing, number of trees per acre, training system, years to bearing, and timing of economic return. Orchard design should reflect the grower's production and cash-flow goals. For example, standard trees produce more fruit when mature, and initial purchase and planting costs are lower. Smaller trees have higher initial planting costs, since more trees are needed to achieve density. Dwarf and semi-dwarf trees generally come into production sooner. Smaller trees simplify many field operations, including pruning, grafting, thinning, pest management, and harvest. Efficiency and safety are greater when a majority of operations can be accomplished from the ground as opposed to on ladders or by climbing. Weeds are less of a problem in the shade of a densely planted orchard.

Photo by Jake Levin

Depending on the species and variety, bareroot trees are often the most practical form of planting stock to ship, and the most economical to purchase. This is a good option for deciduous trees. Other varieties, such as citrus, must be purchased in containers. Given the option of different sizes of bareroot trees, some walnut growers say that investing in a 1-inch tree over a ¾-inch tree is worthwhile, because the larger trees grow more vigorously. An experienced apple grower who produces without irrigation beyond the first year, however, stated his preference for ⅝-inch bareroot trees, which have a good balance of roots and are neither too big nor too small.

Disease and Pest Resistance

Genetic resistance refers to inheritable traits that enable a plant to inhibit disease and resist pest damage. A very important control measure for organic growers is to choose cultivars that are resistant to the pests—especially the diseases—most prevalent in their areas. In some cases, such as that of bacterial spot in peaches, cultivar resistance is the best or only control for a particular disease. A cultivar may be quite resistant to one disease but still susceptible to another. Prima apples for instance, are very resistant to scab but very susceptible to cedar-apple rust. A planting stock resistant to a particular pest provides only relative resistance, not absolute immunity. A moderately resistant or tolerant variety may show symptoms of the disease but exhibit little to no reduction in yield.

Disease resistance must be weighed against other advantages. For example, walnut growers in the coastal regions of California have lost large numbers of trees in recent years to "black line," a fungal disease for which there is no treatment, only resistance. Payne variety is susceptible and Chandler is highly resistant to this disease. (Some say that Chandler also appears to suffer lower damage levels from codling moth and walnut husk fly, the other common walnut pests in the region.) A trade-off is that Paynes mature sooner and can be harvested earlier in the fall, whereas Chandlers come in at least a month later when early rains can hinder harvest operations and make field preparations for planting a winter cover crop difficult or impossible.

While no fruit trees are resistant to insects that damage their fruit, it is possible to find stock that is resistant to insects that feed on other parts of the plant—*Phylloxera*-resistant grape rootstocks, woolly aphid-resistant apple rootstocks, and nematode-resistant peach rootstocks, for example. As important as this resistance is, there is no cultivar of any fruit species with multiple insect pest resistance; therefore, an integrated pest management plan is necessary to protect fruit plants from a complex of several pest species. It will be important to identify the most troublesome pests for your crop and region in terms of frequency of incidence, severity of damage, cost of control, and economic consequences of the damage. Then seek out varieties that are resistant to those key pests and take into account any trade-offs you may make with other desirable characteristics, including seasonality, productivity, and flavor. Substantial crop- and variety-specific information on pest and disease resistance is available on the Web site of the University of California IPM project and other university pomology departments. Be sure to check with local suppliers of planting stock, and talk with other growers in your area about what has worked best for them.

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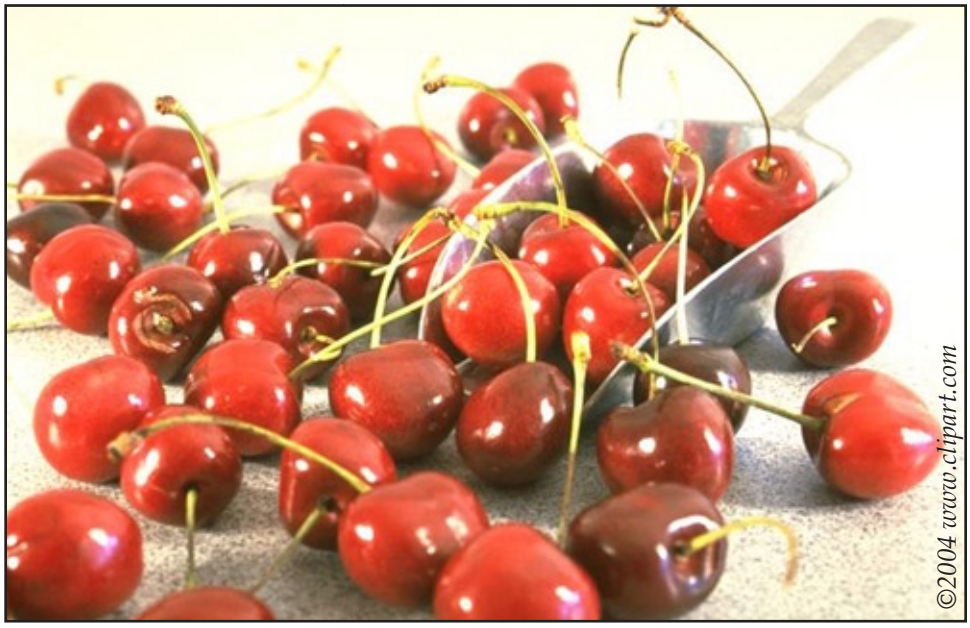
Site Preparation

Important considerations in site preparation include alleviating soil compaction, enhancing fertility, adjusting soil pH, and managing weeds, pests, and diseases. Attention to the details of site preparation can help reduce weed and disease problems and assure a vital planting through soil improvement. What needs to be done depends on the previous use of the land, including crops grown, current vegetation, and the presence of pests and diseases. Many growers rip or chisel the soil to loosen layers of compaction before they plant a new orchard, since deep tillage will be disruptive once the trees are established.

Before establishing an orchard, it is important to adjust the soil pH to best suit the crop you've

selected. Soil tests can assess current soil conditions, including pH, mineral levels, and their relative proportions. Traditionally, pH has been adjusted through applications of lime (to raise the pH) or sulfur (to lower pH). Most fruit plants perform best around pH 6.5, although they tolerate a pH range between 5.5 and 7.2. Blueberries are an exception. They require an acid soil—ideally pH 4.8 to 5.2. Soil test results help to guide applications of soil amendments such as compost, lime, gypsum, or other rock powders, to provide good soil conditions that meet the nutritional needs of the orchard.



In general, fruit crops do not require highly fertile soils for good production, though this varies with the species. Highly fertile soils, rich in nitrogen, can promote too much vegetative growth at the expense of fruiting in trees such as apples. A nutritionally balanced soil, proper soil pH, and plentiful organic matter are the fundamentals of an organic fertility management plan for fruits. Pre-plant soil improvement for organic fruit plantings usually involves some combination of cover cropping and applications of compost, natural minerals, or other organic fertilizers.

> Attention to the details of site preparation can help reduce weed and disease problems and assure a vital planting through soil improvement.

Weed Management Prior to Orchard Establishment

It's easier to manage weeds before an orchard is established. Cover crops (see ATTRA's *Cover Crops & Green Manures*) produce a thick stand that will shade or choke out weeds. Combined with a well-planned sequence of tillage, cover cropping is an effective pre-plant weed suppression strategy that also contributes to soil fertility and stable humus. The basic strategy begins with plowing under or disking the existing vegetation, ripping or deep chiseling to loosen compaction, planting a cover crop to suppress weed growth, mowing down and tilling under the cover crop(s), and finally planting the fruit crop. Several cover crop and tillage sequences may be necessary before planting.

Specific cover crops and management strategies vary with location and purpose. The two cases below raise the kinds of questions you need to ask to choose an appropriate cover cropping system. The cover crops you choose for site preparation (before planting the orchard) may be entirely different from those you want once the orchard is established.

Bart Hall-Beyer, co-author of E*cological Fruit Production in the North* (1), provides one example of how cover crops can be used to suppress weeds in the growing season prior to fruit crop establishment. His program consists of fall plowing, to allow the sod to rot, then disking as soon as the soil is dry in the spring, followed by harrowing every 10 days for at least one month to kill germinating weeds. He next incorporates compost and mineral nutrients and seeds buckwheat as a smother crop. He then tills the buckwheat into the soil after it has started flowering but before seed-

set. Hall recommends additional cultivations at 10-day intervals, followed with rye as a fall cover crop. The rye is incorporated the following spring and the fruit crop planted.

In the Mid-South, researchers at the Kerr Center for Sustainable Agriculture in Poteau, Oklahoma, evaluated a number of cover crops for weed suppression on heavy soils.(2) They converted pasture land to horticultural production, using rotations of cover crops and tillage. By this method, they virtually eradicated Bermuda grass from the fields in one to two years. Among their general observations are the following.

- Dense warm-season cover crop plantings of several species demonstrated a high degree of weed suppression, whether close-drilled in 6-inch rows or planted on wider 32-inch rows and row-cultivated.
- The length of the warm season may allow more than one cover crop to be grown in succession. Some cover crops may also be cut and allowed to regrow.
- Legume cover crops of purple hull peas (cowpeas), crotolaria, and sesbania all demonstrated good-to-excellent weed suppression, while supplying nitrogen and biomass to the soil.
- Of these, sesbania produced the most biomass and was the most effective weed suppressant. When cut with a sickle-bar mower at flowering, it regrew well and continued to suppress weeds. It is very drought-tolerant. Seed cost and delivery, however, were quite high. If allowed to re-seed, sesbania can create a moderate weed problem the following year.
- Crotolaria (sun hemp) was a better nitrogen producer, but a less effective weed suppressant than sesbania. It, too, can be cut at flowering with a sickle-bar mower and allowed to regrow. Like sesbania, it is very drought-tolerant. The cost of seed can be high. Crotolaria seed is toxic—especially to birds—and the plants should not be allowed to go to seed.
- Because crotolaria and sesbania are quite fibrous, they should be mowed with rotary or flail mowers prior to soil incorporation.
- Cowpeas produce somewhat less nitrogen than crotolaria, and less biomass than either sesbania or crotolaria. They are, however, less fibrous and, therefore, decompose faster.
- Allowing cowpeas to flower and produce mature, dry seed prior to incorporation creates an inexpensive, self-seeded succession cover crop.
- Sudan grass proved the most effective of all warm-season weed suppressants. It can be flail or rotary mowed several times if regrowth is desired.
- Winter cover crops can be planted in rotation with warm-season cover crops. A combination of grain rye and hairy vetch was the most effective in this location. Winter peas and oats, and winter wheat—often grown in combination—also have good competitive ability.

Soil Solarization

Soil solarization is placing transparent plastic

Photo by Gary Kramer. ©NRCS 2004

films on moist soil to capture solar energy. Solarization takes four to eight weeks to heat the soil to a temperature and depth that will kill harmful fungi, bacteria, nematodes, weeds, and certain insects in the soil. Solarization can be a useful soil disinfestation method in regions with full sun and high temperatures, but it is not effective where lower temperatures, clouds, or fog limit soil heating. Other disadvantages of solarization as a weed control method include its expense and disposing of the plastics. Solarization is most commonly used in smaller areas, such as greenhouses and nursery beds, though it has been used experimentally to treat orchard soils, either prior to planting or during establishment. Experiments are underway to evaluate using biodegradable spray mulches for solarization. Researchers emphasize that solarization should be seen as just one component of an integrated pest management system, rather than as a "stand alone" technology. A University of California Cooperative Extension leaflet (No. 21377), "Soil Solarization: A Nonchemical Method for Controlling Diseases and Pests," details the technique.(3) The Web site www.uckac.edu/iwgss provides links to current research and publications on solarization.

Orchard Layout and Design

Orchard layout influences the long-term health of the trees and the ease of field operations such as pruning, irrigation, fertilization, and weed and pest management. Everything is related: the decisions you make about the space between rows and between trees in the row will have an impact on everything from disease management to harvest operations. While the specific spacing and training of trees will largely depend on the species, the following questions offer general considerations that will save time, resources, and expenses throughout the life of the orchard.

- What is the lay of the land? Which way does the water run? What is the angle of the sun during different seasons? How will these affect the movement of both water and air, and in turn, temperature and humidity levels, crop ripening, and incidence of diseases and pests? Do the rows need to be planted on the contour for soil conservation or to capture limited seasonal moisture? Or should they be sloped to drain excess moisture? Given the degree of slope, which direction will provide the greatest safety for operating equipment and ease of harvesting ?
- What are the diseases and pests that affect this crop in this region? What are their life cycles? Alternate hosts? Natural enemies? What conditions favor their growth and severity? What design strategies might promote or reduce these conditions? Would a certain orientation of the rows provide better exposure to the sun or better air circulation? Will you rely on seasonal pruning to maintain an open canopy to increase air flow through the foliage and sun to the fruit?
- What equipment will you use for field operations? Consider all possible tasks, including

Photo by Randall Smith©2004 ARS

Researchers emphasize that solarization should be seen as just one component of an integrated pest management system, rather than as a "stand alone" technology.

planting, mowing (or incorporating orchard floor vegetation), cultivation, pruning, irrigation, application of materials for pest management, and fruit harvest. Be sure that your row spacing is adequate to allow entry and maneuverability of any tractor, trailer, spray equipment, string trimmer, wagon, wheelbarrow, or hand cart that you plan to use.

- What crop density do you seek? How soon after planting? The decision will depend on the species and stature of your trees, the cost of purchasing and planting them, the years to maturity, the prevalence of weeds, and other considerations. Using close in-row spacing or double rows of trees may complicate weeding in the first year or two, but thereafter shading will greatly reduce the need for weeding the inter-row. Some farmers plant slower-growing trees (such as walnuts) using closer spacing, then remove every other tree when they reach a certain maturity. The estimated benefits of earlier harvests must be considered against the costs of planting, managing, and eventually removing the trees. Alternatively, annual crops can be grown between immature orchard trees.

Managing An Established Organic Fruit Orchard

Orchard Floor Management/Cover Crops

The orchard floor—the tree rows and alleyways—can be managed in a variety of ways, using tillage or mowing with cover crops, grazing, or mulching (described in detail in the **Organic Weed Management** section). A system that provides full ground-cover provides the best protection against erosion. Some fruit growers have practiced "clean cultivation," eliminating vegetation throughout the orchard, but this system has many disadvantages, even if accomplished with allowed tillage practices instead of organically prohibited herbicides. A bare orchard floor is prone to erosion, gradual depletion of organic matter, increased soil compaction, and reduced water infiltration. It's also difficult to move equipment through the orchard in wet weather. However, a ground cover that is actively growing in the summer uses up water. This is a severe disadvantage in irrigated orchards where water is limited and expensive.

A bare orchard floor is prone to erosion, gradual depletion of organic matter, increased soil compaction, and reduced water infiltration.

Orchard floor management can control erosion, improve the soil, and provide beneficial insect habitat.

- Where they are adapted, orchard grass, fescue, and other cool-season grasses are practical because they go dormant during the heat of the summer, minimizing competition with the fruit crop for water. With proper fertility management, these grasses can also provide plentiful mulch. Likewise, grasses are a good choice in apple orchards, for example, where the excess nitrogen provided by legumes can actually reduce fruit yields.

- Many warm-season legumes are deep-rooted and compete with the trees for water. Normally, they should not be allowed to grow under the tree canopy. However, leguminous ground covers can provide significant nitrogen to fruit trees or vines.(4) Grass and legume ground covers alike promote water infiltration and hold the soil in place during the rainy season. Ground covers help maintain and increase soil organic matter, which increases the soil's ability to retain moisture. Cool season legumes, such as fava or bell beans, vetches, and clovers, also can achieve these goals.

- Planting subterranean clover into established orchards can provide mulch, fertilizer, between-row ground cover, and beneficial insect habitat. This clover reseeds itself in early summer and dies back during the hottest part of the growing season, leaving a relatively thick, weed-suppressive mulch. This system is used in apple and peach orchards in Arkansas (5) and for a variety of orchard crops in California (6, 7, 8, 9), but not where winter temperatures regularly drop below 0°

F. Subterranean clover can provide habitat for such beneficial insects as ladybeetles, syrphid flies, big-eyed bugs, soft-bodied flower beetles, and other predators.

Crop Rotation

In an organic orchard, crop rotation does not mean changing the economic crop itself, but diversifying the vegetation that grows around the fruit crop. California organic almond farmer Glenn Anderson describes how important maximum plant diversity is within the orchard and in the surrounding vegetation. He takes advantage of every practical opportunity to diversify vegetation: the orchard floor grows cover crops; the landscaping around the family home situated in the midst of the orchard provides shelter and food for a variety of beneficial species; the roadway, farm perimeter, and even the paths of the irrigation lines provide habitat for these beneficials. Research studies confirm the positive effects of organic practices on beneficial insects. Several articles compared yields, pest and beneficial insect populations, and water and air quality factors on Anderson's farm to those of his brother's adjacent, conventional almond farm (10) and found favorable results with organic practices. Mr. Anderson gives credit for the health of his orchard to the host of creatures that contribute to ecological balance on the farm. He believes that all the trees, shrubs, and plants he encourages help sustain beneficial insects, spiders, bats, and birds within and around the orchard.(11)

Fruit bats help disperse seeds and pollinate plants.

Photo by Henry Groom

The USDA National Organic Program Final Rule defines crop rotation in 7 CFR § 205.2 as "The practice of alternating the annual crops grown on a specific field in a planned pattern or sequence in successive crop years so that crops of the same species or family are not grown repeatedly without interruption on the same field. Perennial cropping systems employ means such as alley cropping, intercropping, and hedgerows to introduce biological diversity in lieu of crop rotation." According to 7 CFR § 205.205 Crop Rotation Practice Standard, the benefits of rotation are to "(a) Maintain or improve soil organic matter content; (b) Provide for pest management in annual and perennial crops; (c) Manage deficient or excess plant nutrients; and (d) Provide erosion control."

Cover Crops

Steps and considerations for selecting and managing a ground cover:

- State your objectives in order of priority. For example: suppress weeds, break up soil compaction, add organic matter to the soil (increase tilth, water infiltration rates, and water-holding capacity), enhance soil fertility (fix nitrogen), attract and sustain beneficial insects, serve as a trap crop for pests.
- Take into account the climate, rainfall pattern, soil type, and potential for soil erosion.
- Describe desired growth patterns and characteristics: Does this cover crop have a tap root? Will it regrow if mowed? Does it fix nitrogen? How much biomass does it produce? Is it fibrous? How long will it take to break down? Will I need to mow or chop it to speed its decomposition? When should I incorporate it? Will it reseed itself? What is its potential to become weedy if it goes to seed? Does it attract insects? What kinds? Will it serve as beneficial insect habitat? Is

The functional benefits of every kind of crop rotation and diversification help break weed and disease cycles.

it a host for pests? Can it be used as a trap crop?

- Consider planting techniques and timing: When and how should I plant a cover crop? How can I manage its growth for production of organic matter and nitrogen fixation? Are there seasonal weather constraints to getting equipment into the field? What methods provide the best germination rate for the effort—broadcast, drilled, frost-seeded (the technique of broadcasting seed so that it is incorporated by the motion of the soil freezing and thawing)? What equipment do I have available—disc, broadcast seeder, seed drill, flail mower, chisel plow, spading machine? What is the seed cost? Do I need to inoculate it with *Rhizobium* bacteria to increase nitrogen-fixing nodulation?

- Is the best cover crop for my situation a single crop, a mixed seeding, or a series of different cover crops?

The UC SAREP cover crop resource page includes a guide for selecting the right cover crop for your purpose: www.sarep.ucdavis.edu/ccrop/CCPubs/SelectingCoverCrop.html.

Pest Management

Organic pest management relies on preventative cultural, biological, and physical practices. Organisms—insects, mites, microorganisms, or weeds— become pests when their populations grow large enough to prevent growers from reaching production goals. Integrated Pest Management recognizes that the mere presence of a potentially damaging species does not automatically mean that control actions are necessary. Knowledge of pest life cycles and monitoring techniques developed in IPM programs are useful for organic growers as well, because they mirror some of the elements of the organic pest management standard.

Mexican fruit fly laying eggs in grapefruit

The National Organic Program Final Rule 7 CFR §205.206 Crop Pest, Weed and Disease Management Practice Standard reads: "(a) The producer must use management practices to prevent crop pests, weeds and diseases including but not limited to: (1) Crop rotation and soil and crop nutrient practices…; (2) Sanitation measures to remove disease vectors, weed seeds, and habitat for pest organisms; and (3) Cultural practices that enhance crop health, including selection of plant species and varieties with regard to suitability to site-specific conditions and resistance to prevalent pests, weeds and diseases. (b) Pest problems may be controlled through mechanical or physical means including but not limited to: (1) Augmentation or introduction of predators or parasites of the pest species; (2) Development of habitat for natural enemies; (3) Non-synthetic controls such as lures, traps and repellants. (d) Disease problems may be controlled through (1) Management practices which suppress the spread of disease organisms; or (2) Application of non-synthetic biological, botanical or mineral inputs. (e) When the practices provided for in paragraphs (a) through (d) of this section are insufficient to prevent or control crop pests, weeds and diseases, a biological or botanical substance, or substance included on the National List of synthetic substances allowed for use in organic crop production may be applied to prevent, suppress or control pests, weeds, or diseases: Provided, That the conditions for using the substance are documented in the Organic System Plan."

Three tiers of pest management strategies are described in the NOP Final Rule.

1. First, the producer should use cultural management practices that prevent pest and disease problems. These include multiple components of a holistic, systems approach to organic farm management and crop production.

2. In the second tier of pest management, biological and physical methods provide additional protection and need no justification. These practices build on and complement good cultural practices, but cannot compensate for poor cultural practices.

3. The third and final tier—the last resort—may be applying an allowed material if the first two tiers of response are ineffective and if the conditions for their use are described in the grower's Organic System Plan (OSP). A material response may be necessary under some circumstances, but it will be just one component of an integrated pest management plan that is part of an overall OSP.

Common arthropod pests of fruits include insects (aphids, caterpillars, leafrollers, twig borers, flies, psylla, scale insects, leafhoppers, mealybugs, earwigs, thrips, and beetles) and mites. Identification and preventative management are essential to organic production systems. Identification charts are available from many university Extension Web sites and publications. *Organic Fruit Tree Management* (15) provides a useful list of important fruit pests, their hosts, status (potential impact on various stages of fruit tree growth as well as on crop production and quality), identification (adult, immature/larva, pupa, and eggs), life cycle, monitoring/thresholds, and management. This book was written for fruit growers in the North and may not address the key pests in all other regions. Nonetheless, its approach and outline serve as an extremely useful models for growers developing informed and integrated organic pest management strategies for their orchards.

While there are many other components to insect and mite pest management, in recent years there has been a good deal of research on vegetation management to enhance natural biological control. Approaches to cover crop and vegetation management described by Bugg and Waddington (13) include 1) resident vegetation that harbors beneficial arthropods (insects, mites, spiders); 2) strip management of cover crops to ensure the continuous presence of habitat for both beneficials and pests; 3) insectary mixes of plants attractive to beneficial arthropods; and 4) use of mulch from mowing to harbor generalist predators. There is also increasing evidence that managing vegetation adjacent to economic crops (fencelines, roadsides, etc.) as habitat for beneficial insects has a positive impact on pest management. These areas often include native plants and shrubs that flower at different times of the year, providing sources of pollen and nectar for beneficial arthopods. See the ATTRA publication *Farmscaping to Enhance Biological Control*.

The long-term nature of growing fruit using cover crops and other resident vegetation management can sustain populations of predators, parasites, and other beneficial organisms.(14, 15, 16) There are many possible trade-offs that emphasize the need for careful planning and the importance of research and monitoring.

- Apples and pecans: California apples and Georgia pecan orchards planted in a diverse mix of cover crop species provided habitat and food for an array of beneficial organisms, resulting in a decrease of orchard pests.
- Peaches: Some winter annual broadleaf weeds have been implicated in increased populations of tarnished plant bugs in peach orchards, and dandelions and chickweed can serve as hosts for viruses that affect peaches and apples.(15)
- Walnuts: Two species of ladybeetles were more abundant in an orchard floor where a cover crop was maintained from February to May, and helped keep walnut aphid populations in check.
- Apples: Codling moth infestations of apples were lower where bell beans grew.(13) Bell beans are known for their extrafloral nectaries that help sustain beneficial insect populations even when the flowers are not open. Insect-eating birds can also reduce codling moth populations, but not control them. The development of pheromone mating disruption has been a major breakthrough in the past several years, making organic codling moth management feasible and organic apple production competitive.
- Cherries: In regions of California where the mountain leafhopper transmits buckskin disease, growers should use caution in establishing permanent covers that include cool-season alfalfa and clover species that harbor the leafhopper. This case emphasizes the importance of understanding and carefully considering the pest's life cycle, with respect to the presence of host plants where the pest can reproduce.
- Citrus and avocado: Wind-blown pollens from grasses and trees can be alternate food sources for the predatory mite *Euseius tularensis* in late winter and early spring,

and may, therefore, help build and sustain populations of predatory mites that attack pest species that include the avocado brown mite, citrus thrips, citrus red mite, and scale insects.(13)

- Some legumes are also known to attract hemipterous pests like tarnished plant bugs and stink bugs.(17, 18) Where these pests are a problem, legumes may be less desirable as orchard cover crops, unless they can be managed as trap crops for lygus bugs. Alternatives such as mustards, buckwheat, dwarf sorghum, and various members of the Umbelliferae (carrot, cilantro, dill, fennel, anise, etc.) and Compositae (sunflower and other composites) families support substantial numbers of beneficial insects without attracting as many pests. However, mustards flower and seed early, providing early season food for hemipterans, including stink bugs.

Conversations with several organic farmers reinforce these research findings. Many organic walnut growers plant cover crops that are mixtures of legumes— such as bell beans, vetch, or alfalfa— to produce nitrogen and create a beneficial insect habitat, in combination with cereals that produce organic matter and provide support for the legumes. Growers alternate rows when they mow or disc, intentionally leaving strips of cover crops in the orchard to provide areas with flowering plants that sustain populations of beneficial insects. In any orchard setting it is important to watch for gopher problems. In addition to their many benefits, cover crops can also provide food and cover for gophers.

Disease Management

Disease can be a significant limiting factor in organic fruit production. Diseases may be caused by fungi, bacteria, viruses, nematodes, mycoplasmas, or protozoans. Disorders caused by the weather or by nutrient imbalances (deficiency or toxicity) can create symptoms that look like diseases. Proper identification and preventative management are imperative. For example, boron toxicity or blossom-end rots cannot be cured with fungicides. Cooperative Extension and university Web sites can help in identification. The book *Organic Tree Fruit Management* (12) includes detailed descriptions of diseases of fruit crops, including hosts, status (potential impact), symptoms, life cycle, monitoring/thresholds for treatment, and organic management strategies. This book's organic context and perspective are invaluable. Thresholds for action may be distinct in an organic pest management system (in which the impact of a disease organism is considered not only on this year's crop but also in terms of the future implications for control, potential buildup, and impact on the health of the trees), compared to conventional IPM programs (in which the availability and allowability of pesticides is assumed).

Disease can be a significant limiting factor in organic fruit production

As described in the NOP standard, a combination of cultural controls forms the foundation for a good disease-management strategy. As discussed earlier in this publication, selecting resistant varieties or rootstock is of utmost importance, as is selecting the right growing location. In an established orchard, one can practice good sanitation by cleaning up debris, pruning, and removing diseased plants and disease vectors. Some plants can serve as alternate hosts for diseases. Eastern red cedars, for example, are alternate hosts for cedar-apple rust. Wild blackberries can harbor blackberry rust, and wild plums can foster peach brown rot. A good defense against plant disease is to maintain the crop plants in excellent health and vigor, with sufficient—but not excessive—soil nutrients and moisture.

Many diseases of fruit crops only affect a particular species and variety of fruit. There are, however, some diseases that are common to almost all temperate-zone perennial fruit crops. For instance, because of the relatively soft nature and high sugar content of most mature or nearly mature fruits, fruit rots are common afflictions. Sunlight and circulating air help to dry leaf and fruit surfaces, thereby limiting fungal and bacterial infections. The organic grower can help to minimize fruit rots by allowing good air circulation and sunlight penetration into the interior plant canopy. In tree crops, this would mean proper pruning and training. In brambles and strawberries, reducing plant density helps. In

grapes, adequate pruning and removing leaves that shade fruit clusters is beneficial. All fruit crops need a site that allows good air circulation. Well-timed applications of allowed fungicides can be effective in an integrated disease-control program for mildew and fruit rots in certain fruit crops. See **Applying Materials** below.

Soils can be made disease-suppressive through the addition of significant amounts of organic matter to the soil.

Another problem common to many fruit crops is root rot and intolerance to poorly drained soils. Blackberries, most pear rootstocks, and some apple rootstocks are relatively tolerant of heavy or poorly-drained soils, but even these crops will succumb to persistently water-logged conditions. Blueberries, raspberries, and *Prunus* species (peaches, plums, cherries, etc.) are very intolerant of poorly drained soils and are generally susceptible to root-rotting organisms common in such soils. Even in well-drained soils, blueberries and raspberries are often planted in hills or raised beds. Again, site selection is very important.

Soils can be made disease-suppressive through the addition of significant amounts of organic matter to the soil. This has been most vividly demonstrated in Australia, where liming and cover crops—combined with applications of chicken manure, cereal straw, weed residues, and other materials—are used in avocado groves to control *Phytopthora* root rot. This strategy, known as the "Ashburner system," is now common practice in many areas where avocados are grown.(19) In contrast, mulching apple trees in humid areas, such as New York, may increase *Phytopthora* root rot.(27)

To identify fruit diseases and their life cycles, please see fruit production resources compiled by the Cooperative Extension Service. Some of the publications in the **Resources** section of this publication provide an excellent summary of fruit diseases.

Plant Health and Vigor

Maintaining plants in good health and vigor is important in insect pest management. For fruit plants, this adage is more applicable to indirect pests (those that feed on foliage, stems, etc.) than to pests that feed on the fruit. For instance, an apparently healthy plum tree may set a good crop of fruit, yet lose it all to the plum curculio. That same tree might suffer significant defoliation by caterpillars early in the season; yet, if it is in good vigor, it can compensate and bounce back quickly—still producing a marketable crop that year. There are some cases where general plant health and freedom from stress do impart a

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form of "resistance"—not technically genetic resistance—to certain pests. Two examples are apple trees in good vigor that actually cast out invading flathead apple tree borers by smothering them with sap, and plants not suffering drought stress being much less attractive to grasshoppers. For more in-depth information on designing an integrated pest management program for your farming system, please refer to the ATTRA publication *Biointensive IPM*.


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Biological Control

Biological control uses living organisms to manage pest populations. When a pest is endemic (not exotic), natural enemies are present, and biological control occurs naturally. The fact that it is occurring may not be noticed by growers. Researchers monitoring certain pests, such as leafminers, have found that pest populations actually increase after pesticide applications kill their natural enemies.

As described above, biological control can be enhanced by cover crops and habitat management. However, where a known pest appears predictably and can be controlled by a specific biological agent, timed releases of beneficial insects may be in order. Many beneficial insects can be purchased from commercial insectaries for release in fruit plantings. Examples of beneficial arthropods that have been used to control pests in fruit crops include the predatory mites *Phytoseiulus persimilis* and *Metaseiulus occidentalis*, which attack spider mites; lady beetles and green lacewings, which feed on aphids; and *Trichogramma* wasps, which parasitize the eggs of several pests, including codling moth.

As a rule, beneficial arthropods are not a complete control for direct fruit pests, at least not for commercial growers who have a low damage threshold for fresh fruit. Usually, additional control measures are necessary. There are four essential components for successful use of beneficial organisms for pest control.

1. *Selection of the proper natural enemy for a target pest*. For example, Trichogramma wasps parasitize eggs and, therefore, do not directly control adult pests already active in the field.

2. *Proper timing of releases*. Release of natural enemies must coincide with a susceptible stage of the host and should be made early enough in the cropping season to assure success.

3. *Correct rate of release for natural enemies*. This is usually based on the planting density.

4. *Environmental provisioning*. Make sure environmental needs—such as nectar sources, alternate prey, and water—are available for adult beneficial insects. If the necessary environment is not available, beneficials may leave the release area, die, or spend so much time searching for nectar or pollen that they do not efficiently attack pests.

Applying Materials: Pesticides Allowed in Organic Production

Allowed materials include only natural (non-synthetic) materials that are not specifically prohibited, and specifically allowed synthetic materials, as described in 7 CFR §205.600-602 of the NOP. Most, if not all, allowed synthetic materials have annotations that closely restrict how (in purpose, application method, and quantity) they can be used. Before you apply any product, make sure it's allowed for use in organic agriculture. Read the label carefully. Are all the active ingredients allowed? What about the inert ingredients? If it contains any undisclosed inert ingredients, you must have documentation from the manufacturer to confirm that all inerts are allowed by the National Organic Program (on EPA List 4). If in doubt, ask your certifier before you use it.

Many beneficial insects can be purchased from commercial insectaries for release in fruit plantings.

Information to guide your selection and use of materials

- NOP Standards: The National List 205.600-602. This is USDA's ultimate authority. This list, however, can be difficult to use because it is not a positive statement of materials that can and cannot be used. Instead, it states that all natural (non-synthetic) materials are allowed, unless they are prohibited (those materials on list 206.602), and that all synthetic materials are prohibited unless they are allowed, many with restrictions, as named and described on list 205.601. In some instances, it is not clear whether a material is natural or synthetic. For that reason, many organic producers and certifiers also use related resources to help interpret the National Lists and determine the allowability of substances in organic production.

- The Organic Materials Review Institute (OMRI) reviews and evaluates materials for consistency with the National List and, publishes and maintains two other lists. The Brand Name List is available in hard copy and on the Web at www.omri.org. The Generic Materials List is available in hard copy to members for a small fee. These generic and brand-name lists provide an extremely useful resource to help growers identify allowable materials and products. While many organic producers, handlers, and certification agencies rely on and frequently refer to the OMRI lists, users should be aware that OMRI is an independent nonprofit organization, and USDA has not formally recognized or authorized OMRI to interpret the National Organic Standards.

Several new disease-control materials on the market are allowed for use in organic agriculture, including biofungicides, mineral-based essential oil extracts, and botanical fungicides. Growers in some regions are also using compost teas and plant extracts. The OMRI list provides information about the allowability of brand name products, but not their efficacy. You can ask your local Extension agent about any research or use in your region. Copper and sulfur compounds are fungicides that are allowed (with restrictions on their use) and have been used historically by organic growers, but they have several drawbacks. These materials can damage plants if applied incorrectly. Sulfur dust can cause acute eye and respiratory irritation in humans. It is also lethal to some beneficial insects, spiders, and mites, and can set the stage for further pest problems. Long-term frequent use of copper fungicides can also lead to toxic levels of copper in the soil.(20)

Fertilization

Fruits, being largely water and sugars, remove relatively few nutrients from the soil, compared to other crops. Therefore, much of a fruit crop's fertility needs can be met through cover crop management and organic mulches (in systems that use them) and by the application of lime and other slow-release rock powders at the pre-plant stage. Supplementary fertilization may still be required for optimal growth and production.

There are many commercial organic fertilizers available. As noted above, however, organic growers should be familiar with organic standards, and especially the National List of Allowed Materials in the NOP's 7 CFR §205.600-602.

The NOP Rule requires that applied raw manure be incorporated at least 90 to 120 days before harvest of crops for human consumption (90 days if the edible portion does not have contact with soil or soil particles; 120 if it does). Compliance is easy: move grazing animals to another pen or paddock at the appropriate time.

General fertilizer guidelines

- Organic fertilizers—especially uncomposted animal manures—should be incorporated into the soil to avoid nitrogen volatilization and to comply with organic standards. Use shallow tillage to prevent damage to plant roots and to minimize the potential for soil erosion. Manures should be incorporated into the soil at least three or four months before harvest (depending on the crop type) to comply with National Organic Program standards (7 CFR §205.203 (c) (1)).

- Soluble organic fertilizers such as fish emulsion, kelp, and soybean derivatives are suitable for use in drip irrigation and can provide quick supplemental fertility. Compost teas may be allowed and may contribute to disease control (see ATTRA's *Notes on Compost Teas*). Be sure to check with your certifying agency regarding current interpretations of the organic standards for compost production and any restrictions on the preparation or use of compost teas.

- Most organic fertilization programs focus on supplementing nitrogen as the key element, since it is needed in the greatest amount for the crop. You can calculate rates of organic amendments based on standard recommended rates for the crop, but be aware that many fertilizer recommendations still assume the use of synthetic materials. Organic systems behave differently. They generally use slower-release fertilizers and rely on biological activity to break them down into forms that can be absorbed by the plants. For example, only a portion (perhaps half) of the nitrogen applied as stable compost may be available to plants in the first year. The rest is stored and released gradually. To compensate for this, the producer may apply twice as much nitrogen as is needed in the first year of organic management. In subsequent years, however, more of the nitrogen is released from the soil organic matter and becomes available. In a mature organic farming system, nutrients and organic matter are added to maintain, replenish, and build the bank of nutrients in the soil.

- When making fertilizer calculations based on nitrogen, growers need to credit the estimated contributions made by legume cover crops and/or mulches. A cover crop of subterranean clover, properly fertilized and inoculated, can fix from 100 to 200 pounds of nitrogen per acre annually in a "living mulch" system.(8) Other legume cover crops may produce as much or even more, depending on things such as planting date, weather, and mowing.

- Consider the overall fertilizer analysis; basing application rates solely on nitrogen content can cause problems when the fertilizers are not balanced to meet the needs of the crop. For example, repeated use of poultry manure, which is very high in phosphate, can lead both to pollution problems and to zinc deficiency in the crop. These problems can be avoided by regularly monitoring and adjusting fertilizer selection and rates.

- The most reliable means for determining whether fertilization is adequate is to combine field observations with soil or tissue testing. Poor yields, unusual coloration of leaves, and poor plant growth are all clues to a possible nutritional imbalance or deficiency. On most fruit trees, slow elongation of branches often indicates a nitrogen deficiency. Yellowing between the veins of new blueberry leaves usually means the plant is suffering an iron deficiency. Corky bark on certain apple varieties can indicate an over-availability of manganese in the soil.

- Foliar analysis measures the nutrient content of the leaves and can identify a nutrient deficiency or excess well in advance of visible symptoms. It is more helpful than a soil test because the foliar analysis is a measure of what the plant is actually taking up, while a soil analysis only measures what is in the soil—which may or may not be available to the plant. Annual foliar analysis generally provides the best guide for adjusting supplementary nitrogen fertilization.

Photo by Aref Abdul-Baki ©2004 ARS

Organic apple growers on California's Central Coast say that most years they plant only rye or other grass cover crops, because leguminous cover crops would contribute too much nitrogen, inducing excess growth, creating more pruning work, and decreasing fruit production. Growers monitor their nitrogen levels through leaf-tissue and soil analysis, and manage their soil covers accordingly.

For more detailed information regarding sustainable soil fertility management, including the use of organic fertilizers and nutrient testing methods, request these ATTRA publications: *Sustainable Soil Management*, *Alternative Soil Testing Laboratories*, *Alternative Soil Amendments*, *Foliar Fertilization*, and *Sources of Organic Fertilizers and Soil Amendments*.

Organic Weed Management

Some weed control methods, such as smother crops, are discussed in the **Site Preparation** section above. This type of cover cropping is an important tool for weed management that also contributes to good soil management, fertility, and pest management.

Mulches

Organic Mulch

Mulching is a powerful weed management strategy that can also contribute to good soil management, if appropriate natural materials are used. After a planting is established, weeds can be suppressed by applying thick layers of mulch. This can also create habitats for beneficial arthopods, including generalist predators such as big-eyed bugs, soft-bodied flower beetles, and spiders. Organic mulches are usually applied in a circle around tree trunks or vines, and down the whole row in blueberries.

Commonly, tree fruit growers keep mulches away from the tree trunks, particularly in winter, to prevent voles or mice from gnawing on the bark and damaging young trees. Keeping mulches 8 to 12 inches away from the trunk also reduces the likelihood of crown rot and other diseases in susceptible species—most notably apples on certain rootstocks.(23)

Mulch materials may include straw, spoiled hay, leaves, yard trimmings, woodchips, and sawdust. Many of these materials are inexpensive. Still, it's wise to weigh the benefits and risks of each, including hauling costs and the risks of their containing impurities and prohibited materials.

Municipal greenwaste may be available, either raw or from municipal or commercial composting operations. Growers must monitor the incoming product and remove any trash to keep undesirable material out of their fields. Growers should ask compost producers about the sources of their materials and any pesticides that may persist in them. Of particular concern are clopyralid and picloram, herbicides that are extremely resistant to breakdown, even after composting. The sale and use of these materials is restricted in some areas. A Washington State University study showed treated grass clippings to be the primary source of clopyralid entering the organic waste stream. Experience from California, Oregon, and Washington shows that at levels of 1 to 10 parts per billion, clopyralid adversely affects sensitive vegetable crops.(21, 22)

Because organic mulches decompose over time, they require periodic re-applications in order to continue suppressing weeds. However, their decomposition provides other benefits. Mulching with organic matter enhances soil aggregation and water-holding capacity.(4) Researchers from

1937 to the present have consistently found that mulching is the best orchard-floor management system for retaining moisture.(15) In Michigan research, mulching was as effective as irrigation in encouraging tree growth.(24) Organic mulches can have positive effects on tree growth, with improvements in soil quality and shifts toward beneficial nematodes.(27) Mulch can also benefit the crop by moderating soil temperatures, thus reducing plant stress.

Organic mulches provide slow-release nutrients for the long-term health and fertility of the soil. Research indicates that potassium, phosphorus, and nitrogen (primarily from the slow breakdown of the mulch) are more available in mulched systems than in non-mulched systems.(4) Some growers express concern that sawdust may acidify their soil or bind nitrogen in the soil. However, these effects are minimal if the sawdust is not tilled into the soil.

Raising organic matter on the farm is one way to ensure sufficient, clean mulching material.

Raising organic matter on the farm is one way to ensure sufficient, clean mulching material. Farm-raised hay grown outside the orchard can provide weed-free mulch. Cover crops may be grown between tree rows, mowed, and gathered around the trees. Some small-scale growers use the biomass from orchard alleyways, cutting cover crops with a sickle-bar mower and hand-raking the material under the trees. Larger-scale operations often use forage wagons, straw-bale spreaders, or specialized equipment to mechanize mulching jobs. King Machine Co. (25) offers a small, trailer- or truck-mounted square-bale chopper and blower suitable for most fruit crops. Millcreek Manufacturing Co. (26) has developed a row mulcher especially suitable to blueberry, bramble, and grape culture, but also useful in tree fruit orchards. The Millcreek machines are designed to handle bulk organic materials such as sawdust, wood chips, bark, peat, and compost.

Geotextiles

Geotextile mulches are paper or woven plastic fabrics that suppress weed growth. While they allow some air and water penetration, they may reduce water infiltration, whereas organic mulches increase infiltration.(27) Geotextile mulches do not provide the advantages of adding organic matter and nutrients to the soil, and if synthetic, they must eventually be removed. Geotextiles have a high initial cost, though this may be partially recouped in lower weed-control costs over the material's expected field-life—5 to 10 years for polyester fabric; 2 to 3 years for paper weed barriers. Still, some growers find them useful for weed suppression in orchards, tree plantations, and cane fruit culture. The ATTRA publication *Sustainable Pecan Production* provides more detail on the use of geotextiles and outlines additional methods of weed control, including mechanical cultivation, mulches, wood chips, and living mulches.

Sheet Mulch

You can also create weed barriers by sheet mulching: laying down layers of cardboard or newspaper and covering them with organic material. Sheet mulching increases the efficacy of organic mulch as a barrier against emerging weeds. Organic growers should avoid cardboard that is waxed or impregnated with fungicide, as well as color print and glossy paper, in order to be compliant with the National Organic Program standards (7 CFR §205.601(b)(2)(i) and 205.601 (c)).

Cultivation

Cultivation—using mechanical tillage and weed harrowing implements—is the most widely used weed-management practice in fruit production. In systems that maintain permanent vegetation between rows, cultivation may be limited to the tree row under the dripline in an orchard, or extended 1 to 3 feet from the edge of the hedgerow in bramble plantings. The reverse is true where mulches are used in the tree row, and cultivation is used to control weeds and incorporate cover crops in the alleyways. In any case, cultivation must be kept shallow to minimize damage to crop roots and to avoid bringing weed seeds to the surface.

Hand cultivation—enhanced with the use of a wheel hoe—can be effective in small-scale plantings. In large-scale plantings of trees or vines, where in-row tillage is desired, "mechanical

hoes" such as the Weed Badger (28) or Green Hoe (29) are very useful. These tractor-mounted, PTO-driven cultivators can till right up to the tree or vine without damaging the plant. Attachment options include powered rotary tillage tools and scraper blades that can move soil either away from or toward the base of the crop plants. Scraper-blade attachments, commonly known as "grape hoes," have been used in vineyards for decades.

Herbicides Allowed for Use in Organic Production

A few herbicides currently emerging on the market are allowable for organic production, with restrictions on the location of their use. There is ongoing research on using materials such as vinegar, corn gluten, and citric acid as herbicides, although they are not yet widely used by certified organic growers. Such materials may have applications in organic systems, such as for spot treatment of noxious weeds.

Photo by Peggy Greb ©2004 ARS

Weeder Geese, Chickens, and Ducks

For many years, farmers have used geese to control weeds in perennial and annual crops, including strawberries, blueberries, bramble fruits, and tree orchards. In Oklahoma, researchers at the Kerr Center for Sustainable Agriculture used weeder geese in commercial-scale blueberry and strawberry production, with portable electric fencing to keep the birds in a specific zone in the plant row.(30) Investigators at Michigan State University studied the impacts of populations of domestic geese and chickens in a nonchemical orchard system. They found that the geese fed heavily on weeds—especially grasses—and also on windfall fruit.(31) In general, geese are more effective against emerging or small grass weeds, and they have a particular preference for Bermuda grass and Johnson grass—weeds that can be especially troublesome in orchards.(32) ATTRA has additional information on weeder geese available on request.

Those who have raised chickens know how enthusiastically they devour fresh vegetation. If the area they inhabit is small, they will strip it to the dirt. Properly managed, however, their foraging characteristics can be used to the grower's advantage.

> Fred Reid is an innovative producer of raspberries and vegetables in Canada who has successfully employed his flocks of chickens in weed management. He uses a system of fencing to keep chickens in certain areas to accomplish a thorough job of weeding and insect control. He notes that if the vegetation has grown too high and the plants become too fibrous, the chickens will not eat them. However, if you mow tall vegetation in advance, the chickens will process it readily. He excludes the chickens from raspberry plots when the new, tender leaves are emerging and, of course, near harvest time.(33)

Flame Weeding

Flame cultivation uses directed heat to kill weeds. It works not by burning the weeds but by searing them and causing the plant cells to rupture. Farmers began using tractor-mounted flamers in orchard and row crops in the 1940s.(34) Technology and technique have both been refined considerably in recent years. Several tools now commercially available, including flame, infrared, and steam weeders, make heat a viable option for some weed management applications. See the ATTRA publication *Flame Weeding* for more information.

Management of Vertebrate Pests: Mammals and Birds

Several bird species, deer, rabbits, ground squirrels, gophers, mice, voles, raccoons, and other animals can be serious pests of fruit plantings. Organic certification calls for an integrated approach to vertebrate management, including exclusion, trapping, repellents, scare devices, and protection or development of predator habitat.

Gophers and ground squirrels can be managed on organic farms through integrated strategies. Thomas Wittman of Gophers Limited emphasizes that growers should not expect to eliminate these pests, but will do well to keep populations in check. He stresses the importance of keen observation and has tips for effective trapping routines using commercially available traps. Persistent year-round trapping is the primary strategy for most farmers, complemented by enhancing the habitat of key predators such as owls and hawks with nestboxes, perches, and appropriate vegetation.(35)

Explosive propane devices are effective against gophers and ground squirrels. Propane gas ignited in rodent burrows creates an explosion that kills the animals and disrupts their tunnels. Several organic orchardists say that this works, but most promptly abandoned its use because neighbors complained about the noise of the explosion, similar to the sound of a gun shot. Only two materials (sulfur dioxide for underground smoke bombs and Vitamin D3, or Cholecalciferol) are on the National List as rodenticides. These may be used only if they are documented in the Organic System Plan, used with care to avoid harming non-target animals, and only when other management practices are ineffective.

Birds can be especially troublesome in cherry, berry, and grape plantings. Exclusion with bird netting is probably the surest control, but the initial cost can be high for both the material and its placement. Noise devices, "scare-eye" balloons, Mylar tape, artificial hawk kites, and many other home remedies have been tried, with varied success. Successful scare tactics depend on the bird species, bird population pressure, and the grower's management of the devices. It is important to remember that birds and other vertebrate pests are quick to learn, and they often overcome their initial aversion to scare devices or repellents. The grower will achieve the most effective control by moving devices frequently, and by changing or mixing the devices. For example, organic growers describe how they effectively scare certain bird species away from newly emerging crops by placing red- and silver-colored Mylar tape in the field for just a few weeks, then removing it so that the birds do not get used to seeing it. Fruit growers use sonic and visual scare devices only at critical times in the growing season, such as fruit ripening, and remove them promptly as soon as that period is over.

Deer can be devastating to fruit plants, especially young orchards. Methods for preventing or controlling deer damage to crops range from exclusion and cultural methods to scare devices, repellents, and culling or harvest. For more information, see the ATTRA publication *Deer Control Options*. Scent and taste repellents may be effective under light deer pressure, especially if the grower switches periodically from one repellent or deterrent to another. Research at the University of Wisconsin (36) indicates that none of these repellents is very useful under heavy deer pressure. Exclusion fencing may be the only way to manage heavy deer populations. In most states, the Cooperative Extension Service provides suitable plans for deer fencing. Electric fencing appears most effective. Research indicates that even a single strand of electrified wire can work. Where deer problems are severe, however, a seven-strand, sloped, electrified fence may be necessary.(37)

Birds can be especially troublesome in cherry, berry, and grape plantings.

Tree guards made of plastic, hardware cloth, or similar materials can keep rabbits from gnawing on fruit tree trunks.(38) However, northern growers should remember that snow can effectively raise the gnawing height of rabbits.

Mice and voles may be attracted to mulch around fruit plants. Such rodents take up residence in mulch during the winter, feeding and gnawing on roots, stems, and trunks. To reduce the chance of vole damage, mulch should be raked away from the plants in the fall (usually 18 to 24 inches is adequate). Mulch removal may not be practical, however, for blueberry plantings. Keeping the

planting site mowed also helps reduce rodents by exposing them to natural predators such as hawks and owls. For pests such as raccoons, opossums, skunks, etc., tight web-type fencing or non-lethal traps are the best control options.

Postharvest Handling

Many fruits require some type of postharvest handling. Whether done on-farm or off, these processes must be documented in the Organic System Plan. Any off-farm postharvest handling must be done by certified organic facilities, and appropriate measures must be taken to prevent commingling or contamination of organic products with non-organic products during washing, sizing, packing, and storage. A complete audit trail must track produce from its field of origin to the point of final sale. Growers should read the National Organic Program Final Rule, review the National List, OMRI lists, and consult with their certifiers about any materials to be used postharvest, such as cleansers, shellacs, or waxes.

Conclusion

Organic fruit production is a practical option for some growers, but the viability of the enterprise will likely hinge on site, scale, type of fruit, markets, and managerial skills. In general, crops grown in the drier climates of the West have fewer disease and pest problems. This region may, therefore, be better suited to organic fruit production. Strawberries, bush fruits, and brambles are probably easier to grow organically in most sections of the country than grapes and tree fruits. Management requirements for organic production are likely to be higher in any region, and the producer must be closely attuned to local site conditions.

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Photo by Scott Bauer ©2004 ARS

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www.sarep.ucdavis.edu/cgi-bin/CCrop.exe/show_crop_39

Summary of crop growth, planting recommendations and varieties, with a link to photos of subterranean clover growing in orchards.

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www.sare.org/handbook/mccp2/subclovr.htm

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25) King Machine Co.
P.O. Box 586
Scottsburg, IN 47170
812-752-6000
800-365-2467 (toll-free)
www.kingmachine.com

26) Millcreek Manufacturing Co.
2617 Stumptown Road
Leola, PA 17540
800-311-1323 (toll-free)
www.millcreekspreaders.com

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http://organic.tfrec.wsu.edu/OrganicIFP/Home/Index.html

and

Current Trends in Organic Tree Fruit Production. David Granatstein and Elizabeth Kirby. Center for Sustaining Agriculture and Natural Resources
http://organic.tfrec.wsu.edu/OrganicIFP/OrganicFruitProduction/current_trends.PDF

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5673 SE 95 Avenue
Marion, ND 58466-9718
800-437-3392 (toll-free)
www.weedbadger.com

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6645 West Main Road
Portland, NY 14769
716-792-9433
716-792-9434 FAX
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Resources

Sources of Supplies

Harmony Farm Supply
P.O. Box 460
Graton, CA 95444
707-823-9125
707-823-1734 FAX
www.harmonyfarm.com

Flame Engineering, Inc.
P.O. Box 577
LaCrosse, KS 67548-0577
913-222-2873
800-255-2469 (toll-free)
www.flameengineering.com/

Thermal Weed Control Systems, Inc.
N1940 Hwy. 95
Neillsville, WI 54456
715-743-4163

Periodicals

American Fruit Grower
Meister Publishing Company
37733 Euclid Ave.
Willoughby, OH 44094
440-942-2000
www.meisternet.com
Monthly. $19.95/yr.

Good Fruit Grower
105 S. 18th Street, Suite 217
Yakima, WA 98902
509-575-2315
509-454-4186 FAX
www.goodfruit.com
growing@goodfruit.com
$30/yr.

Fruit Growers News (formerly Great Lakes Fruit Growers News)
P.O.Box 128
Sparta, MI 49345
616-887-9008
616-887-2666 FAX
gap@i2k.net
Monthly. $11/yr.

Pomona
North American Fruit Explorers
1716 Apples Rd.
Chapin, IL 62628
Quarterly. $10/yr.

Further Reading

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Davidson, Ralph, and William F. Lyon. 1987. Insect Pests of Farm, Garden, and Orchard. 7th Ed. John Wiley & Sons, New York, NY. 640 p.

Flint, Mary Louise. 1990. Pests of the Garden and Small Farm. Division of Agriculture and Natural Resources Publication 3332. University of California, Oakland, CA. 276 p.
Primarily for California, but lots of good information for any fruit grower.
From: ANR Publications
University of California
6701 San Pablo Ave
Oakland, CA 94608-1239
510-642-2431
800-994-8849 (toll-free)
www.anrcatalog.ucdavis.edu.

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Out of print. Check with any library's interlibrary loan program to borrow a copy. Includes chapters on minor fruits such as elderberries, juneberries, kiwifruit, etc.

Pfeiffer, Ehrenfried. No date. The Biodynamic Treatment of Fruit Trees, Berries, and Shrubs. The Biodynamic Farming and Gardening Assoc., Inc., Kimberton, PA. 30 p.
Available from:
The Biodynamic Farming & Gardening Association
P.O. Box 29135
San Francisco, CA 94129-0135
415-561-7797
biodynamic@aol.com
www.biodynamics.com

Reich, Lee. 1991. Uncommon Fruits Worthy of Attention. Addison-Wesley, Reading, MA. 273 p.
Though not expressly for commercial growers, it provides otherwise hard-to-find information on minor fruit crops like pawpaws, jujubes, mulberries, etc.

Ryugo, Kay. 1988. Fruit Culture: Its Science and Art. John Wiley & Sons, New York, NY. 344 p.

Whealy, Kent. Fruit, Berry and Nut Inventory. Seed Saver Pubs., Decorah, IA. 366 p.
Descriptions of various fruit cultivars extant in U.S. nursery trade.
Seed Savers Exchange
3076 N. Winn Road
Decorah, IA 52101
319-382-5990
sse@salamander.com

Web Resources

Listings of Educational Institution and Government Sponsored Sites
www.crfg.org/related.edu.gov.html

U.C. Fruit and Nut Research and Information Center:
http://fruitsandnuts.ucdavis.edu/
This site has links to specific crops, lists of farm advisors, current research and many

other useful resources.

UC Davis Postharvest Technology and Information Center

http://postharvest.ucdavis.edu/Produce/Storage/index.html

This site provides practical information on postharvest handling of many products.

University of Missouri Extension Publications

http://muextension.missouri.edu/xplor/agguides/hort/#Fruit

While this site includes information for home orchards, there is a piece entitled "Information Sources for Planning a Commercial Fruit Operation" that includes contact information for local Extension horticulture specialists:

http://muextension.missouri.edu/xplor/agguides/hort/g06011.htm

California Rare Fruit Growers

www.crfg.org/

This organization covers a fascinating plethora of tropical fruits, but does not have a commercial emphasis. Contains abundant information on deciduous fruits as well.

Cornell Cooperative Extension Fruit Production Resources

www.hort.cornell.edu/extension/commercial/fruit/treefruit.htm

Much of the pest management information on this site appears to be pesticide-focused at first glance. However, one article discusses Organic Treefruit and IPM: www.nysaes.cornell.edu/ent/treefruit/2002_treefruitPdf/IntCropAndPM.pdf

There are links on this site to "Other State Resources," such as the following two examples.

University of Connecticut IPM for Tree Fruit Crops

www.canr.uconn.edu/ces/ipm/ipmtrfr.htm

Western Maryland Research & Education Center

www.canr.uconn.edu/ces/ipm/ipmtrfr.htm

There are many other state programs that have information on fruit growing, which may or may not have significant resources for organic orchard production.

Kearneysville Tree Fruit Research and Education Center, West Virginia University

www.caf.wvu.edu/kearneysville

This site features keys to pest identification, with great photos of insects and disease symptoms. Lots of useful information for fruit growers in the Mid-Atlantic region. On-line newsletters and publications are archived. Links to other sites.

The Mid-Atlantic Regional Fruit Loop

www.caf.wvu.edu/kearneysville/fruitloop.html

A cooperative effort bringing together information on deciduous fruit tree production in the Mid-Atlantic region. Cooperating state universities include Virginia Tech, West Virginia University, the University of Maryland, Penn State University, and Rutgers University.

North American Fruit Explorers

www.nafex.org/

Members of this network are professional and amateur fruit growers who share information here and in their quarterly journal, Pomona *(see* **Periodicals** *section).*

UC Davis Pomology Dept:

http://fruitsandnuts.ucdavis.edu

Links to all sorts of fruit information from University of California.

University of Massachusetts Tree Fruit Advisor:
www.umass.edu/fruitadvisor/
Fact Sheet series addresses specific issues and crops. Information focuses on apples, but includes peaches, pears, plums, and cherries.

Horticulture Solutions Series. Illinois Cooperative Extension:
www.ag.uiuc.edu/~robsond/solutions/horticulture/fruits.html

USDA articles and updates on organic farming.
www.ers.usda.gov/briefing/Organic/readings.htm
This site features tidbits of information on specific issues: Economic Research Service briefing room, organic farming and marketing, recommended readings.

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The electronic versions of *Tree Fruits: Organic Production Overview can be located at:*
HTML
http://attra.ncat.org/attra-pub/fruitover.html

PDF
http://attra.ncat.org/attra-pub/PDF/fruitover.pdf

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