Strawberries: Organic Production

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This publication provides an overview of organic strawberry production methods. It also covers integrated pest management and weed control techniques that can reduce pesticide use in strawberry production. Included are discussions of weeds, pests, diseases, greenhouse production, plasticulture, fertility, economics, and marketing. Lists are provided of further resources, both electronic and in print.

Strawberries in hoophouse. Photos by Martin Guerena

Plasticulture strawberries.

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Introduction

Strawberries are a viable crop in most areas of the United States. Cultivars have been developed to suit most agro-climatic conditions. In many locations, demand for locally produced berries far exceeds available supplies; small-scale producers can thus get higher returns from strawberries than from most other crops.

Organically grown berries may command a price premium. Organic production excludes the use of synthetic fertilizers and pesticides, and requires soil building and biological pest control. Federal organic standards restrict claims of "organically grown" to those farms that are certified to be organic by a USDA-accredited certification agency. For more information, request the ATTRA publications *Organic Farm Certification and the National Organic Program* and *Organic Orchard, Vineyard, and Berry Crop Documentation Forms*.

Excellent cultural information for conventional strawberry production—planting systems, pest control, cultivar recommendations, etc.—can be obtained from the Cooperative Extension Service in most states (also see **Further Resources** below). ATTRA's *Overview of Organic Fruit Production* provides general information on organic weed control, organic fertilization, and some basic considerations for organic disease and pest control. This publication will cover problems specific to strawberries and will offer organically acceptable solutions. We have not attempted to develop a one-size-fits-all prescription for organic (or other ecologically based) strawberry production. Rather we have introduced the most common challenges and offered some possible solutions and factors for consideration.

For many years, conventional strawberry growers have routinely used the soil fumigant methyl bromide to control weeds, soil-borne diseases, nematodes, and soil-dwelling insects. In October, 1998, the Congress

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attached an amendment to the Clean Air Act which required EPA to make regulatory changes to the US phase-out of methyl bromide, resulting in a 100 percent reduction by 2005. (Anon., 2002) Currently, a critical-use exception has been issued extending the phase out to 2007 for those who believe there are no technically and economically feasible alternatives to methyl bromide. There *are* feasible alternatives in strawberry production, as many organic growers can attest.

Planting Systems

Planting systems for strawberries vary, depending on the environment and production goals. The grower must decide the relative priorities of yield, size, flavor, or other qualities of the fruit, and seek a system that balances these goals. Systems that focus primarily on yield are the least sustainable because of the enormous amount of energy used for maintenance, plastic, and transportation. In many of these systems, the plants are grown on raised beds as annuals. This results in removal of the plants, plastic mulch, and irrigation system at the end of every season. Regardless of the system used, conventional yields are usually higher than organic yields. However, studies have shown that organic producers can earn more profit per acre than conventional producers. (Gliessman et al., 1996)

Raised Bed Plasticulture. Organic and conventional growers in California and Florida, where most of the nation's strawberries are produced, tend to favor this system. They grow plants as annuals, transplanting strawberry crowns in the late summer or early fall. Production starts in the late winter and continues through the summer and into late fall, depending on the area and the varieties grown. Since methyl bromide is not allowed in organic production, crop rotation, green manure crops and compost are *critical* to control soil-borne diseases and pests.

Two types of raised beds are used in these intensive systems. Narrow beds have two rows of plants with one drip line running between them. The distance between beds averages 40 inches. Drip tape is buried at a depth of about 2.5 inches. Wide beds usually have four rows of plants and two drip lines, with 64 inches between beds. Spacing between plants in both types of bed averages 12 to 14 inches.

Strawberries in a basket. Photo courtesy of USDA/ARS

Plastic mulch is used in both narrow and wide beds and can vary from a single strip of plastic laid between the plants to full bed coverage, where holes must be punched for the plant to develop. Some conventional growers in California use clear plastic which warms the bed faster, stimulating early-season growth; these growers use fumigation to control most weeds. Black plastic is used in organic production, primarily for weed control. Since the black plastic prevents the sun's rays from penetrating, the beds remain cool, resulting in slower initial growth of the plants and reduced irrigation frequency compared to clear plastic mulch. There is a plastic mulch on the market that selectively permits soil-warming radiation to penetrate while eliminating the light that promotes weed growth. This type of plastic is preferred by growers in the southeast.

Raised beds provide good drainage. Since they make the flowers and fruit easier to see and reach, raised beds also help growers to forecast yields, while making harvesting easier and faster. Some growers dig deep furrows between the beds so that harvesters do not have to stoop so low to search for fruit. In cold climates, plants in raised beds may be prone to freeze damage. Still, raised beds usually out-produce flat beds. Due to of increased aeration and protection

Related ATTRA Publications

- Organic Farm Certification and the National Organic Program
- Organic Orchard, Vineyard, and Berry Crop Documentation Forms
- Overview of Organic Fruit Production
- Season Extension Techniques for Market Gardeners
- Sources of Organic Fertilizers and Amendments
- Alternative Soil Amendments
- Worms for Composting (Vermicomposting)
- Overview of Cover Crops and Green Manures
- Biointensive Integrated Pest Management
- Farmscaping to Enhance Biological Control

Plasticulture, Sustainability, and Organic Farming

Plasticulture is not without its serious critics. The plastic has to come from somewhere, and it has to be discarded at the end of the one- to three-year production cycle. Clearly, critics say, this is not an environmentally sustainable system. And, says Cornell University fruit researcher Marvin Pritts, PhD, if you consider all the environmental costs to society, plasticulture is also not economically sustainable in the long run. Pritts also points out that even more plastic—in the form of row covers, tunnels, hoop houses, etc.—is needed to make the system work in cold climates.

USDA researchers have shown that fields mulched with plastic cause four times more water runoff than fields mulched with organic materials. Due to this high rate of runoff, fields mulched with plastic suffer up to fifteen times more soil erosion than fields mulched with organic matter. (Anon., 1999c) Planting grasses or other types of vegetation alongside drainage ditches can reduce the rate of erosion and provide habitat for beneficial insects.

Yet, even organic growers—especially those in California, where plasticulture has reigned the longest—are buying into the plasticulture production model. Why? The answer is weeds. Strawberries are notoriously prone to weed encroachment with resultant loss of productivity. Plasticulture provides good to excellent weed control without herbicides. The National Organic Program (NOP) states that plastic or other synthetic mulches are allowed in organic production, provided that they are removed from the field at the end of the growing or harvest season.

Pritts admits that implementing some of these ideas requires well-informed and committed management. Moreover, production in each locale may require fine-tuning to get the right mix of groundcovers and timing for planting, mowing, and other manipulations. This is probably not going to be as easy as rolling out the plastic sheeting. Nevertheless, using small amounts of post-emergent herbicide, though not allowed in organic production, may be more sustainable than the continued use of tons upon tons of non-renewable, non-recyclable plastic mulch. Corn- and soybean-based biodegradable plastics are being developed, but it will be a while before a sturdy and durable biodegradable plastic capable of withstanding solar radiation, moisture, and equipment is available for strawberry production. Synthetic biodegradable polymers are being developed, but since they are synthetic, it seems unlikely they will be allowed in organic production any time soon.

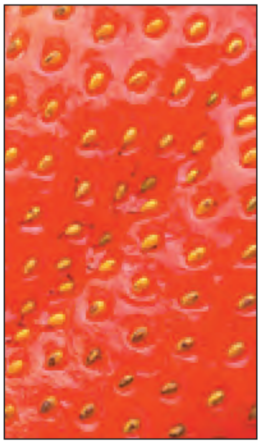
from splashing soil particles, plants in plastic-mulched raised beds have less disease.

Machinery is available to shape the bed, lay out the irrigation line, and cover the bed with plastic mulch all in a single pass. Sources of bed-shapers and transplanters are listed in the ATTRA publication *Season Extension Techniques for Market Gardeners*. Or check the following web pages:
www.mechanicaltransplanter.com/layer.html
www.marketfarm.com/cfms/mulch_layers.cfm

Recent research indicates that any variety that normally does well in a specific region will do well when grown using plasticulture in that region. (Nourse, 1999) However, some of the cultivars that come from the California and Florida systems perform best at a 12- to 14-inch spacing, while many northern cultivars do best at an 8- to 10-inch spacing.

By now, growers and researchers in many states have adapted and validated at least parts of the production model described above. Growers should check with their state Extension Fruit Specialist to see if specific plasticulture guidelines are available for their area. Otherwise, a complimentary copy of *Nourse Farms Success with Plasticulture* can be obtained by calling Nourse Farms at 413-665-2658.

Matted Row System. In this system the crowns are planted in early spring. As the plants produce flowers, the blossoms are removed to encourage runner (or daughter plant) production. The daughters root on the bed and produce a crop the following spring. Weeds can be a problem in this system, and dead leaves and other debris must be removed to reduce disease and pest problems. However, once established, this system can produce for three to four years, depending on pest pressure. The distance between plants is 18 to 24 inches, and the distance between the rows varies from 36 to 50 inches, depending on the cultivation equipment used. According to Marvin Pritts of Cornell University, the matted row system offers northern strawberry growers a low-risk system that requires less focus and time than annual plasticulture systems (Pritts, 2002).



Strawberry seeds. Photo courtesy of USDA/ARS

Researchers at the USDA Agricultural Research Service (ARS) in Maryland have developed a "modified or advanced" matted row system to address weed and pathogenic pests. This system uses matted row-type culture established on raised beds with subsurface drip irrigation and *organic* mulch. The mulch consists of a mixture of hairy vetch (45 kg/hectare [40.1 lb/acre]), rye (78 kg/hectare [69.6 lb/a]), and crimson clover (34 kg/hectare [30.3 lb/acre]) that fixes some nitrogen and provides an economical, biodegradable mulch for suppressing weeds and diseases, and reducing erosion. The organic mulch is cut or rolled down in April and two weeks later the bare root strawberry plants are planted through the layer.

Since 1996, the small-fruit breeding program has conducted replicated performance trials on both the advanced matted row system and a regional adaptation of annual hill plasticulture. Both of these systems were managed without methyl bromide fumigation or fungicide application. Data from these trials were used to compare advanced matted row and plasticulture for yield, fruit quality, and length of harvest season. Yield for the two systems was variety-dependent, and the advanced matted row system had later production and slightly lower fruit quality. (Black et al., 2002)

Strawberries. Photo courtesy of USDA/ARS

Ribbon Row System. This system can employ high-density or low-density planting on a single row. With low-density planting, the spacing is 12 to 36 inches between rows and 14 to 18 inches between plants. With high-density planting, the distance between the rows is the same but the distance between plants varies between 4 and 12 inches. The crowns are planted in the fall. Once they start blooming, the flowers are not removed, and fruit is produced in the first season. Runners are removed to stimulate flower formation and to increase fruit size. At the end of the second season the planting can be changed to the matted row system by letting the runners fill in empty spaces on the beds.

Varieties

Selection of appropriate varieties is important. Besides determining yields and quality, the variety also determines production seasons and pest-control practices. Your county extension agent can usually recommend varieties that have been shown to respond well to the area's climatic conditions. However, variety trials are usually conducted utilizing conventional production systems. The variety's performance may be different in an organic system. Therefore, organic growers are advised to plant more than one of the recommended varieties and conduct their own variety trials. Other organic growers in your area may also be able to advise you.

Strawberry varieties are classified as either "June-bearing" or "Everbearing." June-bearing or short-day varieties start forming flower buds as the day-length gets shorter and temperatures get cooler. Everbearing or day-neutral varieties are insensitive to day length and produce fruit throughout the season as long as night-time temperatures drop below 60° F. (Strand, 1993)

Trials conducted in the northeast comparing strawberry varieties under conventional and organic management systems demonstrated that the "Honeoye" variety was the most productive in terms of numbers and weight of harvested fruit and most profitable for organic producers. (Rhainds et al., 2002)

See **Appendix B** for a list of recommended strawberry varieties.

Fertility

ATTRA's *Overview of Organic Fruit Production* covers organic fertility management in a general way. However, there are at least two aspects of strawberry production that are unique and distinct from other perennial fruits with respect to fertility.

June-bearing strawberries set buds for the following year's fruit in the fall. (Most perennial fruit crops set their fruit buds in the spring or early summer.) To get a good bud set, the plants must have adequate chilling and not be nutritionally stressed. Therefore, fertilizer applications are usually warranted in the late summer, giving the organic fertilizer material enough time to break down and provide nutrients for the plants during the crucial fall bud-set.

Timing is critical in supplying nitrogen to berry crops and the nitrogen release rates for organic fertilizers may not match the nitrogen needs of the crop. A study on organic fertilizers in California found great variability in the nitrogen availability of different sources of fertilizers. (Gaskell, 2004) These included guano, feather meal, liquid fish emulsion, fish meal, pelleted chicken manure, compost, and a green manure crop. Initially, the soil nitrate nitrogen from the green manure crop and compost kept the level of nitrogen at adequate amounts (50 to 75 ppm) for three to four weeks and then declined to background soil levels below 10 ppm.

Supplemental fertilizing is therefore necessary to carry the crop through the season. Strawberry producers using the annual plasticulture system must rely on soluble organic fertilizers applied through drip irrigation lines. Farmers using these systems must face solubility and the capacity of these products to be filtered through fine mesh without plugging drip emitters. Products injected into the system may not emerge at the same concentration. In other systems, foliar or side-dress applications will be warranted.

While all perennial fruit crops will benefit from the fertility provided by pre-plant cover-cropping and green-manuring, strawberries are so prone to weed problems that pre-plant preparations to reduce weed pressure are practically mandatory in organic production. A thick cover crop of a grass/legume mix will help to smother out many weeds and will provide important long-term improvements in soil fertility and soil organic matter. In areas such as coastal California, long growing seasons and high land rents may make the extended use of cover crops uneconomical. However, many growers believe that the long-term benefits of cover crops and rotations to soil fertility and pest and disease suppression are worth the cost.

Compost can be used as a supplement or alternative. Spreading and incorporating the compost on the beds only, avoiding the furrows, will help concentrate fertility and microorganisms where they are most needed. Compost application rates vary from 10 tons/acre to 3 tons/acre. Supplemental fertigation is necessary to carry the plants through the production season: Research from Ohio has shown that vermicompost (compost made from earthworm waste) applications increased strawberry growth and yields significantly. (Arancon et al., 2004) These responses seemed not to be dose-dependent. Strawberries at one site grew fastest and yielded most in response to the 10 ton/hectare (4.05 ton/acre) vermicompost application rate, whereas strawberries responded positively and similarly to both the 5 ton/hectare (2.02 ton/acre) and 10 ton/hectare rates of application at another site. These responses could not have been mediated by the availability of macronutrients, since all plots were supplemented with inorganic fertilizers to equalize macronutrient inputs for all treatments. Based on other research in the laboratory, however, the responses could have been due to production of plant growth regulators by microorganisms during vermicomposting.

The foliar application of aerobically-prepared compost tea increased yields in a British Columbia study. (Welke, 2004) Besides reducing incidences of *Botrytis*, the compost tea treatment increased yields in strawberries by 20 percent compared to the control and water sprays.

For more information on organic fertilizers, vermicomposting, compost and cover crops, request these ATTRA publications: *Sources*

Related ATTRA Publications

Bug Vacuums for Organic Crop Protection

Sustainable Management of Soil-Borne Plant Diseases

Notes on Compost Teas

Use of Baking Soda as a Fungicide

Direct Marketing

Farmers' Markets

Community Supported Agriculture

Selling to Restaurants

Entertainment Farming and Agri-Tourism

Organic Marketing Resources

of Organic Fertilizers and Amendments, *Alternative Soil Amendments*, *Worms for Composting (Vermicomposting)*, and *Overview of Cover Crops and Green Manures*.

Weed Control

Weeds are one of the biggest problems that organic strawberry growers face. Preplant site preparation is critical. Refer to ATTRA's *Overview of Organic Fruit Production* for site preparation strategies as well as for basic weed-control ideas.

Cultural Methods

Organic growers will find that some hand weeding is necessary. Weeds in organic plasticulture systems can become troublesome even where black plastic mulch is used. In such situations, the weeds emerge from the planting holes made for the strawberry plants. The rows must be straight and the plastic laid precisely to allow mechanical cultivation of the furrows without damaging the beds and plastic.

A variety of colored mulches have been studied in California to determine their contribution to weed control and crop response. Black mulch provides the best weed control but does not warm the soil as well as clear plastic. Soil warming with clear plastic results in plants that grow and produce earlier in the season, but weeds are not controlled. Research determined that the effect of mulch color on transmittance of photosynthetically-active light (400 to 700 mm) through mulches was the key weed-control factor. (Johnson and Fenimore, 2005) Green and brown plastic mulches provided the best combination of soil warming and weed control benefits at all trial locations.

The matted row system (where plants from runners form a 6- to 30-inch-wide solid bed) is commonly used by strawberry growers in many regions of the U.S. This method precludes mechanical cultivation for weed control within the bed, though cultivation is commonly used to renovate or narrow a bed. Weed problems tend to increase with the age of the planting. Many organic growers have therefore chosen shorter fruiting rotations. That is, a bed may be allowed to fruit for two seasons before it is turned under and replanted to a cover crop.

A weed competition study in a mature matted row planting was conducted over a three-year period by Marvin Pritts and Mary Jo Kelly of Cornell University (2004). The impact of weeds on subsequent productivity was determined. Plants in the weed-free plots had the highest yield, while season-long uncontrolled weed growth reduced productivity by 51 percent. However, plants in several plots with a limited amount of weed competition had higher yields than those in the continuously weeded controls. This indicates that plants from a well-established matted row planting may be tolerant to a limited amount of weed competition for at least two years. Growers should direct a majority of their efforts and resources towards controlling weeds in the planting year. Once the planting is well established, growers may limit the number of times they hand weed to two or three per season.

Planters' paper, a black paper mulch, was used in matted rows for a biodegradable mulch study. (Weber, 2003) It reduced weeds but degraded quickly along the edges where it was covered by soil, allowing the wind to tear and blow large pieces off the plots. The rate of degradation the first year was quick but the paper still reduced weed population compared to clear mulch and the control.

European strawberry growers and researchers have led the way in innovations and research involving mechanical weed control in strawberries.

Mechanical Methods

European strawberry growers and researchers have led the way in innovations and research involving mechanical weed control in strawberries. Recent research in the U.S. has confirmed the usefulness of the flex-tine harrow, the brush hoe, and the finger weeder for weeding strawberry plantings. (Pritts and Kelly, 1999) For instance, the brush hoe required only three passes per season plus two hand weedings for complete weed control, compared to standard cultivation with a rototiller, which required three passes and four hand weedings. Visit the European Weed Research Society's

Physical Weed Control Web page *www.ewrs.org/pwc/glossary.htm* for more information on these and other mechanical cultivation tools. In plasticulture systems, harvest crews are sometimes used to weed when the weed pressure is high or when the harvest day is short.

Biological Methods

Before the widespread adoption of herbicides, geese were commonly used for weed control in commercial-scale strawberry production. In areas of concentrated crop production, farmers often had the benefit of weeder-geese services for hire. Weeder geese can still be used to control grasses and a few broadleaf weeds, but close management of the geese is essential. Not every farmer will find the extra requirements suitable to his or her management regimen. The extra work may be offset to some degree by on-farm consumption of the geese or by sales of geese and their products. In any case, the geese must be removed before fruiting season, because they will eat strawberries before going after grass.

Under the National Organic Program (NOP), raw animal manure must be composted unless it is incorporated into the soil not less than 120 days prior to harvest of a crop whose edible portion has direct contact with the soil surface or soil particles. Therefore, geese would need to be removed from the field and their manure incorporated at least four months prior to the beginning of strawberry harvest. ATTRA has more information on the proper management of weeder geese available on request.

Organic Mulches

Strawberry plants, especially in the North, are commonly mulched with straw over the winter to minimize cold damage. In the spring, the straw is raked into the aisles where it provides some control of weeds and helps to keep the berries clean. Caution must be taken with some organic mulches in that they may harbor pests like snails, slugs, cutworms, earwigs, and sow bugs. On the other hand, straw provides excellent habitat for spiders and has been known to reduce diseases. A study in Ohio showed that straw mulch between strawberry rows was equally or more effective than fungicides for controlling leather rot (*Phytophthora cactorum*). (Ellis et al., 1998)

Research in West Virginia indicates that shredded or chopped newsprint makes an excellent and safe mulch. (Baniecki et al., 1995) It can be applied over the top of the plants at the onset of winter, just like straw. It should be applied in a layer 4 to 5 inches thick (this will require about 500 to 600 pounds of chopped paper per 1,000 square feet), and will be subject to being windblown until it is stabilized by rain or overhead irrigation. Only newspaper or other recycled paper, without glossy or colored inks, may be used as mulch under the National Organic Program standards.

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Woolen landscaping fabric was the best alternative treatment in a study conducted in Minnesota. (Forcella et al., 2003) A one-ply woolen fabric centered over the crop nearly eliminated weeds from rows, promoted daughter plant rooting, and allowed maximum fruit yield equivalent to that obtained in plots that were hand weeded.

Cornell small-fruit researchers Marvin Pritts and Mary Jo Kelly have worked extensively with cover crops for weed suppression in strawberries. They have tried several species—including tall fescue, marigold, buckwheat, and ryegrass—but sudangrass has the most desirable characteristics: rapid establishment, low water use, low nutrient use, and competitive displacement of weeds. Their research suggests that interseeding sudangrass between beds and mowing it twice a year provides acceptable weed control without herbicides, especially when used in conjunction with a winter straw mulch. However, a later study found that a sorghum-Sudan grass hybrid "killed" cover crop suppressed pathogens and weeds but adversely affected strawberry growth and yields. (LaMondia et al., 2002)

See the **Matted Row System** section above for information on a USDA study using a killed cover crop mulch (hairy vetch, rye, crimson clover) to suppress weeds and reduce erosion.

In USDA zones 6 and colder, another option is to plant spring oats in the fall. Freezing weather will kill the oats, leaving a nice mulch. Yet another option is to plant sorghum-Sudan grass in the late summer; it is not at all cold tolerant, and will be killed by the first frost. For information on the USDA's hardiness zones, check the Web site *www.usna.usda.gov/Hardzone/ushzmap.html*.

Thermal Controls

Timing is critical for successful thermal control of weeds. The younger the weed, the easier it is to desiccate.

Thermal technology, from flamers to infrared burners, keeps evolving with new products emerging onto the market. At present, thermal control methods include handheld flamers, mounted row crop flamers, infrared weeders, steamers, hot water, and hot foam. Timing is critical for successful thermal control of weeds. The younger the weed, the easier it is to desiccate. Grasses can be burned back but the growing point usually sends out new growth. Some of these devices may not fit in a particular system but others may be successful components of a weed control program.

For a list of thermal devices for weed control, see **Appendix A**.

Vinegar and Essential Oil Herbicides

The use of vinegar for weed control has been the least-toxic choice of many home gardeners. Its effectiveness varies, depending on the type of weeds sprayed and the concentration of acetic acid. Most vinegar available commercially is 5 percent acetic acid. Through distillation, the concentration can increase to 15 percent and by other non-synthetic processes to 30 percent acetic acid. Caution must be taken with formulations greater than 5 percent. Though there are more concentrated solutions of acetic acid that are derived synthetically, these types are not allowed in organic production systems. Some commercial formulations of vinegar herbicide include lemon juice or citrus oil. The mode of action consists of the acidic solution degrading the leaf's waxy cuticle layer, causing desiccation. The thicker the cuticle layer on the weeds, the more frequent the applications or the more concentrated the solution should be. If preparing a homemade solution of vinegar herbicide, include citrus oil or lemon juice along with a small amount of liquid soap as a surfactant. Some commercial formulations are Alldown™ (SommerSet Products, *www.sumrset.com*) and Ground Force™ (Abby Laboratories, *www.abbylabs.com*).

The Organic Materials Review Institute (OMRI) lists vinegar and clove oil herbicides as restricted, meaning the need for and use of these herbicides must be explained in the Organic System Plan. Essential oil herbicides (clove, thyme, and mint oils) contain phytotoxic compounds that have been reported to kill grasses and broadleaf weeds. Commercial products include Xpress™ (Bio HumaNetics, *www.biohumanetics.com*) which is a formulation of thyme (10.4 percent) and clove (10.1 percent) oils and Matran 2™ which is 45.6 percent clove oil. According to the manufacturer, the addition of the yucca extract ThermX 70 (0.3 fl. oz. /gallon) with fulvic acid (6 fl. oz./gallon) to Matran 2™ significantly enhances its coverage and performance. Matran 2™ is also used in combination with vinegar. Be careful when spraying weeds and keep the sprays off strawberry plants. Also care needs to be taken to avoid contact or inhalation, as the high acid content will burn skin and lung tissue. For more information on vinegar as an herbicide, check the USDA Web site *www.ars.usda.gov/Services/docs.htm?docid=9666*.

Woven Synthetic Fabric Mulches

Synthetic fabric mulches (trade names: Weed Lock, Weed Barrier, Weed Stopper, etc.) offer some of the same weed suppression as regular plastic mulches, but have the advantage of being water- and air-permeable. Though initially more expensive than regular plastic, the higher-quality grades of fabric mulch can be used year after year. These woven mulches are used in essentially the same way as plastics in the systems described above. However, because they are water-permeable, it should not be necessary to add irrigation lines under the mulches in areas with adequate rainfall.

Insect and Mite Control

Numerous insects feed on strawberry plants and threaten yields. Extension Service specialists are familiar with pests common to specific areas and can help with proper identification, which is the first step in pest management. A scouting program with regular monitoring can help growers determine both the pest pressure and presence of beneficial insects. Once pest pressure reaches the economic threshold, control actions are necessary. If biological controls are to be used, they must be deployed before the pests reach critical levels. That is why monitoring is so important. In large operations, where harvest crews are used regularly, training the crew foreman to identify insect pests and diseases can help in the monitoring process.

Beneficial-insect habitats planted alongside strawberry fields provide shelter, pollen, and nectar sources to predators and parasites of insect pests. Beneficial insects are able to take refuge in the habitat when fields are treated with a pesticide. When purchased beneficial insects are released, these habitats encourage the beneficials to remain and continue their lifecycles, helping reduce pest populations. Some pests may also inhabit the refuge along with beneficials, so it is important to monitor these habitats: For additional information, request ATTRA's *Biointensive Integrated Pest Management* and *Farmscaping to Enhance Biological Control*.

Although pest problems vary with location, common strawberry pests include white grubs, strawberry weevils, strawberry rootworms, caterpillar worms, lygus bugs, and spider mites. For more detailed information on the pests themselves, refer to the publications listed in the **Further Resources** section below (see especially the publications by Funt et al., 1997, Kovach et al., 1990, Maas, 1987, and Strand, 1993).

White Grubs

Primarily a problem in the eastern U.S., white grubs can cause serious damage if strawberries are planted immediately after a sod crop. White grubs are the larvae of May and June beetles and other beetles in Scarabaeidae. Late-summer or early-fall plowing destroys many larvae, pupae, and adults in the soil and also exposes these stages to predators. The milky-spore-disease bacteria, *Bacillus popillae* and *Bacillus lentimorbus*, are important natural enemies of Scarab beetles. Grubs ingest spores of these bacteria on the thatch or roots of the grasses they eat. The spores then germinate and the bacteria multiply inside the grubs, which die and disintegrate, leaving many new, viable spores to spread the disease to succeeding generations. (Daar, 1988)

Beneficial nematodes are also effective against soil-dwelling grubs. *Steinernema carpocapsae* will infect its host near the soil surface while *Heterorhabditus bacteriophora* actively searches for its host below the soil surface. (Flint and Dreistadt, 1998) These nematodes and milky-spore bacteria are widely available through mail-order garden supply companies.

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Strawberry Clipper (Strawberry Bud Weevil)

The strawberry clipper or bud weevil, *Anthonomus signatus*, occurs only east of the Rockies. Adult beetles emerge in the early spring, lay eggs in the buds, and then cut partly through the stem, causing strawberry buds to fall over or fall to the ground.

Contrasting studies on strawberry clipper or bud weevil have been conducted. One study found that most of the 12 varieties studied compensated for a significant amount of flower bud loss, provided that the loss occurs early in the development of the inflorescence. (Pritts et al., 1999) A later study showed that liberal thresholds developed from the previous studies were exceeded in two of the three research sites and damage levels were severe enough to reduce yields significantly. (Handley et al., 2002) The clipper moves at the very slow rate of 30 feet per season. In a new planting, it is unlikely that the damage would extend more than 30 feet from the perimeter into the plot. Damage may be somewhat more extensive in older plantings, but still limited by the rate of movement of the clippers (they will have moved approximately 60 feet into a two-year planting and 90 feet into a three-year planting). Organic growers should destroy damaged buds, which contain eggs, eliminate trash and nearby foliage that provide hibernation sites for adult weevils, and apply an organically approved insecticide as a last resort.

Strawberry Rootworm

Strawberry rootworm (*Paria fragariae*) adults feed mainly at night, making holes in the leaves. The larvae feed on fine roots and eat the crowns close to the ground. Cultural control consists of plowing infested fields after harvest and setting new plantings away from woods (favorable hibernation sites) and from older strawberry plantings.

Apparently, IPM damage thresholds have not been established for the rootworm. If the grower feels that pesticide treatment is necessary based on scouting, nocturnal treatment should be aimed at the foliar-feeding adults, since there are no effective or registered insecticides available for control of the larvae. Soil-dwelling predators such as ground beetles or insect-attacking nematodes like *Steinernema* species may provide some control.

Strawberry Root Weevil

The adults of these species feed mostly on leaves, causing minor damage. The larval stage is the problem, as the larvae feed on roots and crowns of the strawberry plants. Root weevils have many alternate hosts including other small fruits, cranberries, grapes, mint, hops and many ornamental plants. Rotation with nonhost crops like corn, wheat, clover, and alfalfa can reduce populations. (Berry, 1998)

Like other ground-dwelling pests, Strawberry Root Weevils are susceptible to attack from ground beetles and from parasitic nematodes such as *Steinernema* or *Heterorhabditus* species. The root weevils are crawling insects that also have been excluded from fields by fences, trenches and barriers like sticky tape. (Bomford and Vernon, 2005; Strand, 1993)

Lygus Bugs

The tarnished plant bug or lygus bug (primarily *Lygus lineolaris* in the East and *L. hesperus* in the West) can be troublesome, especially in plantings of day-neutral varieties which fruit throughout the growing season. Adults and nymphs (the nymphs cause the most damage) suck sap from the plant and inject a toxic saliva. This feeding results in a characteristic deformation of the fruits called cat-facing, which makes the berries unusable and unmarketable.

Lygus bug. Photo courtesy of USDA/ARS

Keeping any groundcover well clipped for a distance of five to ten yards around a strawberry field, and otherwise destroying places favorable for hibernation, may help reduce lygus-bug populations. Adult lygus bugs hibernate under leaves, stones, and bark. They usually lay eggs in the stems of herbaceous cultivated plants and broadleaf weeds. Legumes (vetches, clovers, alfalfa, etc.) can harbor large populations of these pests. This must be considered if beneficial habitats using these plants are established near strawberry plantings.

Trap crops are also useful in lygus bug management. In California, an annual trap crop mix of one dormant and one semi-dormant alfalfa variety, two radish varieties (Daikon and Cherry Belle) and sweet alyssum has been used with success. Lygus bugs move in from surrounding fields and settle on the trap crops, which can then be treated with insecticides or vacuumed. (Dufour, 2000) Bug vacs range from tractor-mounted machines to small hand-held devices and are actually vacuum cleaners for pests. A trial by University of California researchers concluded that three similar grower-designed vacuum machines reduced lygus bug damage compared to untreated controls, but were not equal to chemical control with a pyrethroid insecticide. The damage, though reduced, was still considered economically unacceptable. (Pickel et al., 1995) Research done in Watsonville, California, demonstrated that lygus bugs were more attracted to a field-edge alfalfa trap crop than to a radish/mustard or strawberry row. (Swezey, 2004a) Vacuuming the alfalfa trap crop with a tractor-mounted bug vac reduced damage due to lygus bug feeding in associated strawberry rows when compared to vacuuming the whole field.

Bug vacuum. Photo courtesy of USDA/ARS

This saved operating costs of the bug vac and increased marketable fruit. For more information on Bug Vacs, see the ATTRA publication *Bug Vacuums for Organic Crop Protection*.

Research conducted in New England found variation in susceptibility to the lygus bug among 20 strawberry cultivars. (Handley et al., 1991) Honeoye, Sparkle, Veestar, and Canoga suffered the least from feeding, while Kent, MicMac, Scott, Blomidon, and Redchief suffered most.

A fungus, *Beauveria bassiana*, has some efficacy against lygus bugs. In New York, three years of tests concluded that the commercial formulation of *B. bassiana*, Mycotrol™, reduced lygus damage about 50 percent compared to untreated controls, but was still considerably less effective than synthetic insecticides such as malathion. (Kovach and English-Loeb, 1997) Mycotrol™ worked best when targeted at younger nymphs and when humidity levels were adequate. In combination with other cultural controls (choosing the right cultivar and close mowing near the planting), use of Mycotrol O™ (Laverlam Intl.), Botanagard (Laverlam Intl.) or Naturalis (Troy Biosciences) could be of help to organic growers in controlling lygus.

While the lygus bug has several natural insect enemies, none of the native ones has proved consistently effective in providing a commercial level of control in strawberries. A small (1/8th-inch) wasp, *Peristenus digoneutis*, was introduced from Europe in 1984 and has exhibited excellent control potential. However, this nymphal parasitoid is difficult to rear, and is not commercially available. While it is spreading naturally in the northeastern U.S., it has not moved south of latitude 41°N (New York City). (Day et al., 1990) In California, *Peristenus digoneutis* and *P. stygicus* were released in 1998. They have become established and annual increases in parasitism were noted in 2000-2002. (Fuester et al., 2004) Higher rates of parasitism by *P. digoneutis* were observed in New York on organic or casually sprayed farms than on intensively treated farms. (Tilmon and Hoffmann, 2003) *Anaphes ioles* is a lygus egg parasitoid that has been used in California and in other states with some success. Researchers who released 15,000 *A. iole* weekly on one-acre strawberry plots observed a 64 percent suppression of *Lygus hesperus* compared to a 44.7 percent reduction achieved with a pesticide application. (Udayagiri et al., 2000)

Since lygus nymphs are most troublesome, aim scouting efforts at this life stage. Start checking for nymphs as soon as flowers

Since lygus nymphs are most troublesome, aim scouting efforts at this life stage. Start checking for nymphs as soon as flowers appear.

A scouting method for two-spotted spider mites has been developed in British Columbia and successfully implemented both there and in New York.

appear. Tap 10 to 15 flower clusters over a white plastic saucer so that the bright green nymphs can be seen and counted. Determine the average number of nymphs per cluster (total number of nymphs divided by total number of clusters). If sampling is concentrated near weedy borders, the action threshold is 1 nymph per cluster, but if done randomly throughout the planting, 0.5 nymphs per cluster should be considered adequate to prompt a pesticide treatment. (Kovach et al., 1993) However, Cornell researchers caution that growers who intend to use the slow-acting biological insecticide *B. bassiana* may need to use a lower threshold. (Kovach and English-Loeb, 1997) If other natural enemies of lygus are present—such as spiders, bigeyed bugs (*Geocoris* species), assassin bugs (*Zelus* and *Sinea* species), damsel bugs (*Nabis* species), and lacewing larvae (*Chrysoperla* species)—you might want to consider adjusting the threshold numbers accordingly.

Parasitic wasp *Peristenus digoneutis*. ***Photo courtesy of USDA/ARS***

Mites

The web-spinning spider mites are in the genus *Tetranychus*, which includes the two-spotted spider mite, Pacific spider mite, and strawberry spider mite, among others. These plant-feeding mites consume juices from strawberry leaves. Large populations can reduce photosynthetic capacity, resulting in weakened plants and reduced fruit yields. Some growers who do not often use botanical pesticides may see very few mites—if not reduced by pesticides, the natural enemies of the mites will usually keep them in check. These natural enemies include other mites such as *Phytoseiulus persimilis*, *Metaseiulus occidentalis*, and *Neoseiulus californicus*, and insects like bigeyed bugs, damsel bugs, minute pirate bugs, lacewings, spider mite destroyers, and six-spotted thrips. Growers can buy some of these predators from commercial insectaries to release on the farm. The predators can also be attracted and conserved naturally through the use of insect habitats.

Insecticidal soaps, "narrow range" oils, vegetable oils, neem-based products such as Trilogy®, and sulfur are acceptable miticides in organic production (check with your certifier regarding specific products). Application instruments must thoroughly cover the leaves' undersides, and products that are diluted must be applied in high volumes (more than 100 gallons of water per acre) to achieve complete coverage. Both oils and soaps can burn plants if over-applied or if high temperatures (greater than 80° F) occur during and after treatments.

A scouting method for two-spotted spider mites has been developed in British Columbia and successfully implemented both there and in New York. (Kovach et al., 1993) To sample for these mites, walk diagonally across the planting while randomly picking one mature, fully expanded leaflet from every other row, until 60 leaves are collected. If 25 percent are infested with mites (about 5 mites per leaflet), treatment may be in order. Again, the number of natural enemies should also be considered when determining a threshold for chemical treatment. While this scouting method is probably applicable to most areas, growers outside the New York region should check with their local Cooperative Extension Service for scouting guidelines.

Contact Information for Beneficial Organisms

Companies that sell mites and other beneficial organisms are listed in the California Environmental Protection Agency's Department of Pesticide Regulation booklet, *Suppliers of Beneficial Organisms in North America.* (Hunter, 1997) An online PDF booklet is free online and contains contact information for 142 commercial suppliers of the more than 130 beneficial organisms that are currently used in biological pest control. It not only indexes the suppliers by the natural enemies they sell, it also matches the beneficial organisms with their target pests.

Some of the mites you see when scouting may be *predator* mites. You may need a magnifying glass to distinguish between these beneficial mites and the pest mites. One key to telling them apart is that the beneficial predator mites are generally more active than the two-spotted mites—they typically move quickly about the leaf surface looking for prey. Depending on your geographical area and the species involved, the recommended ratio of beneficial mites to pest mites varies, but seems to average approximately 1:10. That is, if there appears to be at least one beneficial mite for every 10 pest mites, control of the pest mites will probably be achieved naturally without the intervention of miticidal sprays.

Dust that accumulates on the spider mite's webbing creates an ideal shelter for the mites and their eggs. These little dust "tents" discourage predators and prevent the miticide from reaching the mites and their offspring. California growers commonly water roads, post "slow" signs, plant windbreaks and beneficial insect habitats, and use fencing to decrease dust in strawberry fields.

Other Pests

Other arthropods that will occasionally reach pest status include aphids, spittlebugs, whiteflies, Cyclamen mite, various caterpillars, earwigs, and leafhoppers. If they become a problem, consult your local farm advisor, visit the numerous websites listed below under **Further Resources**, or call ATTRA's toll-free number for information.

Disease Control

Diseases in plants occur when a pathogen is present, the host is susceptible, and the environment is favorable for the disease to develop. Altering any one of these three factors may prevent the disease from occurring. Organisms responsible for plant diseases include fungi, bacteria, nematodes, and viruses. If these organisms are present, then manipulation of the environment and the host, to make it less susceptible, helps manage diseases on strawberries.

Soil health and management are the keys for successful control of plant disease. A soil with adequate organic matter can house numerous organisms such as bacteria, fungi, nematodes, protozoa, arthropods, and earthworms that may suppress soil-borne pathogens. This disease suppression is caused by either antagonism, competition for nutrients, or competition for space around the root (the rhizosphere) and induced systemic resistance (ISR) or systemic acquired resistance (SAR) triggered in the plant. Increasing soil organic matter by incorporating cover crops or adding compost and organic fertilizers will help maintain these beneficial organisms. For more information, see the ATTRA publication *Sustainable Management of Soil-Borne Plant Diseases.*

Soil health and management are the keys for successful control of plant disease.

Rotating strawberries with other crops is a critical factor in organic production and many certifying agencies require it as a component of the organic system plan. Crop rotation reduces insect, disease and weed pests, improves soil fertility, improves soil tilth and structure, reduces soil erosion and improves water management. Cover crops, vegetable crops, legumes, and cereals are recommended rotation choices. Avoid Solanaceous crops like tomatoes, potatoes, peppers, and eggplant that may harbor diseases such as *Verticillium.* Research in the Salinas Valley of California found that incorporating broccoli residues reduced *Verticillium dahliae* in the soil and that rotation with broccoli may be a feasible approach to manage *Verticillium* diseases in susceptible crops. (Subbarao et al., 1999)

Compost teas or extracts and other innovative concoctions such as yeast-sugar solutions, sodium bicarbonate (baking soda), and milk have become popular as foliar disease preventatives among many organic growers. Compost teas and yeasts introduce non-plant-pathogenic microorganisms and biocontrol agents that compete with and antagonize disease spores as they try to establish themselves on the host. Baking soda works at the chemical level, interfering in spore germination. For more information, request ATTRA's publications *Notes on Compost Teas* and *Use of Baking Soda as a Fungicide*.

Elemental copper and sulfur have long been used by conventional and organic growers as pesticides for foliar bacterial diseases and powdery mildew, respectively.

Root Rot Complex

Soil borne fungi such as *Phytophthora*, *Pythium*, *Rhizoctonia* species, and *Verticillium dahliae* are major pathogens that affect strawberries worldwide. In organic production, the cultural methods described above —crop rotation, compost application, and solarization—aid in the control of these diseases. Other cultural controls include using resistant varieties, planting strawberries in a pathogen-free, well-drained soil, avoiding over-watering, and planting only certified disease-free plants. Some growers inoculate the soil or the plants with a variety of commercially available biological products such as Vesicular Arbuscular Mycorrhizae

Soil Solarization

Imagine harnessing the sun's energy to destroy your enemies. Like Archimedes—the ancient Greek who used mirrors to concentrate sunlight to burn the Roman fleet—farmers can destroy or disable insects, diseases, nematodes, and weeds in the field. The technique known as solarization consists of laying clear plastic mulch on moist soil. Heat is trapped under the plastic, raising the soil's temperature, killing or debilitating pests. Most of the research worldwide has concentrated on hot and arid areas, but any place with hot summers is a potential site for this system. Usually this soil pasteurization process takes four to six weeks, but the amount of time depends on many factors such as rain, wind, day length, soil texture, and the quality of the polyethylene mulch. Ultraviolet-protected plastic is recommended so the mulch can be removed and re-used.

Before solarization, certain types of organic matter, such as compost and residues from *Brassica* crops such as broccoli and the mustards, can be added to the soil for "bio-fumigation." When heated in the solarization process, this organic matter releases volatile compounds that are toxic to many pests. Before solarization takes place, the land where the crop is to be seeded or transplanted must be prepared for planting. Beds must be shaped, drip tape installed, and fields leveled. This is to avoid stirring up the soil after solarization, which would bring fresh pest organisms to the soil surface. Depending on outside temperature, intensity of sunlight, and types of pests, soil solarization can provide good pest control 8 to 10 inches deep, although the best control is generally obtained down to 6 inches.

Special caution: During solarization, drip tape must be buried at least one inch deep to avoid damage from the sun's rays. In experiments where the tape was placed on the surface of the bed and then covered with clear plastic, the drip tape was damaged by sunlight that was magnified by water droplets condensing on the underside of the plastic.

Research conducted in southern California and Oregon has demonstrated that solarization has potential as a component in an integrated pest management program for root diseases in strawberry production. (Hartz et al., 1993; Pinkerton et al., 2002)

Soil Solarization websites

Soil Solarization Home: *http://agri3.huji.ac.il/~katan*

International Workgroup on Soil Solarization and Integrated Management of Soil-borne Pests: *www.uckac.edu/iwgss*

Soil Solarization: A Nonchemical Method for Controlling Diseases and Pests:
http://ucce.ucdavis.edu/fi les/filelibrary/40/942.pdf

(VAM) or Arbuscular Mycorrhizae (AM), *Trichoderma* species (Promot, SoilGard), *Streptomyces griseovirdis* (Mycostop), and *Streptomyces lydicus* (Actinovate).

Anthracnose

Anthracnose can be very serious, causing strawberry plants to die out in midsummer. The disease produces a rust color throughout the crown and eventually stops the plants from growing. Symptoms are most noticeable during summer dry spells.

Since high soil fertility favors anthracnose, little or no fertilizer should be applied when disease pressure is strong. However, resistant cultivars can be grown successfully at much higher fertility levels. (Maas, 1987) Anthracnose is more prevalent in the Southeast than elsewhere. Commercial growers in the Southeast should avoid planting on former strawberry sites and use locally adapted resistant cultivars.

Botrytis (gray mold)

Gray mold, caused by the fungus *Botrytis cinerea*, is one of the most common and serious fruit rot diseases. The fungus grows best in cool damp weather, and gray mold can be devastating if rainy weather coincides with harvest, when strawberry fruit is at its ripest and most susceptible. Pickers handling infected berries can spread the infection to healthy berries. Control of gray mold is aided by removing infected debris from the field and by providing good drainage. Infected fruit can be picked off the plants and placed in the furrow as long as a cultivator can go through the field and bury this fruit. Clean mulch, which keeps fruit off the ground, is also highly recommended. Removing leaves from the field as soon as the harvest season ends can significantly reduce the incidence of gray mold on fruit in June of the following year. (Sutton et al., 1988)

The following biorational products are available commercially for *Botrytis* control: Serenade (Agraquest), Mycostop (Verdera Oy), and Promot (JH Biotech). Research in Israel found that combining two biocontrol agents (a yeast and bacterium) resulted in better suppression of *Botrytis* and reduced the variability of disease control. (Guetsky et al., 2001)

Although there is not a high level of gray-mold resistance in any one strawberry cultivar, Earliglow is relatively resistant compared to most cultivars. (Turns, 1990)

Leaf Spot

Leaf spot diseases—identified by the presence of spots on strawberry leaves and stems—can be caused by the fungi *Mycosphaerella fragariae*, *Ramularia tulasnei*, or *Phomopis obscurans*, or by the bacterium *Xanthomomas fragaiae*. These pathogens are spread by splashing water and are harbored by dead leaves and other plant debris. Sanitation, as well as the recommendations mentioned above on foliar disease preventatives, apply to leaf spot.

Some diseases of strawberries are anthracnose, gray mold, leaf spot, and powdery mildew.

Please Note

Preventive treatments such as sulfur, copper, or compost teas applied prior to wet weather are advisable for many diseases like leaf spot, gray mold, and powdery mildew. Also, studies have shown that systems using organic mulches have a reduced incidence of soil-borne pathogens.

Powdery Mildew

Powdery mildew is a fungal disease that affects strawberry foliage, flowers, and fruit. Caused by *Sphaerotheca macularis*, its spores prefer intermittently moist conditions and will not germinate in free-standing water. In coastal California strawberry fields, the practically year-round production season, foggy cool nights, and warm days make the disease a major and very persistent problem. Sulfur is the most common control agent on both conventional and organic farms. Milk has been used successfully against powdery mildew on cucurbit crops. (Bettiol, 1999) Sonata™ is an OMRI-approved commercial formulation of *Bacillus pumilis* that is used on strawberries for powdery mildew control. Seven-to fourteen day application intervals are recommended, depending on disease pressure.

Greenhouse Production

Five factors—light, heat, pollination, pest control, and economics—make winter strawberry production in a greenhouse very different from field production.

Lighting is critical for winter production. The day-neutral cultivars (e.g., Tribute and Tristar) or the short-day types (e.g., Jewel) are much easier to grow during the short days of winter than most of the traditional June-bearing types. It is difficult and expensive to get the June-bearing types to fruit out of season. Even with the day-neutral types, some supplementary lighting will be necessary to get high-quality fruit.

Strawberries must be picked and handled very carefully.

Supplementary heat will have to be available (in some cases the lighting will provide enough heat). While some non-fruiting vegetables (e.g., leafy greens, such as spinach) can produce well in unheated greenhouses, strawberry plants need about a 68° F day and 54° F night to produce good yields of high-quality berries.

The grower will have to provide pollination. Bumblebees are probably the best pollinators in a greenhouse environment. Two commercial sources, GB Systems (P.O. Box 300, Locke, NY 13092; 315-497-3129) and The Green Spot (93 Priest Rd., Nottingham, NH 03290; 603-942-8925) sell bumblebees and bumblebee nesting boxes.

Certain pests (usually the larger ones, e.g., tarnished plant bugs) can be effectively excluded from greenhouses, but others, such as mites, aphids, whitefly, thrips, and fungus gnats are likely to thrive and proliferate. Due to the need for bumblebees for pollination, controlling these pests with conventional pesticides is not a good idea. Fortunately, they can be effectively managed with biological controls, such as beneficial mites and lacewing larvae. For the details of greenhouse pest management, contact ATTRA for our series of publications on greenhouse IPM (or go directly to *www.attra.org/attra-pub/gh-ipm.html*).

Finally, prospective greenhouse growers should spend some time exploring local markets (restaurants, groceries, etc.) Off-season greenhouse growers will be competing with strawberries from California, Mexico, Chile, and Florida. Prices will have to offset the costs of production, so growers will have to produce an outstanding product. Cornell researcher Marvin Pritts found that the break-even price for greenhouse-grown strawberries was $3/pint. He reports, however, that a small but significant number of consumers are willing to pay that price for high-quality berries.

For more detailed information on greenhouse strawberry production, go to *www.hort.cornell.edu/department/faculty/pritts/BerryDoc/Berrydoc.htm*.

Harvest and Postharvest

Strawberries must be picked and handled very carefully. The fruit must be firm, well-colored, and free from rot. When harvested at the right time and handled properly, strawberries will remain in good condition for many days. Most California- or Florida-grown strawberries found in supermarkets are picked three-quarters ripe to withstand shipping. The color of these strawberries is a full red but the taste is disappointing. Small-scale growers who pick ripe fruit can easily compete with supermarket berries by offering a tastier, fresher berry to local consumers.

Proper postharvest handling of strawberries is essential. Cooling the berries will remove field heat and increase shelf life. Harvesting early in the day while temperatures are cool and then pre-cooling the fruit before shipping will extend the shelf life significantly.

Forced-air cooling is the most common method used on strawberries. The flats are stacked parallel to each other in a cold room with an open space between the flats. A tarp is then placed over the top and ends of the stacked cartons, with a fan located between stacks. The fan pulls cold air between the gaps of the stacked flats, removing the field heat from the berries. It is vital that the fruit be cooled as soon as possible. The more the delay between harvesting and cooling exceeds one hour, the greater the losses to deterioration. (Kader, 1992) Water loss from strawberries can be a problem, so it is critical to maintain high humidity in the cooling facility. Avoid wetting the fruit, which can cause decay problems.

Fresh-market strawberries are usually sold in pint or quart baskets covered with plastic wrap. However, one-piece molded-plastic containers called "clamshells" are rapidly replacing this packaging. The time and labor involved in packing the fruit in the traditional pint-size plastic baskets is considerable, because shippers and buyers grade fruit packed in this manner by the arrangement of the fruit in the flat. This puts additional burden on the farm worker to pack the fruit correctly. The use of clamshells makes the strawberry pickers' job a little easier; the wholesalers are not as concerned with the appearance of the fruit pack since it looks uniform with the clear lid. Many of these clamshells are recyclable. A drawback to the clamshells is the greater difficulty of cooling the fruit. The holes in the containers are not big enough to allow for rapid cooling, so extra time in the forced-air cooler is necessary. The clamshell containers also hold less fruit than the pint baskets and are sometimes sold at a lower price. If you sell wholesale or directly to stores, the buyers may require this type of packaging.

Wholesale strawberries that are shipped long distances are placed on pallets and are covered by bags that are injected with carbon dioxide after the fruit is thoroughly cooled. This modified-atmosphere process is patented by the Transfresh Corporation of Salinas, California and is known as the Tectrol® Atmosphere Pallet System. The process extends the shelf life of the fruit, allowing for transport and marketing. It is also accepted in organic production. It should be noted that large volumes need to be shipped to make this process economically feasible. For more information on the Tectrol® system go to the Transfresh web site at *www.transfresh.com/index.asp*.

Economics

Strawberries are one of the most popular fruits in the U.S. The majority of commercial production is in California, Florida, Oregon, and Washington. Growers in these states produce 95 percent of reported U.S. output. Growers in the South, East, and Midwest generally have small strawberry acreages located near population centers, and rely on direct-market sales.

Strawberries are a high-value crop, but they also have special production requirements, a short shelf life, and a brief marketing season. Initial investment in land preparation, irrigation and other equipment can cost about $2,000 per acre for a matted row system (Ernst, 2003) to $10,000 per acre for a plasticulture system. (Karcher, 2002). However, plasticulture systems produce earlier and have higher yields—up to double the yield of matted row systems. Earlier harvest may allow producers to receive the higher prices available at the beginning of the season.

Strawberries are one of the most popular fruits in the U.S.

Organic strawberries are in high demand and this segment of the organic industry continues to grow at a rapid pace. Organic strawberries now rank sixth among all California organic fresh commodities, with over 160 organic strawberry growers registered with the California Organic Program. (Swezey, 2004b).

Continuous cropping of strawberries is not possible in an organic system that relies on crop rotations. The production cycle is shorter (one to two fruiting years) and yields are both lower and more variable than in conventional systems. Labor requirements may be as much as twice those of a conventional system. (Pritts and Handley, 1999) Since they face higher costs of production (**Table 1**), organic growers must secure a premium price in order to make a profit.

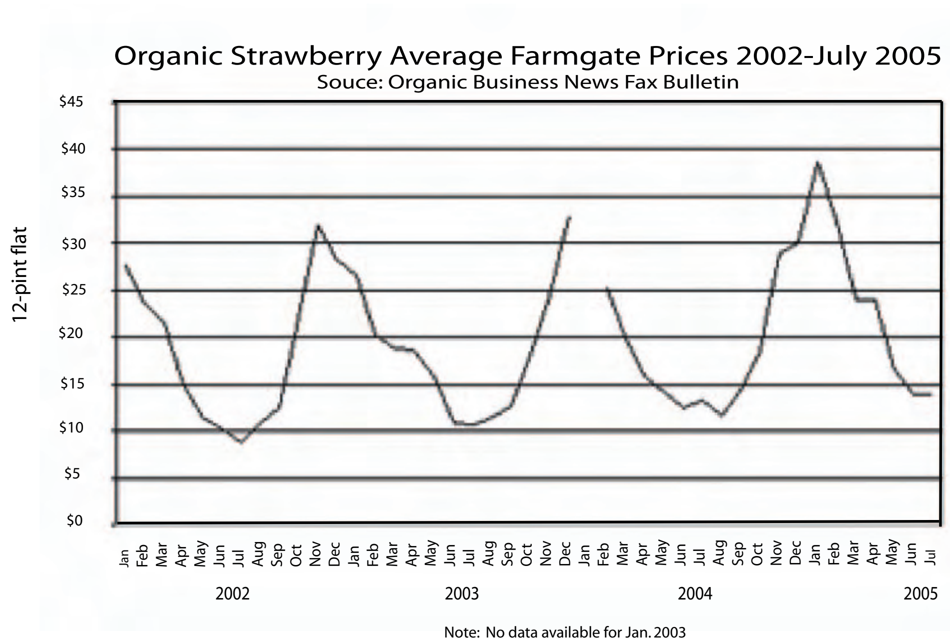
California research shows that at median organic production levels, profitable organic production can begin at an average price of

Table 1. Sample Organic Strawberry Production Costs and Returns ($ per acre), Central California Coast, 2003 (Bolda et al., 2003)	
GROSS RETURNS	
3,750 12-pound trays @ $8.50	$31875
OPERATING COSTS	
Transplants	$1323
Fertilizers	$1114
Irrigation	$704
Insect & Disease Control	$778
Materials	$163
Assessment Fees	$237
Harvest Materials	$6938
Harvest Labor	$1500
Machine Labor	$639
Non-machine Labor	$12399
Fuel, lube, repairs	$273
Interest on operating capital	$881
CASH OVERHEAD COSTS	
Insurance, taxes, land rent, etc.	$2544
NON-CASH OVERHEAD	
Buildings, machinery, equipment	$513
TOTAL COSTS	$30006
NET RETURNS	$1869

$8.00 to $8.50 per 12-pound tray. (Swezey, 2004b) Since a 12-pint flat weighs about 10.25 pounds, profitable organic production at median organic production levels would begin at an average price of about $6.80 to $7.25 per flat. Prices for a 12-pint flat were reported in the *Organic Business News Fax Service* reports as averaging about $14 farmgate in June and July of 2005, indicating that profitable production is quite possible. In areas where local market demand is strong and a high proportion of the crop is sold directly to the consumer, prices tend to be higher.

As is clear from the chart below, organic strawberry prices generally drop during the April to August period. Use of season-extension techniques to bring strawberries to market during other periods of the year can allow producers to capture some of the higher out-of-season prices.

Prices for fresh-market strawberries have been relatively stable in recent years because of increasing demand. However, organic price premiums are declining as larger growers get into organic production, marketing and distribution systems improve, and a larger supply of organic berries reaches the market. For instance, in Monterey County, California, a top strawberry-producing area, price premiums for organic



strawberries went from $0.75 per pound in 2001 to $0.11 per pound in 2002. (Monterey County Agricultural Commission, 2003)

Marketing

Four basic marketing alternatives are available to the strawberry grower: wholesale markets, cooperatives, processing firms, and direct sales to retail outlets or consumers.

In wholesale marketing, either you or a shipper can take your crop to the market. Shippers generally sell and transport strawberries for a predetermined price. Wholesale marketing is subject to price fluctuations and is not usually very profitable, compared to direct marketing. Jim Cochran of Swanton Berry Farm in California, says, "I consider myself lucky to get five percent of gross. So, on a twenty-dollar flat of strawberries, (there is) a dollar for the company to keep." (Inouye and Warner, 2001). Marketing cooperatives generally use a daily pooled cost and price, which spreads price fluctuations among all participating producers. Depending on your location and size, processors may or may not be a marketing option. Processors are less likely to contract with small-acreage growers.

If you are interested in exploring wholesale or processing markets, a good place to start is the Organic Trade Association's Organic Pages Online directory at *www.theorganicpages.com/topo/index.html*. Using this directory, you can locate organic strawberry buyers and contact them to learn more about potential opportunities.

Strawberries are successfully direct-marketed in a variety of ways, including farmers' markets, roadside stands, and pick-your-own (PYO) operations. With pick-your-own operations, you save on harvest costs, but you must also be willing to accept some waste. The trend in recent years has been toward an increase in pre-picked strawberry sales at the farm, and a reduced reliance on pick-your-own marketing. (Poling and Monks, 1994) When Pritts *et al.* compared the profitability of retailed berries picked by hired hands to marketing with a pick-your-own (PYO) strategy, profits were far lower in the PYO system. (Pritts et al., 1999). Poor picking by inexperienced customers was assumed to reduce yield in the PYO by 10 percent. The PYO's savings in harvest labor were not outweighed by the lower price charged to the consumer. For more information on PYOs, including the results of a survey of PYO strawberry customers, go to *www2.ncsu.edu/unity/lockers/users/c/cdsafley/are22.PDF*.

Local restaurants and retailers such as grocery or health-food stores are another possible market, but you must take the time to contact produce managers and provide good-quality strawberries when stores require them.

For more information on direct-marketing options, see the ATTRA publications *Direct Marketing*, *Farmers' Markets*, *Community Supported Agriculture*, *Selling to Restaurants* and *Entertainment Farming and Agri-Tourism*. For information on organic markets, see ATTRA's *Organic Marketing Resources*.

Other ATTRA Publications of Interest

- *Overview of Organic Fruit Production* Fertilization, pests, weed control, obstacles
- *Biointensive Integrated Pest Management* Uses, benefits, monitoring, economic thresholds, planning, tools & options, microbial pesticides

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For a free (single) copy of the booklet, contact:
California EPA-Dept. of Pesticide Regulation
Environmental Monitoring and
Pest Management Branch
1020 N. Street, Room 161
Sacramento, CA 95814-5624
916-324-4100
www.cdpr.ca.gov/docs/ipminov/bensuppl.htm

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Further Resources

Print Resources

Cooperative Extension. *Almost every state's Cooperative Extension Service has one or more publications on strawberries, most of them free. Contact your county office. To find your county office online go to:*

www.csrees.usda.gov/Extension/index.html if you do not have access to the Internet, look in your phone book or call ATTRA.

Funt, R., M. Ellis, and C. Welty (eds.). 1997. Midwest small fruit pest management handbook, Bulletin 861. Ohio State University, Wooster. 181 p.
$5.50 softbound, $11.00 hardbound plus $3.85 postage from:
Extension Publications
385 Kottman Hall
2021 Coffey Rd.
Columbus, OH 43210-1044
614-292-1607.

Kovach, J., W. Wilcox, A. Agnello, and M. Pritts. 1990. Strawberry scouting procedures. Cornell Cooperative Extension, Ithaca, New York. 53 p.
Contact:
NRAES, Cooperative Extension
152 Riley-Robb Hall
Ithaca, NY 14853-5701

Maas, J.L. (ed.). 1987. Compendium of strawberry diseases. American Phytopathological Society, St. Paul, Minnesota. 138 p.
$37 plus $5 shipping and handling from:
APS Press
St. Paul, MN 55121-2097
800-328-7560

Organic Business News *offers current prices for organic crops (fresh fruits, vegetable and herbs, dairy, grains, beans, and oilseeds) on a weekly basis through its* Organic Commodity Price Fax Bulletin. *Annual subscriptions (50 issues) are $205 by fax, $110 by U.S. mail. Visit the Web site for information on subscription discounts.*
Contact:
Organic Business News
Hotline Printing and Publishing
P.O. Box 161132
Altamonte Springs, FL 32716
407-628-1377
407-628-9935 FAX

DnnsClnk@cs.com
www.obn.hotlineprinting.com

Pritts, M., and D. Handley (eds.). 1998. The strawberry production guide for the Northeast, Midwest, and Eastern Canada, NRAES-88. NRAES, Ithaca, New York. 162 p.
$45.00 per copy (plus shipping and handling) from
NRAES, Cooperative Extension
152 Riley-Robb Hall
Ithaca, NY 14853-5701

Proceedings of the North American Strawberry Growers Association
(Proceedings of the annual meetings).
Contact:
Erin Bruzewski, Executive Secretary
2400 Beck Rd.
Howell, MI 48843

Strand, L. L. 1993. Integrated pest management for strawberries. University of California Pub. 3351. University of California, Oakland, California. 142 p.

Electronic Resources

California Strawberry Commission
www.calstrawberry.com/

Midwest Small Fruit Specialists
www.ag.ohio-state.edu/~sfgnet

North American Strawberry Growers
www.nasga.org/

North Carolina Cooperative Extension Small Fruit
www.ces.ncsu.edu/hil/smfruit-index.html

Northwest Berry & Grape Info Net
http://berrygrape.orst.edu

Oregon Strawberry Commission
www.oregon-strawberries.org/

Organic Strawberry Production Systems
www.hort.cornell.edu/department/faculty/pritts/organic.html

2005 Southeast Regional Strawberry Plasticulture Production Guide
www.smallfruits.org/SmallFruitsRegGuide/Guides/2005culturalguidepart1bs1.pdf

Strawberry Information Link
www.citygardening.net/strawinfo/

Strawberry Production in Florida
http://edis.ifas.ufl.edu/BODY_CV134.html

Strawberry WebRing
http://F.webring.com/hub?ring=strawberry

Plant Sources:

AG Ammon Nursery Inc.
P.O. Box 488
Chatsworth, NJ 08019
609-726-1370
609-726-1270 FAX

Allen Plant Company
P.O. Box 310
Fruitland, MD 21826-0310
410-742-7123
410-742-7122
410-742-7120 FAX

Boston Mountain Nurseries
20189 N Hwy 71
Mountainburg, AR 72946
501-369-2007
501-369-2007 FAX
pense@valuelinx.ne

Burnt Ridge Nursery
432 Burnt Ridge Rd
Onalaska, WA 98570
360-985-2873
360-985-0882 FAX
burntridge@myhome.net
http://landru.myhome.net/burntridge/

Cooley's Strawberry Nursery
P.O. Box 472
Augusta, AR 72006
501-724-5630

Coulter Farms
3871 N Ridge Rd
Lockport, NY 14094
716-433-5335
716-434-5700 FAX
coultfarms@aol.com

Daisy Farms
28355 M-152
Dowagiac, MI 49047
616-782-6321
616-782-7131 FAX
daisyfarms@beanstalk.net
www.daisyfarms.net

DeGrandchamp's Nursery
15575 77th St
South Haven, MI 49090
616-637-3915
616-637-2513
info@degrandchamps.com
www.degrandchamps.com

Edible Forest Nursery
Box 260195
Madison, WI 53726
edforest55@hotmail.com

Edible Landscaping
P.O. Box 77
Afton, VA 22920
434-361-9134
434-361-1916 FAX
www.ediblelandscaping.com

Fall Creek Farm & Nursery Inc.
39318 Jasper-Lowell Rd
Lowell, OR 97452
541-937-2973
541-937-3373 FAX
berries@fallcreeknursery.com
www.fallcreeknursery.com

Hartmann's Plant Company
P.O. Box 100
Locata, MI 49063
616-253-4281
616-253-4457 FAX
info@hartmannsplantcompany.com
www.hartmannsplantcompany.com

Indiana Berry & Plant Co, LLC
5218 W 500
South Huntingburg, IN 47542
812-683-3055
812-683-2004 FAX
berryinfo@inberry.com
www.inberry.com/index2.html

Jersey Asparagus Farms Inc.
105 Porchtown Rd
Pittsgrove, NJ 08318
800-499-0013
856-358-6127 FAX
jaf@jafinc.com
www.jerseyasparagus.com

KM Spooner Farms Inc.
9710 SR 162 E
Puyallup, WA 98374
253-845-5519
253-845-5717 FAX
spoonerkm@aol.com
www.spoonerfarms.com

Krohne Plant Farms Inc.
65295 CR342
Hartford, MI 49057
616-424-5423
616-424-3126 FAX

Lassen Canyon Nursery Inc.
1300 Salmon Creek Rd
Redding, CA 96003
530-223-1075
530-223-6754 FAX
info@lassencanyonnursery.com
www.lassencanyonnursery.com

Lewis Nursery and Farms Inc.
3500 NC Hwy 133
West Rocky Point, NC 28457
910-675-2394
910-602-3106 FAX

Norcal Nursery Inc.
P.O. Box 1012
Red Bluff, CA 96080
530-527-6200
530-527-2921 FAX

Northwind Nursery & Orchards
7910-335th Ave NW
Princeton, MN 55371
612-389-4920
northwind9@juno.com

Nourse Farms Inc.
41 River Rd
South Deerfield, MA 01373
413-665-2658
413-665-7888 FAX
info@noursefarms.com
www.noursefarms.com

One Green World
28696 S Cramer Rd
Molalla, OR 97038
503-651-3005
800-418-9983 FAX
www.onegreenworld.com

Oregon Exotics Nursery
1065 Messinger Rd
Grants Pass, OR 97527
541- 846-7578
541-846-9488 FAX

Raintree Nursery
391 Butts Rd
Morton, WA 98356
360-496-6400
888-770-8358 FAX
www.raintreenursery.com

Saint Lawrence Nurseries
325 State Hwy 345
Potsdam, NY 13676
315-265-6739
trees@sln.potsdam.ny.us
www.sln.potsdam.ny.us

Sakuma Bros Farms Inc.
P.O. Box 427
Burlington, WA 98233
360-757-6611
360-757-3936 FAX
craigf@sakumabros.com

Southmeadow Fruit Gardens
P.O. Box 211
Baroda, MI 49101
616-422-2411
616-422-1464 FAX
smfruit@aol.com
www.southmeadowfruitgardens.com

Spooner Farms
9710 SR 162 East
Puyallup, WA 98374
800-532-5487

Tower View Nursery Inc.
70912 CR 388
South Haven, MI 49090
616-637-1279
616-637-6257 FAX
mnnelson@btc-bci.com

Tripple Brook Farm, Inc.
37 Middle Rd
Southampton, MA 01073
413-527-4626
413-527-9853 FAX
info@tripplebrookfarm.com
www.tripplebrookfarm.com

Virginia Berry Farm
Box 4
Ruther Glen, VA 22546
800-448-2312
804-448-4430 FAX
berryman@bealenet.com

Weeks Berry Nursery
6494 Windsor Island Rd N
Keizer, OR 97303
503-393-8112
503-393-2241 FAX
plants@weeksberry.com
www.weeksberry.com

Whitman Farms
3995 Gibson Rd NW
Salem, OR 97304
503-585-8728
503-363-5020 FAX
lucile@whitmanfarms.com
http://whitmanfarms.com

Appendix A: Sources of Thermal Weeders

Handheld Flamers

BernzOmatic 800-654-9011

Flame Engineering, Inc.
P.O. Box 577
LaCrosse, KS 67548
888-388-6724
785-222-3619 FAX.
flame@awav.net
www.flameeng.com
Red Dragon

Peaceful Valley Farm Supply
P.O. Box 2209
Grass Valley, CA 94945
888-784-1722 (toll-free)
contact@groworganic.com
www.groworganic.com
Flamers and supplies

Rittenhouse & Sons
RR#3, 1402 Fourth Ave., St. Catharines
ON, Canada L2R 6P9
800-461-1041 (toll-free)
prosales@rittenhouse.ca
www.rittenhouse.ca/asp/menu.asp?MID=88
Weed Torch

Row Crop Flamers

Flame Engineering, Inc.

Two- to eight-row flamers for tractor operation (see above).

Thermal Weed Control Systems, Inc.
N1940 State Hwy 95
Neillsville, WI 54456
715-743-4163
jonesconsulting@juno.com

Four- to eight-row flamers for tractor operation, hooded models

Flame Weeders
Rt. 76, Box 28
Glenville, WV 26351
304-462-5589
flame-weeders@juno.com
www.flameweeders.cjb.net

Push along

Infrared Weeders

Forevergreen
19974 12 Avenue, Langley
BC, Canada V2Z1W3
604-534-9326
info@chemfree-weedcontrol.com
www.chemfree-weedcontrol.com

Ecoweeder, push along and handheld

Rittenhouse & Sons

Infra-Weeder, push along and handheld (see above)

Steamers

Sioux Steamer
One Sioux Plaza
Beresford, SD 57004
605-763-3333
888-763-8833 (toll-free)
605-763-3334 FAX
www.sioux.com

Hot Foam

Waipuna U.S.A
715 N Independence
Romeoville, IL 60466
630-514-0364
jeffw@waipuna.com

OESCO, Inc.
P.O. Box 540, Route 116
Conway, MA 01341
413-369-4335
800-634-5557 (toll-free)
413-369-4431 FAX
info@oescoinc.com

Aquacide

Infrared and Hot Water

Sunburst
P.O. Box 21108
Eugene, OR 97402
541-345-2272
info@thermalweedcontrol.com
www.thermalweedcontrol.com/

(adapted from Quarles, W. 2004. *The IPM Practitioner*. May/June. p. 8.)

Appendix B: Recommended Strawberry Varieties

There are many short-day and day-neutral varieties from which to choose. The day-neutral varieties are: Aromas, Diamante, Fern, Hecker, Irvine, Muir, Ogallala, Ozark Beauty, Pacific, Seascape, Selva, Tillicum, Tribute and Tristar. Choose those that are adapted to your area and desired production systems. Remember always to check with the local extension agent when choosing varieties for your area and plant more than one variety if you can.

Alaska: Brighton, Fern, Hecker, Irvine, Mrak, Muir, Ozark Beauty, Ogallala, Quinault, Selva, Streamliner, Superfection, Tillicum, Tribute, Tristar, Yolo.
www.uaf.edu/coop-ext/publications/freepubs/HGA-00235.pdf

Arkansas: Cardinal, Carmarosa, Chandler, Delmarvel, Earliglow, Lateglow, Noreaster, Sweet Charlie, Tribute, Tristar.
www.uaex.edu/Other_Areas/publications/PDF/FSA-6103.pdf

California: Albion, Aromas, Camarosa, Camino Real, Chandler, Diamante, Gaviota, Oso Grande, Pacific, Seascape, Selva, Ventana.
www.calstrawberry.com/commission/varieties.asp

Colorado: Catskill, Empire, Fairfax, Fort Laramie, Geneva, Guardian, Marlate, Ogallala, Ozark Beauty, Quinault, Redchief, Red Rich, Redstar, Robinson, Superfection, Tribute.
www.colostate.edu/Depts/CoopExt/4DMG/VegFruit/Fruits/smlfruit.htm

Florida: Calibrate, Camarosa, Florida Belle, Florida 90, Rosa Linda, Sequoia, Sweet Charlie, Strawberry Festival, Tioga.
www.napa.ufl.edu/2000news/newberri.htm

Georgia: Apollo, Delite, Cardinal, Earliglow, Sunrise, Surecrop.
www.caes.uga.edu/news/kits/gaagres/commodities/strawberries.html

Idaho: Allstar, Benton, Blomidon, Catskill, Cavendish, Earliglow, Fort Quinault, Glooscap, Guardian, Honeoye, Jewel, Laramie, Lateglow, Lester, Micmac, Redchief, Scott, Shuksan, Surecrop, Totem, Tribute, Tristar.
www.extension.uidaho.edu/idahogardens/fvh/straw.htm

Illinois: Allstar, Annapolis, Delmarvel, Earliglow, Honeoye, Jewel, Kent, Seneca, Tribute, Tristar.
www.urbanext.uiuc.edu/strawberries/growing.html

Indiana: Delite, Earliglow, Fort Laramie, Guardian, Sunrise, Ozark Beauty, Redchief, Sparkle, Surecrop.
www.hort.purdue.edu/hort/courses/HORT414/Strawberrylecture.html

Iowa: Annapolis, Cavendish, Delmarvel, Honeoye, Jewel, Kent, Mohawk, Primetime, Winona.
www.ag.iastate.edu/farms/2001reports/se/StrawberryVarietyTrial.pdf

Kansas: Allstar, Earliglow, Guardian, Northeaster, Ogallala, Ozark Beauty, Primetime, Redchief, Tribute, Tristar.
www.oznet.ksu.edu/library/hort2/mf598.pdf

Kentucky: Camarosa, Chandler, Jewel, Northeaster, Sweet Charlie.
www.ca.uky.edu/agc/pubs/pr/pr410/small.htm

Maine: Allstar, Bounty, Catskill, Earliglow, Guardian, Lateglow, Midway, Mira, Mohawk, Northeaster, Surecrop.
www.umext.maine.edu/onlinepubs/htmpubs/2184.htm

Massachusetts: Catskill, Earlidawn, Fletcher, Guardian, Midway, Raritan, Redchief, Sparkle, Surecrop.

Michigan: Annapolis, Earliglow, Honeoye, Redchief, Glooscap, Allstar, Jewel, Bounty, Tribute, Tristar.
http://webl.msue.msu.edu/vanburen/strawvar.htm

Minnesota: Cavendish, Kent, Mesabi, Winona.
www.extension.umn.edu/extensionnews/2002/NewStrawberryVarieties.html

Missouri: Allstar, Cardinal, Earliglow, Guardian, Honeoye, Jewel, Lateglow, Ogallala, Ozark Beauty, Redchief, Sparkle, Surecrop, Tribute, Tristar.
http://muextension.missouri.edu/xplor/agguides/hort/g06135.htm

New Hampshire: Allstar, Cavendish, Cornwallis, Earliglow, Redchief, Sparkle.
http://extension.unh.edu/Pubs/HGPubs/growstra.pdf

New Jersey: Delmarvel, Earliglow, Guardian, Latestar, Lester, Northeaster, Raritan, Redchief, Sparkle, Tribute, Tristar.

New Mexico: Everbearing ('Superfection'), Fern, Fort Laramie, Gem, Guardian, Ogallala, Ozark Beauty, Quinault, Robinson, Selva, Sequoia, Streamliner, Surecrop, Tribute, Tristar, Tufts.
www.cahe.nmsu.edu/pubs/_h/h-324.html

New York: Allstar, Bounty, Cavendish, Delite, Earliglow, Fletcher, Guardian, Honeoye, Jewel, Kent, Raritan, Redchief, Scott.
www.cce.cornell.edu/counties/Suffolk/grownet/SMFRUIT/strawberry.htm

North Carolina: Camarosa, Chandler, Gaviota, Gem Star, Oso Grande, Sweet Charlie, Treasure.
www.ncstrawberry.org/docs/ProductionMethods.htm

North Dakota: Dunlap, Ft. Laramie, Gem, Honeoye, Redcoat, Stoplight, Trumpeter.
www.ext.nodak.edu/extpubs/plantsci/hortcrop/h16w.htm

Ohio: Delite, Earliglow, Guardian, Kent, Lateglow, Lester, Midway, Redchief, Surecrop, Tribute.
http://ohioline.osu.edu/hyg-fact/1000/1424.html

Oklahoma: Albritton , Allstar, Arking, Blakemore, Canoga, Cardinal, Chandler, Delite, Earliglow, Fletcher, Guardian, Holiday, Hood, Lateglow, Luscious Lady, Ozark Beauty, Scott, Spring, Sunrise, Surecrop, Tennessee Beauty, Trumpeter.

Oregon: Benton, Fern, Ft. Laramie, Hecker, Hood, Olympus, Ozark Beauty, Puget Reliance, Quinault, Rainier, Redcrest, Selva, Sumas, Tillikum, Tristar, Totem.
http://eesc.orst.edu/agcomwebfile/edmat/html/ec/ec1307/ec1307.html#anchor163809

Pennsylvania: Allstar, Annapolis, Cavendish, Delite, DelMarvel, Earliglow, Guardian, Honeoye, Idea, Jewel, Kent, Lateglow, Latestar, Lester, Mohawk, Northeaster, Primetime, Raritan, Redchief, Seneca, Settler, Sparkle, Tribute, Tristar, Veestar.

South Carolina: Albritton, Apollo, Cardinal, Chandler, Delite, Douglas, Earliglow, Florida 90, Sunrise, Surecrop, Tioga.

Texas: Allstar, Cardinal, Chandler, Douglas, Pajaro, Sequoia.
http://aggie-horticulture.tamu.edu/hillcountry/Strawberries/intro.html

Utah: Fort Laramie, Guardian, Hood, Ozark Beauty, Robinson, Selva, Sequoia, Surecrop, Tristar.

Virginia: Allstar, Delite, Delmarvel, Earliglow, Honeoye, Lateglow, Ozark Beauty, Redchief, Sunrise, Surecrop, Tribute, Tristar.
www.ext.vt.edu/pubs/envirohort/426-840/426-840.html

Washington: Hood, Nanaimo, Puget Reliance, Quinault, Rainier, Selva, Shuksan, Tillicum, Totem, Tribute, Tristar.
http://gardening.wsu.edu/library/smfr009/smfr009.htm

Wisconsin: Annapolis, Cavendish, Crimson Fern, Fort Laramie, King, Earliglow, Glooscap, Honeoye, Jewel, Kent, Lategrow, Lester, Mesabi, Mira, Ogallala, Ozark Beauty, Raritan, Redchief, Seascape, Selva, Seneca, Sparkle, Tribute, Tristar, Winona.
http://s142412519.onlinehome.us/uw/pdfs/A1597.PDF

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