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Peaches: Organic and Low-Spray Production

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This publication describes the major diseases and insect pests of peaches and discusses organic or least-toxic control options for each. It emphasizes the considerable climatic differences between the arid West, which is relatively amenable to organic peach production, and the humid East, where it is more difficult to grow peaches without synthetic fungicides and insecticides. It profiles a successful organic peach grower in California, discusses new-generation synthetic and organic pesticides, and describes organic peach research for the East, as well as a model reduced-spray program for the East. A "post-script" examines the dilemma of the environmentally conscious consumer in regard to peaches. The last section lists additional references, publications, and electronic information sites.

Contents

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Introduction

Peaches can be difficult to produce even with good conditions and synthetic pesticides. At least two key insect pests and several serious diseases present formidable obstacles to organic or low-spray production. Nevertheless, with proper management, disease-resistant cultivars, and a good site, growers can greatly reduce—and in some cases eliminate—their reliance on synthetic pesticides. Because of new directions in research emphasizing biological and other alternative pest and disease controls, the future looks promising for low-spray and organic peach production.

Many considerations and practices are the same for both low-spray/organic and conventional peach growers. For instance, all growers need to make variety choices with cold-hardiness and chilling requirements in mind. Also, pruning and training will be approximately the same for all kinds of culture. Information on these topics is available from sources such as the Cooperative Extension Service, state peach production councils, orcharding texts, and trade magazines.

Organic approaches to managing fertility, weed control, and orchard-floor vegetation apply across tree-fruit crops (apples, peaches, pears, cherries, plums). For general information on organic orchard practices, see ATTRA's *Tree Fruits: Organic Production Overview.* This publication, by contrast, focuses primarily on controlling insect pests and diseases in peach production.

Disease problems that can be economically damaging for peach growers include brown rot, peach leaf curl, plum pox, bacterial spot, peach scab, peach mosaic virus, peach tree short life, and peach re-plant disorder. Pests that cause problems for peach growers include Oriental fruit moth, plum curculio, peach tree borers, peach twig borers, nematodes, and plant bugs (e.g., stink bugs). These problems are addressed below. Information on other pests and diseases of local or intermittent importance is usually available from regional Cooperative Extension publications.

Also, ATTRA's Biorationals: Ecological Pest Management database can provide organic and least-toxic options for all of the major peach diseases and pests.

Related ATTRA Publications
www.attra.ncat.org

Tree Fruits: Organic Production Overview

Apples: Organic Production Guide

Organic Pear Production

Grapes: Organic Production

Postharvest Handling of Fruits and Vegetables

Farmscaping to Enhance Biological Control

Notes on Compost Teas

Use of Baking Soda as a Fungicide

Biointensive Integrated Pest Management

A Note on Terms

The term *low-spray* has no precise definition. It simply refers to a reduced-synthetic-pesticide spray program relative to a region's prevailing conventional practices. For example, instead of eight to 12 spray applications during a growing season, a low-spray program using sophisticated monitoring and other integrated pest management (IPM) techniques may consist of only two to four.

The terms *organic* and *organically grown* have precise legal definitions. Organic production and marketing of food crops is regulated at the federal level. Before land can be certified organic, it must be free of synthetic pesticides and commercial fertilizers for three years, and thereafter only pest-control and fertilizer inputs approved for organic production may be used. Producers who want to label or market their produce as organic must be certified by an agent accredited by USDA's National Organic Program. For more information, see the ATTRA publication *Organic Certification*. **If your operation is certified organic or if you are seeking certification, check with your certifier before using any pest-control material mentioned in this publication (whether we describe it as "organic" or not) to confirm its acceptability for organic production.**

Geographic Factors that Affect Disease and Pest Incidence

Geographic location and climate play a particular role in the incidence and severity of peach diseases and pests. Primary threats in one growing area may be of little concern in regions where the weather is drier, insects or diseases are not established, or the growing season is shorter. Resistant cultivars, especially those suited to a specific climate, can also reduce the impact of certain diseases.

As an example, the plum curculio, a key pest of many tree fruits, is not present west of the so-called "tree line" (running roughly from Fort Worth, Texas, through Fargo, North Dakota). The curculio's absence—coupled with reduced disease pressure in much of the arid West—facilitates organic peach production. The peach twig borer, however, is a greater problem west of the Rocky Mountains than in the East. Meanwhile, in the high-rainfall areas of the Pacific Northwest and coastal California, peach leaf curl is a common disorder.

Eastern growers must contend with plum curculio, bacterial spot, and increased incidence of fungal diseases. At present, commercial-scale organic production of peaches in the East is very difficult, largely because of the plum curculio and the brown rot fungus, which is endemic under wet, humid conditions. However, some of the techniques and new-generation pest control products discussed in this publication can improve the opportunity for low-spray and organic peach production in the East. Appendix 1: Hypothetical Pest-Control Calendar for an Eastern Organic Peach Grower provides a summary of a possible approach for eastern growers. Eastern commercial-scale growers wanting to reduce the amount of pesticides sprayed on their peach crop can take some encouragement from studies conducted by agricultural researchers in the Southeast. Research from Clemson indicated years ago that under proper management the number of annual sprays could be reduced from 12 to six, resulting in a savings of almost $50 (in 1984 dollars) per acre (Gorsuch and Miller, 1984). Details of this management program are presented in the box "A Reduced Spray Program for Eastern Growers," on page three. Subsequently, a consortium of various southeastern university

A Reduced Spray Program for Eastern Growers

More than 25 years ago Clemson, University Extension specialists Clyde Gorsuch and R. W. Miller reported research that would allow peach orchardists to cut the standard number of pesticide applications in half, from 12 to six, provided they met certain criteria. Gorsuch's and Miller's basic principles are still relevant, and better fungicides and insect monitoring techniques available today might allow for reducing pesticide use even further.

They established several criteria for a minimal spray schedule:

- All trees are sprayed thoroughly and applications carefully adjusted to the proper stage of plant development (e.g., a "petal-fall" spray must be applied at petal fall);
- There are no sources of brown rot within a quarter mile (wild plums and unsprayed peaches are the main culprits to be eliminated);
- Anthracnose and powdery mildew are not a threat;
- Scab has been controlled in previous years;
- No resistance to Benlate or Topsin-M has been detected (newer fungicide options make this criterion a little less important than it was 15 years ago, though development of resistance to pesticides by pathogens must always remain a concern);
- The spray materials used are chosen according to weather conditions and disease development in the orchard;
- Weed control is excellent (unmown weeds and grass provide an ideal environment for spore production from peach mummies and provide habitat for catfacing insects like stink bugs); and
- Brush piles are destroyed before bloom.

A primary focal point of these criteria is sanitation in and near the orchard to remove sources of brown rot and insects. Early-season sprays for plum curculio still have to be applied, and if diseases other than brown rot and scab are a problem, the producer may have to adjust the spray schedule accordingly.

The authors cautioned that this is an effective program for good managers who are willing to scout the orchard on a weekly basis for brown rot, scab, other diseases, plum curculio, oriental fruit moth, Japanese beetles, and other potential pests. If problems appear, prompt application of a pesticide will probably be required to avoid economic loss. This reduced spray program should be attempted only when such prompt action can be taken.

(See also Appendix I: Hypothetical Pest-Control Calendar for an Eastern Organic Peach Grower.)

Brown rot is the single-largest hurdle to organic production of peaches in both the East and the West.

entomologists (Johnson et al., 2002) confirmed that careful monitoring for insect pests (coupled with pheromonal control of Oriental fruit moth) could reduce insecticide sprays from the usual seven to 12 to as few as one to four in some years.

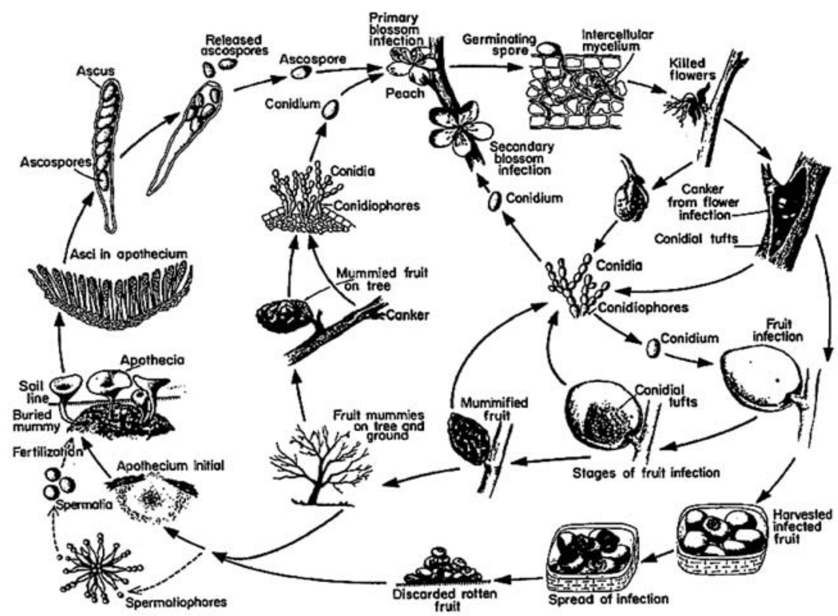
More recently, preliminary research being conducted at Rutgers University indicates that organic production in the East could be possible with individual bagging of fruit. Though most U.S. growers have deemed this uneconomical, it is being done commercially in China, Japan, and Spain. Furthermore, a changing marketplace with increasing demand for organic and locally grown produce could render this technique economically viable. See the box "Handbagging: Promising organic peach research in New Jersey" on page 18 for more details.

Diseases

Brown Rot

When peaches are grown under the warm, humid conditions conducive to fungal diseases, it can be difficult to forego the use of fungicides. Brown rot (causal organisms: *Monilinia fructicola* and *M. laxa*) is foremost among fungal diseases of peach, and peach producers struggle with it continually as it affects both fruit yield and quality, infesting blossoms, twigs, and fruit in all stages. Brown rot is less prevalent west of the Rocky Mountains than in the East, but even in the West brown rot can be troublesome in seasonably wet or foggy microclimates. Brown rot is the single-largest hurdle to organic production of peaches in both the East and the West.

Figure 1. Disease cycle of brown rot.



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Life-cycle information on brown rot is presented in Figure 1. Ideal conditions for infection arise during warm, rainy periods (70-77°F is optimum). Brown rot occurs as blossom blight early in the growing season. Two to three weeks before harvest, it infects the fruits as they soften and ripen, causing rot both at harvest and in storage—some of the infected fruit may not display symptoms until after harvest. Blossom blight during bloom is an indicator for extensive brown rot infections later in the season, although a wet year can produce heavy infections of brown rot from residual inoculum present in cankers and fruit, even without blossom blight (Brannen and Schnabel, 2002).

Brown rot on peach. Photo: A.R. Biggs, West Virginia University Extension

In the East, control of brown rot is complicated not only by higher rainfall and humidity but also by increased levels of insect feeding (especially by the plum curculio), which spread the inoculum and open the fruit to infection. Moreover, the presence of alternate hosts such as wild plums and other wild *Prunus* species can further aggravate the situation. Under such conditions, commercial-scale organic production of peaches is currently extremely difficult.

Cultural Considerations that Impact Brown Rot

Control of brown rot involves the integration of several tactics. Although not adequate for brown rot control by themselves, cultural practices and orchard sanitation are the first line of defense.

Planting-site selection and pruning are critical to providing sufficient air circulation and sunlight penetration within the canopy. In terms of brown rot control, this helps by speeding the drying of fruit and plant surfaces, thereby inhibiting germination and growth of the brown rot fungus. A slight slope will enhance air drainage. Another means of enhancing air movement through the orchard is to site the orchard some distance from surrounding woods. This really has a two-fold effect on brown rot in the orchard: 1) air movement is not blocked or slowed by the presence of surrounding trees; and 2) the plum curculio, which spreads brown rot, is kept somewhat at bay because it overwinters in the forest-floor leaf litter and moves from the woods into the orchard during bloom and petal fall in the spring.

Pruning to open the tree to sunlight penetration and good air circulation facilitates rapid drying of the foliage and flowers after rain or overhead irrigation. Thinning branches to open the center of the tree is a good practice—this can be done in July, as well as during the regular dormant-season pruning.

Orchard sanitation practices that help control brown rot include pruning out and removing infected twigs and cankers and disposing of dropped, culled, or mummified fruit. Andrew Brait of Full Belly Farm in California claims that being “fastidious about orchard sanitation, removing all dropped fruit and mummies” in their six acres of peaches is the center and mainstay of their brown rot control strategy (though they do augment with up to three bloom applications of lime sulfur or cuprous oxide) (Brait, 2010).

Among the tree fruits, peaches require comparatively more nitrogen to stay productive, but University of California researchers determined that excessive nitrogen fertilization increases fruit susceptibility to brown rot (Burnham, 1994). They also found that pre-harvest sprays of calcium reduced brown rot infection compared to non-sprayed trees but were not equal to fungicidal control.

Peach-cultivar resistance to brown rot is not highly developed, yet some differences between cultivars do exist. For example, research on peach-cultivar susceptibility to brown rot fungus by the Kearneysville Tree Fruit Research and Extension Center at West Virginia University reveals that, of 44 cultivars observed, only three—Babygold 5 (a canning peach), Elberta, and Glohaven—had any detectable levels of resistance (but not enough to forego sprays). The remaining cultivars were "susceptible" or "highly susceptible." www.caf.wvu.edu/kearneysville/tables/brownrotsus.html

Spraying for Brown Rot Control

Organic growers have traditionally relied on sulfur or sulfur-containing fungicides to control brown rot, and nothing better has yet been developed. The first application of sulfur should be done at the "pink" stage, just before the petals open. Applications should be repeated at seven-day intervals, especially if rain occurs, for a total of three applications. Two other applications should also be made—one at petal drop, the other at sepal drop (usually about 10 to 14 days after petal drop). The crop is still susceptible to infection later in the season, but treatments during the early "critical" stage will reduce the amount of crop loss without leaving a sulfur residue at harvest. When the weather is hot and dry, the need to spray is not as great. Conversely, since sulfur is only a protectant and not a treatment (it has to be on the plant tissues before and during an infection period), a period of frequent, heavy rains could require the orchardist to spray more often.

Augmenting sulfur with Surround™ WP Crop Protectant provides better disease control than sulfur alone, according to Dr. Michael Glenn at USDA's Appalachian Fruit Research Station in Kearneysville, West Virginia (Glenn et al., 2001). Derived from processed kaolin clay, Surround is an Organic Materials Review Institute (OMRI)-approved pest control product shown to control or suppress certain insects and diseases. In 2010 Dr. Glenn told ATTRA that although the sulfur-Surround mix certainly works in helping to suppress brown rot, it shouldn't be used much past the 3-cm (roughly 1-inch) fruit-diameter stage. The Surround is so slow to weather off of the fuzzy fruit that the residue becomes a serious cosmetic issue for consumers (ironically, the consumer might mistake the essentially non-toxic Surround residue for pesticide residue). Accordingly, the research was discontinued, but the principle is still sound and the possibility exists for a direct-marketing orchardist to educate clientele about the nature of such residues.

Peach-cultivar resistance to brown rot is not highly developed.

Carl Rosato of Woodleaf Farm near Oroville, California, received funding from the Organic Farming Research Foundation (OFRF), the Kokaro Foundation, and the University of California to test "natural" anti-fungal substances on his 3-acre peach orchard during the 1992-1994 growing seasons. The substances included compost tea, hydrogen peroxide, kelp sprays, grapefruit seed extract, rock dusts, a pink mucoid yeast, copper fungicides, vinegar, and combinations of these. In descending order, better control was obtained with:

- Algrow kelp mixed with basalt rock dust (55% marketable fruit)
- Algrow kelp alone (42%)
- compost tea + pink mucoid yeast (41%)
- hydrogen peroxide + pink mucoid yeast (40%)

Rosato's full research report, *Peach Brown Rot Control* (OFRF Grant 92-96), is available on the OFRF website (Rosato, 1994).

In 2011, Rosato provided ATTRA with an update on his brown-rot-control strategy. First, it is helpful to understand that the part of California where his farm is located has a Mediterranean climate—a wet winter season alternating with a dry warm growing season—which is ideal for fruit production. Secondly, Rosato grows about 45 varieties of peaches selected for fresh-market quality as well as brown rot resistance.

For brown rot control, Rosato relies primarily on a spray mixture of micronized sulfur plus rock dust (e.g., Azomite™). However, for a foliar spray that provides both nutritive and pest-control benefits, Rosato likes to blend a foliar "brew" for all pre-bloom, bloom, and post-bloom sprays. A common tank mixture (per acre) may include: six to eight pounds Azomite; five to 15 pounds micronized sulfur; five pounds soluble potassium sulfate; one pound Solubor™ (boron); one pound kelp; and Thermax 70™. For the pre-bloom spray, he adds copper specifically for brown rot control. Bloom sprays begin at one-third bloom and proceed every five to seven days all the way through petal fall, for a total of two to three sprays. Post-bloom sprays depend on the weather. When rain or humidity approaches, he religiously applies a brew spray as a prophylactic before the weather arrives, and again every five to seven days depending on environmental conditions. Brown rot pressure decreases dramatically when it is hot and dry—around 85 to 90° F.

Harvested fruit is also susceptible to brown rot infection.

OFRF also funded studies at Oregon State University, conducted by Hans Wittig and Dr. Jay Pscheidt between 1992 and 1995, that looked at anti-fungal properties of aerated compost tea, seaweed extracts, micronized sulfur, a yeast *(Aureobasidium pullulans)*, and M-Pede™ insecticidal soap. Of these, insecticidal soap, sulfur, and a yeast plus seaweed mixture were most effective in suppressing peach brown rot in the wet spring and arid summer conditions of western Oregon. A synopsis of Wittig's research is available on the OFRF website (Wittig and Pscheidt, 1996).

A relatively new biofungicide, Serenade™ (*Bacillus subtilis,* QST 713 strain), is OMRI approved and has demonstrated laboratory and field control of brown rot in California. However, in Massachusetts, researchers found Serenade "relatively ineffective for controlling fungal diseases under Northeast conditions" (see www.umass.edu/fruitadvisor/2009/netfmgsan156/5-characteristics.pdf). Similarly, in British Columbia, Canadian researchers found Serenade "suppresses"—but does not control—brown rot (see www.agf.gov.bc.ca/cropprot/tfipm/brownrot.htm). For more information on Serenade, see the AgraQuest website at www.agraquest.com

Other materials registered for brown rot control are listed in ATTRA's Biorationals: Ecological Pest Management Database (though please note that simple registration does not imply a specific level of effectiveness under different conditions; for example, Serenade is registered for brown rot control in the entire United States but might only be effective under relatively low disease pressure, such as that in the West).

Post-Harvest Brown Rot Control

Harvested fruit is also susceptible to brown rot infection. To prevent infections at harvest and during storage, peaches should be picked and handled with care to avoid punctures and skin abrasions on the fruit. Any damaged fruit should be discarded, since wounds facilitate entry of the fungus. Rapid cooling or hydrocooling to remove field heat prior to refrigeration at 0 to 3° C will also help reduce infection (Agrios, 1978).

Hot water treatments hold some promise for post-harvest control of brown rot. The hot water treatment takes two basic forms: mist or dip. In both cases the water is 50 to 52° C (approximately 122° F), but the mist treatment lasts approximately 15 minutes, while the dip lasts only two to four minutes. Chlorinated water helps prevent post-harvest diseases, but note that USDA Organic Regulations (§ 205.605(b)) disallow chlorine use on food surfaces. For additional information *Postharvest Handling for Organic Crops* is available from the University of California Division of Agriculture and Natural Resources (publication 7254).

Peach Leaf Curl

Peach leaf curl, caused by the fungal organism *Taphrina deformans*, is a common disorder in peach and nectarine orchards, especially during wet springs. Infected leaves become misshapen, deformed, and necrotic, resulting in premature defoliation with subsequent re-sprouting of new leaves. This kind of stress reduces fruit yield and predisposes the tree to pest attack.

The life-cycle diagram in Figure 2 (page 8) shows that the infection period for leaf curl is when new leaves start emerging from buds in the spring. Spraying after the buds have opened is ineffective because infection takes place as the young leaves emerge, and the fungus develops inside the leaf.

Farmer Profile: Carl Rosato, Organic Peach Pioneer

(Parts of this profile are excerpted with permission from “Woodleaf Farm” in the Winter 1997-1998 edition of *California Certified Organic Farmers* newsletter; it has been updated and revised per an online interview with Rosato by ATTRA in 2011.)

Carl Rosato in his California peach orchard. Photo: Courtesy of Carl Rosato

If Carl Rosato ever decides to erect a sign at the entrance to his Woodleaf Farm, it should read “Home of the Pampered Peach.” Tucked onto a hillside near Lake Oroville [California] are three and a half acres of Carl’s trees, producing peaches with a near-legendary flavor.

Rosato’s fertility program would make any tree happy. When preparing a new orchard site, he starts with 50 tons per acre of organic matter and then adds limestone, gypsum, and kelp. Rosato, who is also a soil consultant, emphasizes that nutrition is a fundamental aspect of orchard management. He follows the Albrecht approach to mineral balancing and soil management, paying attention to calcium-magnesium ratios, optimum micronutrient levels, and soil organic matter. For example, he applies two tons of compost per acre in April, again in June, and again in September (for a total of six tons per acre per year). To get the most from the compost, he waters it in and tries to keep it moist for a week or so. He will continue to irrigate (at the rate of two and a half inches per week) during the hottest and driest months to keep the soil moist enough for the soil organisms to thrive.

Rosato’s biggest pest or disease problem is brown rot, and his intensive brown-rot-control efforts are detailed in the section on Brown Rot. When there has been a little leaf curl in the spring, he will put on a leaf-fall spray at the end of the season and a pre-bloom spray the following spring for curl, and it helps as a brown rot cleanup spray, too. For curl, Rosato sprays lime sulfur, which has been shown to work much better than copper sprays, but he does feel that keeping the soil levels of copper “adequate” seems to help reduce leaf curl problems.

Western flower thrips usually affects nectarines but has moved into the peaches. Rosato monitors populations by tapping branches with a stick to make the thrips fall onto a light-colored piece of paper. If the thrips are plentiful, then a spinosad spray like Entrust™ is applied (in the evening to protect the bees) when the fruit is at petal fall and for the next few weeks after petal fall. He thins off damaged fruit during thinning time and leaves only perfect fruit that is about eight inches apart in the tree.

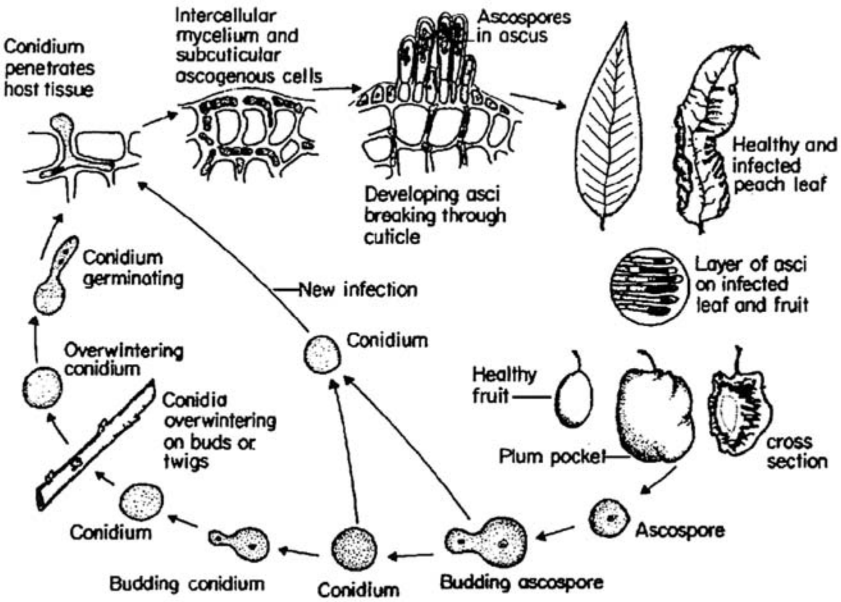
Rosato used to have peach twig borer problems but his diligence (using *Bacillus thuringiensis* sprays as indicated by pheromone traps) over the years has virtually eliminated this insect as a pest.

The orchard is now replanted, young again, and newly trained to the central leader system with all fruit getting picked from the ground without ladders. It is easier to get good coverage with the sprays now that the trees are lower. Pruning in May/June to remove vigorous growth and prevent it from blocking out sunlight to the fruit is important. “I prune quickly again in July to take out anything vigorous that was missed in the first pruning. The last pruning is done after early September and before bloom. September and October pruning keeps the trees from having so much vigorous growth in the spring. Keeping the trees pruned well helps keep the humidity down in the tree and pruning out any deadwood or cracked branches gives brown rot fewer places to live.”

Rosato commands top dollar for his product, working five or six farmers markets per week in Berkeley, Marin, San Francisco, Sebastopol, and Chico. He used to sell at even more markets, but says that after growing and selling peaches for over 24 years, “Sustainable is being able to continue with joy throughout your life. Getting to the end of a good fruit season and still having a smile, a laugh, and a spring in your step is what I consider sustainable farming.”

You can keep up with Rosato and learn more about his growing methods by going to his website: www.woodleaffarm.com.

Figure 2. Disease cycle of leaf curl.



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Accordingly, sprays must be applied during the trees' dormant period—after the leaves have fallen and before the first budswell in the spring. Many orchardists spray just prior to budswell during the months of February and March. Orchards with a history of severe peach leaf curl benefit from a double application: in the autumn at leaf fall and again in late winter or early spring just before budswell.

Peach leaf curl. Photo: Paul Bachi

Fortunately for the organic grower, lime sulfur—one of the most effective fungicides for control of peach leaf curl—is allowed in certified organic production. Bordeaux and copper fungicides—also approved for certified organic programs—are effective as well, but not as effective as lime sulfur.

Pscheidt and Wittig performed trials comparing Kocide™ (copper hydroxide), lime sulfur, several synthetic fungicides, and Maxi-Crop™ seaweed for leaf curl control. Lime sulfur and one of the synthetics (ziram) were best, roughly twice as effective as Kocide. Seaweed sprays, despite positive anecdotal reports, were completely ineffective.

Severe leaf-curl infection can cause the tree to shed many of its leaves and to replace them with a second flush of growth. At this time the tree will benefit from a soil application of a quickly available soluble fertilizer such as compost tea or fish emulsion to help it recover.

There are various levels of resistance to leaf curl among varieties; however, because of the relative ease of controlling the disease, breeding for resistance has not been a priority. Redhaven, Candor, Clayton, and Frost are some of the cultivars with resistance to leaf curl, though none is immune.

Pest Control Products in Organic Production — The OMRI List

the Organic Materials Review Institute (OMRI) provides a technical review of organic crop-production materials (fertilizers and pest controls) supplied by manufacturers to determine compliance with certified organic standards. Products that receive an "Allowed" or "Regulated" status may use the "OMRI Listed" seal on packaging and in literature.

The OMRI Products List is a directory of products for organic production or processing. The OMRI Generic Materials List is a catalog of over 900 materials and their status in organic production, processing, and handling. Both lists are searchable online and available in print form. Farmers looking for pest-control products in organic production will find that the OMRI lists are a helpful starting point.

Plum Pox

In October 1999, the presence of plum pox, or Sharka virus, was confirmed in Adams County, Pennsylvania—the first outbreak in North America. The disease has since been found in Cumberland County, Pennsylvania, and in Canada. This has caused much concern among producers because plum pox is an exceptionally destructive disease of stonefruit. Infected fruit are unmarketable because of spots and ring blemishes, and fruit may also drop prematurely. Plum pox is transmitted either by aphids or by grafting. The disease was not found in nursery stock, and an ongoing quarantine has apparently contained the outbreak of plum pox to a limited area, although testing is ongoing.

In 2007, USDA plant breeder Dr. Ralph Scorza released the 'HoneySweet' plum, which is functionally immune to plum pox (Kaplan, 2007). The pox-resistant genes from this plum can be incorporated into peach and other stonefruit so that, eventually, pox-resistant peach cultivars will probably be available to growers. (Note: 'HoneySweet' is the product of genetic engineering, and, as such, is not allowed in certified organic systems.)

Bacterial Spot

Bacterial spot of peach. Photo: U. Mazzucchi

The telltale symptom of bacterial spot (caused by the bacterium *Xanthomonas pruni*) is small light-brown lesions on leaves. Eventually the affected tissue falls out, leaving a characteristic shotgun-hole appearance. Severe bacterial spot infections may cause premature defoliation and subsequent re-sprouting, similar to peach leaf curl. Bacterial spot on fruit occurs as sunken, dry lesions that eventually crack, opening the fruit to secondary infections and reducing fruit quality.

Selecting disease-resistant cultivars is the principal means of controlling bacterial spot. Appendix II is a table from the Kearneysville Tree Fruit Research and Extension Center at West Virginia University on peach cultivar susceptibility to bacterial spot.

Fortunately for organic growers, copper fungicides—unique in that they also function as bactericides—are allowed for control of bacterial spot. The first spray should be applied before the tree leafs out in the spring; this timing often allows copper-based peach-leaf-curl sprays to double for bacterial-spot treatment. The next period when infection pressure is heavy is petal fall and for three weeks thereafter. Additional spray coverage may be necessary depending on varietal susceptibility and humid weather conditions.

Since the occurrence and severity of bacterial spot depend on moisture, this disease is rarely a problem west of the Rocky Mountains, and in the East growers are able to rely on resistant varieties as the best line of defense. Contact the Cooperative Extension Service for resistant varieties suited to your region.

Peach Scab

Peach scab. Photo: Courtesy of Clemson University - USDA Cooperative Extension Slide Series

Peach scab is caused by a fungus *(Cladosporium carpophilum)* that overwinters in twig lesions.

Splashing rain spreads the fungal spores to young fruit and new shoots. Scab symptoms include small, dark-green spots on the immature fruit. As the fruit matures, the spots enlarge and turn brown and may cause the fruit skin to crack. Sulfur and most other fungicides that are applied for brown rot will also control peach scab. There are no resistant cultivars. Pruning to improve air circulation and reduce wetness in the tree can help manage the fungus and prevent twig infection (Kain and Agnello, 2001).

Peach Mosaic Virus

First identified in the United States in 1931, peach mosaic virus has since appeared in a number of western states. Spread by grafting and by the peach bud mite, the disease results in delayed and rosette foliation, low fruit production, and deformed fruit. The disease has largely been controlled in the United States through quarantines and destruction of infected trees (Swift, 1998). In areas where peach mosaic virus quarantines have occurred, there may be restrictions on planting susceptible cultivars.

Cytospora Canker

Cytospora is probably the leading cause of peach tree death in much of the eastern United States.

The two related fungi *(Leucocytospora cincta* and *L. leucostoma)* that incite cytospora canker are opportunists, invading sites where damage has occurred due to mechanical injury, cold, poor pruning techniques, improper pruning time, borers, or other causes. The first visible symptom is the oozing of gummy sap near the wound, beginning when temperatures warm in the spring. Since peaches exude this gummy sap in response to almost any wound (e.g., borer attack), it can be difficult to diagnose this disorder correctly. One diagnostic clue is that cytospora cankers usually have an elongated or elliptical shape because the fungus advances more rapidly up and down the branch than around the branch (Snover, 1999). The bark dries out and dies but usually remains intact the first year. In succeeding years the bark becomes broken, disfigured, and covered with a black fungus overgrowth. The disease progresses slowly, and a tree with cytospora can survive for many years past the initial infection.

While cytospora can be found in California (more commonly on European plums), it is a much more serious disease on peaches in the eastern half of the country where winter temperatures—especially fluctuating winter temperatures—often lead to tissue damage. In fact, it is probably the leading cause of peach tree death in much of the eastern United States.

Control is limited to cultural techniques. Management begins by choosing planting sites away from older peach and plum trees and eliminating wild or untended plums and peaches near the orchard. Because a cold-damage area is often the primary infection site, painting trunks with white latex paint to reflect the winter sun can be helpful, although this practice is not allowed in organic production. Avoid planting on a south- or southwest-facing slope because such a site can induce the trees to warm up too soon in the early spring or late winter, resulting in cold damage if temperatures fall.

Other management techniques likewise center around minimizing damage to the trees, thus denying infection sites to the pathogens. Such techniques include pruning only in the early spring when temperatures have warmed, avoiding leaving pruning stubs, removing dead and diseased branches, and controlling borers.

Peach Replant Disorder

Peach replant disorder is an ill-defined disease complex that causes stunting of newly planted peach trees in soil where peaches have been grown previously. According to Greg Browne, ARS Research Plant Pathologist in Davis, California, there is much to learn about the problem. A complex mix of soil organisms may contribute to replant disorder, including several parasitic nematode species, oak root fungus, and *Phytophthora*. Much less is known about possible roles of other suspects (USDA-ARS, 2002).

Control is elusive. For many years, conventional growers relied on the fumigant methyl bromide to combat the problem, but in addition to environmental problems with methyl bromide, it is now deemed too expensive. A three-year fallow period seems to work. It has been suggested that amending the area where the tree is to be planted with compost or other organic materials would inhibit the disorder, but at least one study concluded this was not the case (Drenovsky et al., 2005). Perhaps organic growers would be best advised to avoid old peach-orchard sites or provide the three-year fallow.

Peach Tree Short Life

The leading cause of tree death in the Southeast, Peach Tree Short Life (PTSL) costs peach growers about $10 million in damages annually. It is seen as a sudden collapse and death of peach trees in the spring, usually when they are between three and seven years old.

Like peach replant disorder, the cause(s) of PTSL is imperfectly understood; however, unlike replant disorder, PTSL can affect older trees. USDA horticulturist Thomas G. Beckman and Clemson University scientists co-developed a rootstock called Guardian that protects trees from PTSL (USDA-ARS, 1998). Where PTSL is known to be a problem, or on old peach-orchard sites, Guardian should be considered as the rootstock of choice.

Other Diseases

Root and crown-rot diseases like *Phytophthora, Verticillium,* and *Armillaria* are important considerations when choosing planting locations and rootstocks. Other peach diseases that may be significant, depending on grower location, include peach rust, powdery mildew, and shothole fungus.

Bacterial canker (more commonly a disease of cherries) can also affect peaches, though research shows that hedgerows can provide a protective barrier for organic orchards (Tabilio et al., 1998). The control is presumably due to protection from driving rains and sun scald because the causal bacterium, *Pseudomonas syringae,* is an "opportunistic" pathogen that often achieves primary infection at wound sites.

New-Generation Fungicides: Safer and More Effective

Concerns about the toxicity of fungicide and pesticide residues on food have prompted research that is yielding a new generation of safer and more-effective fungicides. These fungicides are based on new types of chemistry and biology that are seen as improvements over older fungicides. Because they are synthetic fungicides, however, they are not allowed in organic production.

Newer, Safer, Synthetic Fungicides

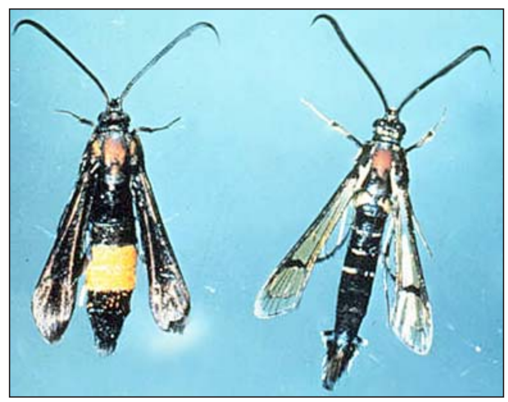
New classes of fungicides include strobilurins and phenylpyrroles, which were both initially discovered in nature (though fungicide formulations are synthesized analogs). Strobilurin, for example, was first isolated from wood-decaying European strobilurin mushrooms, while phenylpyrroles were first found in bacteria. The strobilurin fungicides Abound™ (azoxystrobin) and Flint™ (trifloxystrobin), and the phenylpyrrole fungicides Medallion™ (fludioxonil) and Scholar™ (fludioxonil), exhibit good activity against brown rot in peaches. Because these fungicides have low mammalian toxicity and short persistence in the environment, the EPA has classified them as reduced-risk pesticides.

The sterol inhibitors are another class of new fungicides. They include Elite™ (tebuconazole), Indar™ (fenbuconazole), Nova™ (myclobutanil), and Orbit™ (propiconazole), all of which are registered for peaches and exhibit excellent brown rot control, yet boast very low mammalian toxicity. However, the nature of their mode of action predisposes them to development of resistance by the pathogen. One way to avoid this resistance is to rotate fungicide use among different chemical classes—for instance, alternate sprays of a strobilurin with a sterol inhibitor.

Insect Pests

Peach Tree Borers

The peach tree borer *(Synanthedon exitiosa)* and lesser peach tree borer *(S. pictipes)* can be major pests of peaches. Borers feed on the inner bark of trees, where they may kill the tree by girdling, or cause the bark to peel away, exposing the tree to other pests and diseases. Other hosts for the borers include wild and cultivated cherry, plum, prune, nectarine, apricot, and certain ornamental shrubs of the genus Prunus. The adult peach tree borer is a clearwing moth, steel blue with yellow or orange markings. The moths are day fliers and can easily be mistaken for wasps.



Peachtree borer (female L.). Photo: Courtesy of A.R. Biggs, West Virginia University Extension

These insects overwinter as larvae in burrows at the base of the host tree. Because the eggs are laid over a long period of time, the larvae vary greatly in size. Some are more than 1/2 inch in length, while others are very small, not more than 1/8 inch long. The larvae pupate in the trunk of the tree and usually begin to emerge as adults in June. Adult emergence and egg laying occur from June through September, peaking during August.

The females are attracted to trees that have previously been damaged by borers, or to which some mechanical injury has occurred. Therefore, it is important to prevent damage to the tree trunk in order to minimize borer attack. Trees in poor vigor because of weed competition or drought stress also seem to be more susceptible to borer attack and damage.

Peach growers seeking to reduce their use of pesticides can use a variety of tactics to control this pest. Pheromones for monitoring and for mating disruption are available and effective (see "Resources, Pest Control Products" section), but growers should be aware that in order for the pheromones to work properly, the orchard needs to be at least three acres, and some say greater than five acres, in size (www.ca.uky.edu/entomology/entfacts/ef200.asp). See the box "Pest Control with Pheromonal Mating Disruption" for more information.

Interior white latex paint, painted or sprayed on the base of the trunks, provides a physical barrier, inhibiting newly hatched larvae from entering the trunk. The paint also fills cracks in the bark, the preferred site for oviposition and larval feeding. It is important to note that USDA Organic Regulations prohibit the use of any paint that contains synthetic materials in organic production.

It is easy to detect a tree that is infested with peach tree borers, since large amounts of gum exude from the damaged areas. The grower can use this exudate to locate a larva, and can then kill it by using a knife or flexible wire to probe the larva out of the trunk. The soil should be removed from around the base of the tree to a depth of three inches before starting this process, since larval damage also occurs under the soil line. This method of control is feasible for small plots but probably not practical in a commercial orchard.

Borer damage and resulting gummy exudate. Photo: Rex Dufour, NCAT

The bacterium *Bacillus thuringiensis* (B.t.) can be used to control the larvae before they have entered the trunk. Because B.t. does not have a long residual effect, the trunk should be sprayed weekly during the peak period of moth flight, late July through August.

A biological control, the commercially available insect-parasitic nematode Steinernema *carpocapsae,* has also been used successfully to manage peachtree borers when applied as a lower-trunk drench in warm spring or fall weather (Tabilio et al., 1998).

Peach Twig Borers

The peach twig borer *(Anarsia lineatella)* is only a minor pest in the eastern United States, but it's a significant problem in Texas and the West. The larvae emerge in the spring and then bore into twigs and buds before pupating into dark gray moths. Later generations of larvae attack maturing fruit during the summer, entering fruit near the stem end and rendering it unfit for sale.

Treatment after borers have entered the tree is much less effective than treatment during the dormant or bloom periods. Peach twig borers are usually not a problem in orchards that are sprayed each year at the delayed dormant period with lime sulfur or with a 3% oil emulsion. Two to three *Bacillus thuringiensis* sprays at bloom also appear to be effective against the twig borer.

The peach twig borer has many natural enemies and parasites, including the parasitic wasps *Paralitomastix varicornis, Macrocentrus ancylivorus, Euderus cushmani, Hyperteles lividus, Erynnia* species and *Bracon gelechiae,* as well as the grain mite *Pyemotes ventricosus.* The California gray ant, *Formica arrata,* can be beneficial when it preys on peach twig borer, but it unfortunately also protects aphids and scales (U.C. Statewide Integrated Pest Management Project, 1998). Other predators of the peach twig borer include lacewings, ladybugs, and minute pirate bugs. These insects can be attracted to the orchard by habitat plantings, cover crops, and hedgerows. The ATTRA publication *Farmscaping to Enhance Biological Control* provides information on this topic.

Mating disruption can also be effective if properly implemented (see "Pest Control with Pheromonal Mating Disruption" on page 13).

Pest Control with Pheromonal Mating Disruption

Many growers use mating disruption with sex pheromones—chemicals naturally produced by insects as a means of communication—as part of an overall IPM program. Specific pheromones are available, in various types of dispensers, to control peach twig borers, peach tree borers, and Oriental fruit moths. The most common dispenser is a twist tie attached to the upper limbs of orchard trees. During the mating period, female insects release pheromones that signal their location to males. By releasing quantities of these pheromones into the orchard, the grower can confuse and disrupt the insect's mating cycle. Efficacy is greatest in orchards that have low moth populations and are not close to other untreated peach or almond orchards. In order to work, the system must be applied as evenly as possible to areas at least three acres in size. Small orchard size and uneven orchard terrain will limit the success of mating disruption.

Time the placement of pheromone dispensers in orchards according to state Cooperative Extension recommendations or when moths are first caught in pheromone traps. Correct timing during the pest life cycle is crucial in applying the pheromone confusion products effectively.

Monitor the orchard regularly to identify which species is emerging and when. It is also important to identify the time of second flight emergence for the peach twig borers, as well as the second flight of Oriental fruit moths, so that treatment can be renewed at the most effective time. Regular monitoring also verifies that the system is working and alerts the grower if additional or alternative treatment is needed.

Mating disruption twist ties or lures for the peach tree borer, peach twig borer, and Oriental fruit moth are available through Great Lakes IPM, Peaceful Valley Farm Supply, or Harmony Farm Supply (see "Resources, Pest Control Products" for full contact information). In research trials, new high-dosage, low-density microsprayers and "puffers" have shown promise as a means of dispensing pheromones with improved consistency and less labor compared to the twist-tie system.

Keep up with innovative pest control options by accessing ATTRA's Biorationals: Ecological Pest Management Database.

Oriental Fruit Moth

The Oriental fruit moth *(Grapholitha molesta)* is related to the codling moth, a pest of apples, and causes the same type of fruit damage. Larvae burrow in the new shoots in the spring, then move through the stem into the developing fruit. They feed near the pit, so there may be no visible damage to the fruit on the surface, but the fruits become much more susceptible to brown rot, and they break down rapidly after harvest. There are up to seven generations of worms each year, with the earliest one feeding on young leafy shoots in the same way the peach twig borer does, and later generations feeding on the fruit, like the codling moth in apples. The overwintering stage is a full-grown larva from the last generation of the previous season. The larva spins a cocoon in the litter around the trees or on the bark itself. Pupation and adult emergence occur in the spring, and the moths lay their first eggs just after the peaches bloom. Trees that are allowed to grow dense, succulent foliage are especially attractive to the moths.

Pheromone-based mating disruption systems for Oriental fruit moth are proven, effective, and easy to use. One product, the Isomate-M™ pheromone dispenser, has proven as effective as chemical control in California tests (see "Pest Control with Pheromonal Mating Disruption" at left). There are some restrictions to pheromone use in organic production, concerning inert ingredients, so organic growers should check the regulations before purchasing a particular system.

Oriental fruit moth damage to twig. Photo: Clemson University - USDA Cooperative Extension Slide Series

Degree-day models or charts can help growers in timing pesticide application or placing mating disruption lures to coincide with the emergence of the pest. Many state Extension offices or universities provide timing tools developed specifically for their regions.

In addition to pheromonal mating disruption, control measures could include planting the right peach varieties. Early-maturing types discourage damage because the peaches are picked before the insects attack the fruit. This reduction in the moths' food supply helps control their population. Remove infested fruit and stem tips to further reduce populations. Good orchard sanitation—removing leaf litter and dropped or culled fruit where larvae overwinter—will further reduce attacks. Dormant larvae can be destroyed by cultivating to a depth of two to four inches, one to three weeks before the peaches bloom. Another part of cultural control is annual pruning to control overly vigorous growth on the trees, making them less attractive to the moths. Parasitic braconid wasps can be used as part of an IPM strategy against the Oriental fruit moth. Growers have had success with five releases of adult wasps four days apart, beginning in May and using about 500 adults per acre. To control the moth effectively, some growers supplement a parasitic insect program with a single spray of an appropriate insecticide shortly before harvest.

One of these braconid wasps, *Macrocentrus ancylivorus,* is being researched by the University of California's Walter Bentley (Kearney Agriculture Center, walt@uckac.edu). He observed that while the wasp was effective, it could not successfully overwinter on the fruit moth. Bentley planted about ¼ acre of sunflowers in three consecutive plantings (May, June, July) adjacent to his 3-acre research plot of peaches. The sunflower is a host for the sunflower moth *(Homeosoma electellum),* which itself is a good overwintering host for the wasp. This strategy led to a high rate of parasitism of the Oriental fruit moth and allowed the wasp to overwinter successfully on the sunflower moth. The result is that orchard managers might not in the future have to buy and release these parasitoids repeatedly. Research is ongoing.

Plum Curculio

The main insect pest of peaches east of the Rocky Mountains is the plum curculio *(Conotrachelus nenuphar).* This pest is especially difficult to control organically and damages fruit in three ways: 1) by direct feeding; 2) by laying eggs which become larvae and tunnel in the fruit; and 3) by spreading brown rot. The impact can be severe—damage to more than 90% of fruit is not uncommon in unsprayed orchards.

Plum curculio oviposition scar. Note crescent shape. Photo: Gus Howitt, Michigan State University Extension

The life cycle of the curculio will illustrate why this pest is so hard to control, as well as indicate windows of opportunity for control. The adult weevils overwinter in woodlots, fence rows, and hedges and move into the orchard during bloom to feed on young flowers and to mate. After mating, the female bores a small hole in the skin of a developing fruit, deposits a single egg, and then makes a crescent cut below the hole to protect the egg from being crushed by the rapidly expanding fruit tissue. The female lays an average of 150 to 200 eggs, which hatch two to 12 days later. The grub tunnels into the fruit's central seed cavity, where it feeds until it has completed its development—about three weeks. Then it generates and releases pectin enzymes that "trick" the host fruit into dropping prematurely, eats its way out of the fallen fruit, and enters the soil to pupate. At the end of pupation, adults emerge to eat again and look for an overwintering site. In other words, the curculio spends much of its life hidden out of sight—under leaf litter in the woods, inside the fruit, and under the soil surface. Moreover, when the curculio moves from the fruit to the soil, it does so after first inducing the fruit to drop to the ground, and then tunnels out the bottom of the fruit to enter the soil and pupate. You can be an orchardist and rarely see a plum curculio!

Cultural Controls for Plum Curculio

The life-cycle information suggests cultural control methods for the plum curculio, but none of these methods alone or in combination provides a cost-effective level of control for the commercial orchard. As already mentioned, fruits that are infested with curculio larvae normally drop from the tree before the larvae complete their feeding. Therefore, prompt gathering and disposal of these fruit drops—before the larvae leave them to enter the soil—reduces the number of first-generation adults. Sometimes the fruit that drops in May contains very few curculio larvae; in these cases, the drop may be a result of heavy fruit set, poor pollination, or both. Examine a sample of the drops to determine whether enough are infested to justify quick disposal. The drops on the two or three outside rows of the orchard are more likely to be heavily infested than those farther inside the orchard. Carefully destroy the infested drops.

Disking or otherwise cultivating during the pupal period is a mechanical control method. In its pupal form, the plum curculio is very fragile. If the pupal cell is disturbed, it fails to transform into an adult. Pupation usually occurs within the upper two inches of soil. The most desirable time to begin cultivation for destruction of pupae appears to be about three weeks after the infested fruits start to drop from the tree. Cultivation should be continued at weekly intervals for a period of several weeks. Cultivation before the curculios pupate is of little value. If the pupal cell is broken before pupation occurs, another cell is made by the larva. Covering the drops with soil before the larvae emerge from them is undesirable because it protects the larvae from drying in the sun.

Plum curculio adult. Photo: Clemson University - USDA Cooperative Extension Slide Series

Although whole-orchard cultivation is moderately effective in controlling the curculio, it can lead to severe erosion and loss of soil organic matter. It is a non-chemical means of curculio control, but its soil-degrading effects make it unsustainable in most situations.

Historically, when homesteads just had one or a few trees, penning enough chickens under the trees to keep the soil bare seems to have provided good control. While no one is suggesting that large-scale orchardists control curculio with chickens, this apparently successful management of the hard-to-control pest should offer some hope for small-scale orchardists and, perhaps, insights into other control techniques.

Similarly, Michigan State research with apples indicates that foraging hogs could provide significant mortality to the curculio during fruit drop and pupation (Grieshop et al., 2010).

Another innovative technique is worth mentioning. C.J. Walke, Organic Tree Fruit Specialist with the Maine Organic Farmers & Gardeners Association, says that in his small (roughly one acre) commercial plum orchard, he augments his sprays of Surround by laying large pieces of carpet scraps under the tree (2010). This greatly eases his collection of curculio-infested drops and probably blocks the curculio larvae from entering the soil to pupate.

Monitoring for Plum Curculio

Since the plum curculio moves into orchards from adjacent woodlots, fence rows, or hedges during bloom, it can be valuable to carefully check fruit growing along the perimeter of the orchard for the tell-tale crescent-shaped oviposition (egg laying) marks (see photo). Only recently have effective traps been made available for detecting this pest (the "Tedders" pyramid traps available through Great Lakes IPM; see Resources section).

However, growers with any orchard history of plum curculio damage often tend to forego early monitoring and simply begin sprays at petal fall for three reasons: 1) the curculio is a "given"— if you've had the pest in the past, you will almost certainly have it again; and 2) it can be so devastating to a high-value peach crop that any monitoring misses are serious; and 3) growers should not spray insecticides during bloom (to avoid killing pollinators), when the curculio is moving into the orchard. Therefore, growers reason that when the petals fall, the curculio is already present in some numbers and needs to be controlled.

Nonetheless, monitoring still has a place in determining the frequency and for how long into the season spraying must continue. For example, a grower might correctly assume from orchard history, even without monitoring, that at petal fall she needs to apply Surround. However, if a heavy rain washes off some of the Surround, but not all, she might want to determine by examining the fruit for oviposition scars (see photo, page 15) whether she needs to reapply. Or, for another example, perhaps the grower is relying on PyGanic for curculio control. Because of the short environmental persistence of PyGanic, there is little residual control even 12 hours after application, and she will need to determine by periodic (every two to three days) monitoring of traps whether new curculios are still entering the orchard.

The adult curculios are in the orchard and active for two to three weeks after petal fall.

Spraying to Control the Plum Curculio

Surround™ WP Crop Protectant, derived from processed kaolin clay, is an OMRI-approved organic pest-control product shown to be effective for control of plum curculio. Surround is unique in that it provides pest control through particle-film technology rather than toxic chemistry. Particle films deter insects by creating a physical barrier that impedes their movement, feeding, and egg-laying. Dr. Michael Glenn, Director of the Appalachian Fruit Research Station and one of the developers of Surround, cautioned that peach growers should discontinue seasonal sprays of Surround when the fruit is three centimeters (slightly more than one inch) or less in diameter because it is very difficult to remove the visible residue from mature fruit without washers and detergent (Glenn, 2010).

PyGanic™ is an OMRI-approved, pyrethrum-based (from the pyrethrum daisy), quick-knockdown, short-residual, broad-spectrum insecticide. At this point, it seems to be the organic pesticide of choice for plum curculio control. (Surround is technically not a pesticide and the new spinosad-containing pesticides are not adequate.) One of PyGanic's beneficial qualities—the short residual life (i.e., it biodegrades quickly, in about 12 hours)—is also one of its weaknesses because you have to spray often. The adult curculios are in the orchard and active for two to three weeks after petal fall. Another trait of PyGanic, its non-selective toxicity to insects, is also both boon and bane. It can be employed against a wide variety of pests, but it will also kill beneficials. In fact, it is highly toxic to bees and should never be sprayed during bloom. Moreover, an over-reliance on PyGanic or any pyrethroid for pest control can result in a "secondarily induced pest outbreak," that is, an outbreak of scale or mites or aphids because their natural enemies, like lady beetles and green lacewings, have been killed by the pyrethroid.

The synthetic insecticide Imidan™ (phosmet) has been the mainstay of integrated pest management of plum curculio because of its relatively low mammalian toxicity, its two-week persistence (meaning usually only two sprays for plum curculio control—at petal fall and two weeks later), and its low impact on beneficial insects. Some of the new neonicotinoids, such as Actara™, are registered for plum curculio control and boast even lower mammalian toxicity than Imidan; however, the neonicotinoids are under increasing suspicion regarding honeybee colony collapse and have been banned in several European countries.

Check with your Cooperative Extension Agent or ATTRA's Biorationals: Ecological Pest Management Database for the latest recommendations for pesticides and their safe use.

Tarnished Plant Bug and Other "Catfacing" Insects

Tarnished plant bugs, lygus bugs, and stink bugs are insects that pierce and feed on young fruit, causing depressions known as "catfacing" in the mature fruit. The best cultural control for these insects is orchard sanitation and regular, close mowing of the orchard floor to deny them habitat (they prefer legumes); however, if the orchard floor vegetation is allowed to get lush and is then mowed, that can force these pests into the trees to feed on the fruit. An alternative strategy is to use habitat plantings that attract these bugs (again, clovers and other legumes are preferred) as well as their predators. Keeping the habitat watered, lush and unmown, or mowing alternate

Chaffin Family Orchards: A Large-Scale, Diversified, Integrated Fruit and Livestock Success Story

Chaffin Family Orchards seems to belie the notion that only small-scale operations can integrate livestock and crops successfully. This five-generation, 2,000-acre family farm located at the eastern edge of the Sacramento Valley near Oroville, California, produces olives, beef cattle, sheep, chickens, eggs, citrus, stone fruits, and avocados, all in an integrated, mutually supportive fashion. The farm is certified organic.

Livestock are used to harvest forages from rocky soils that cannot support trees and to manage forage growth in the orchards. Sheep move through the orchards, providing a well-trimmed carpet under the trees.

Chickens play a major role in Chaffin's stone fruit orchards. Three "egg-mobiles" (chicken houses on wheels, moved by tractor), each containing 250 laying hens, as well as smaller pens with young meat birds, are moved into olive and stonefruit orchards at opportune times to clean downed fruit and bugs. They also clean nearby wooded areas of bugs and pests. Manure from all the livestock provides a valuable fertilizer resource, and the eggs are marketed as "free-range, organic."

See the video at www.youtube.com/watch?v=YA4QysDaLxU

alleys, may keep the bugs from migrating to the crop. Predators of these pests include bigeyed bugs, damsel bugs, assassin bugs, and collops beetle, as well as the egg predator minute pirate bug, and the egg parasite *Anaphes ioles.* In addition to these potential controls, botanicals such as PyGanic, rotenone (OMRI-approved but restricted), and neem appear effective against tarnished plant bug. Surround is also effective but will leave a residue on the fruit if used mid-season when these insects are a problem.

Brown Marmorated Stink Bug

The brown marmorated stink bug (BMSB) is a recently introduced (1998 was the first official sighting in United States) pest from Asia, where it is a major agricultural pest. Like a lot of other introduced pests, it has, at least temporarily, left its natural enemies behind and is spreading rapidly across the United States, damaging fruit and vegetable crops along the way. The mid-Atlantic states have been hit especially hard. In Pennsylvania in 2010, losses to fruit and vegetable crops approached 50 percent (Gill, 2010). The damage to peaches is similar to that done by other catfacing bugs, but the damage is usually deeper into the flesh.

The BMSB is shield-like in shape, similar to other stink bug species, but is a mottled light-brown in color with dark-brown "marmorations"—regularly spaced indentions—around the margin of the "shield." More information and photos are available online: http://ento.psu.edu/extension/factsheets/brown-marmorated-stink-bug

Currently there is little control information specific to the BMSB, and growers are relying on various broad-spectrum insecticides to control it. There is considerable concern that this pest and efforts to control it "could reverse much of the progress we've made in IPM, which has

Brown marmorated stink bug. Photo: David R. Lance

helped Pennsylvania growers to reduce pesticide use by as much as 75 percent in recent decades," according to Pennsylvania State University entomologist Greg Krawczyk (2011).

Spotted Wing Drosophila

While the exotic brown marmorated stink bug is invading the Northeast, the spotted wing drosophila *(Drosophila suzukii)* (SWD), an accidental introduction from Southeast Asia, is wreaking havoc on the West Coast and in Florida (and in 2010 the first SWD were found in Michigan and Wisconsin). A member of the vinegar fly family, the SWD is related to the tiny fruit flies that are commonly seen in U.S. households around damaged, cut, or over-ripe fruit, but the SWD attacks undamaged, ripening fruit in the field.

Damage to California crops in 2008, the first year Spotted Wing Drosophila was discovered, was estimated at $500 million.

The fly is gnat-size, with red eyes and a light-brown body. The males have visible spots on the tips of their wings. The female deposits her eggs in fruit (host range includes just about any thin-skinned fruit, including peaches, blueberries, grapes, plums, tomatoes, etc.). The eggs hatch shortly thereafter, and the larvae tunnel and feed around the egg-laying site, causing noticeable depressions in the fruit. Often at this point, opportunistic bacteria and fungi invade the site and cause additional damage. The SWD can have 10 or more generations a year, and each female can lay 300 or more eggs. The potential for damage is huge. Damage to California crops in 2008, the first year SWD was discovered, was estimated at $500 million.

There is not yet an established control protocol. The least-toxic, effective pesticide appears to be spinosad, a biological insecticide which is OMRI approved. It should be cautioned, however, that the spinosad-containing GF-120™ bait that is used for cherry fruit fly does not seem to be attractive to drosophila.

Oregon State University has developed a simple and inexpensive trap for monitoring. More information and photos appear online: http://swd.hort.oregonstate.edu/files/webfm/editor/FINAL_Monitoring_Trap_5-15-2010.pdf

University of California also has a helpful SWD site: www.ipm.ucdavis.edu/EXOTIC/drosophila.html

Scale and Other Pests

Scale and plant-feeding mites can become serious pests, especially if their predators have been

Hand-bagging: Promising organic peach research in New Jersey

Rutgers University researcher Dr. Dan Ward has been working the last four years on developing components of an organic peach-growing system for the Mid-Atlantic, with individual fruit bagging as the centerpiece. While at first glance this might seem impractical, Ward explains that individual bagging of peaches is part of commercial production in China, Japan, and Spain. In these countries, specialized bags are available that are quickly and easily applied; bags are even available in different colors and with different levels of transparency (important in the development of fruit color).

Moreover, if you consider the costs of fungicides and insecticides, organic or otherwise (including the costs of multiple applications), individual bagging of fruit, which excludes both pests and diseases, doesn't look so bad. Add to these considerations the recently introduced and pernicious brown marmorated stink bug, which is proving very difficult to control with insecticides but may be easily excluded by the bags, and bagging might become a very competitive growing technique. With all these changing factors, it's difficult to provide an up-to-date economic analysis, but a premium for locally grown, organic peaches might just be the thing that makes such a labor-intensive technology pay for itself.

Pests and diseases of the leaves, shoots, roots, and trunk (e.g., leaf curl, peach tree borers, etc.) will, of course, not be deterred by the bags, so other methods of control for those will still be necessary.

Other aspects of Dr. Ward's organic growing system include geotextile fabric mulches for weed control. To combat rodents that can be attracted to such an environment, Ward applies gravel around the trunks, both over and under the mulch.

Dr. Ward said that bags specifically designed for peaches can be purchased from Japan in several different colors and styles, but that shipping costs are high. One supplier is Shibataya Kakohshi Co., Ltd, Niigata, Japan (overseas@shibataya.com). In the United States, Wilson Orchard and Vineyard Supply (www.wilsonirr.com/catalog_i4342079.html?catId=272951) can provide growers with bags that are intended for apples but can be used on peaches.

thinned out by broad-spectrum pesticides, organic or not. Late-dormant-season (when temperatures are warm but the trees are still dormant) applications of crop oils can smother scale and some mite species.

According to Patrick Byers, University of Missouri Extension Horticulture Specialist, San Jose scale has become especially troublesome in much of the Midwest in both commercial and home peach plantings (Byers, 2011). He stressed that the dormant-season oil sprays are important not to skip because scale can have explosive population increases under certain conditions.

Aphids can also be major pests, particularly for organic growers in the West. Various "soft" control techniques—including organic pesticide spraying, habitat manipulation, and release of beneficial insects—are available.

Nematodes are another potential pest; nematode-resistant rootstocks are available (see "Peach Tree Short Life" in the Disease section). Also see ATTRA's Biorationals: Ecological Pest Management Database and ATTRA's Nematodes: Alternative Controls for more information on alternative nematode control strategies.

Conclusion

Intense disease and insect pressure makes peaches one of the most difficult tree fruits to produce organically. In parts of the arid West, commercial organic peach production is feasible when the grower adequately addresses brown rot, peach twig borers, and Oriental fruit moth.

In most of the East, commercial-scale organic production is greatly complicated by the plum curculio and brown rot. However, with new pest management tools—Surround™, PyGanic™, Serenade™, Isomate-M™—organic peach production is far more plausible than just a few years ago. Moreover, the changing marketplace favoring local production might make hand-bagging of peaches a viable alternative for organic growers. Meanwhile, low-spray production with limited use of the least-toxic synthetic inputs is a proven alternative for eastern growers.

Post-Script Commentary: The Peach Problem and the Local Foodie's Dilemma

Environmentally friendly peach production represents a conundrum for the organic farmer, local food advocates, and the health-conscious consumer. Peaches are a high-value crop and require a high level of inputs because the diseases and pests that attack peaches can be absolutely devastating. In such a scenario, many farmers are reluctant to experiment because the consequences of failure can be so severe. Commercial-scale, organic production of peaches in the humid eastern half of the United States is very, very difficult (I've heard it called the "Holy Grail of organic farming"—elusive and perhaps mythical) and replete with its own environmentally questionable practices since it would, most likely, be dependent upon many sprays of sulfur and pyrethrum-derived products. By themselves, these might be considered of low mammalian toxicity but, given the number of sprays necessary for disease and insect control, they become disruptive of natural systems in the orchard (not to mention expensive). In fact, a case could be made that an intensive IPM program using the latest, least-toxic, *synthetic* pesticides might be more environmentally benign than an organic system if the organic system relied on multiple sprays of the currently available organic pesticides. At present, there is virtually no significant commercial-scale organic peach production in the East.

Consequently, the knowledgeable "foodie" in the East is faced with a dilemma (really a trilemma, but we'll get to that in a minute): buy organic peaches long distance from the West or buy almost-certainly-sprayed peaches produced more locally. And it should go without saying that the farmer is in a similar bind. A high-value crop like peaches is very tempting, but a farmer committed to organics would be ill advised to try organic peach production.

So, what did they do "back in the day"? This is a great question. Like some of you, I remember my grandmother serving up her unsprayed peaches. Mine lived in Dallas, Texas, and she had a single backyard tree. And we know from history that the Cherokee and other Native Americans had peaches. Thomas Jefferson had a small (by today's standards) 160-tree peach orchard. "Wild" (though not native—the peach spread readily in the New World after being introduced by the Spanish) peaches were scattered across the Southeast and Southwest. And that—the fact that they were scattered—explains why so many single peach trees did relatively well: the comparative isolation of these trees (and peaches are

Intense disease and insect pressure makes peaches one of the most difficult tree fruits to produce organically.

self-pollinating, so a single tree can do just fine in that regard) meant the plum curculio, brown rot, borers, and other pests and diseases couldn't readily spread from tree to tree and become established as they so easily do in an unsprayed orchard today. (I can remember looking at my own 40-tree peach orchard after a particularly bad year and feeling like I had simply "set the table" for the plum curculio and brown rot, rude guests if ever there were!)

But the "scattered-trees hypothesis" doesn't explain Jefferson's apparent success as evidenced in his journals. Again, the answer is provided in the written record, but, unfortunately, it is a largely unsustainable answer because it relied on so-called "clean cultivation"—the continuous plowing and cultivating of the soil around and between the trees. Clean cultivation buries brown-rot infected mummies, destroys the pupal cases of the plum curculio, and otherwise interferes with the life cycle of several major and minor peach diseases and pests. However, clean cultivation also opens the soil to wind and water erosion and is almost certainly unsustainable in that sense. Few organic farmers I know would be willing to practice clean cultivation today, and, in fact, the USDA Organic Regulations regarding maintaining or enhancing soil fertility would almost certainly exclude clean cultivation as an organic practice.

Nevertheless, perhaps we can take a lesson from the old days and refine it with our modern understanding of soil fertility and pest and disease life cycles. Perhaps one or two post-harvest cultivations would bury those brown rot mummies and destroy those curculio pupal cases. Perhaps the orchardist could then follow up with compost or manure applications along with a well-chosen cover crop. Perhaps pesticides (organic or otherwise) could be held in reserve until really needed as indicated by sophisticated monitoring. Perhaps a local clientele could support this farmer by compensating for the real costs of production.

Or—and this is the third way I alluded to earlier (the third choice in the "trilemma")—perhaps more people will take responsibility for growing their own food, and enough chickens will be penned-in under one or two peach trees to keep that little bit of ground bare but fertilized and free of brown rot and bugs. I've seen this done successfully by two different home growers in Northwest Arkansas—not every peach was perfect, but both families had more peaches than they knew what to do with. Likewise, home growers need not worry so much about the "economics" of hand-bagging individual peaches. In short, this third way—VERY local production—sidesteps the economic hurdles of larger-scale commercial production and makes small-scale organic production of peaches quite possible for both East and West.

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530-796-2214

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Greene County Extension Office, University of Missouri Extension
2400 South Scenic
Springfield, MO 65802
417-881-8909
417-881-8058 FAX
email: byerspl@missouri.edu
http://extension.missouri.edu/greene

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Further Resources

Pest Management Products

Great Lakes IPM
10220 E. Church Rd.
Vestaburg, MI 48891
989-268-5693
989-268-5911
800-235-0285
989-268-5311 FAX
www.greatlakesipm.com

Harmony Farm Supply
3244 Hwy. 116 North
Sebastopol, CA 95472
707-823-9125
www.harmonyfarm.com

Pacific Biocontrol Corporation
620 E. Bird Lane
Litchfield Park, AZ 85340
623-935-0512
www.pacificbiocontrol.com

Peaceful Valley Farm Supply
P.O. Box 2209
Grass Valley, CA 95945
530-272-4769
www.groworganic.com

Publications

Titles from the University of California:

ANR Communication Services
1301 S. 46th Street
Building 478 - MC 3580
Richmond, CA 94804
800-994-8849
http://anrcatalog.ucdavis.edu

Integrated Pest Management for Stone Fruits
Publication 3389. 1999. 264 p.
A manual for managing pest problems and diseases in apricots, cherries, nectarines, peaches, plums, and prunes. ($35.00)

Peaches, Plums, and Nectarines: Growing and Handling for Fresh Market
Publication 3331. 1989. 252 p.
From orchard site selection to produce distribution. 153 color photos, 36 black and white photos, 44 tables and charts, glossary, and index. ($45.00)

Natural Enemies Handbook: The Illustrated Guide to Biological Pest Control
Publication 3386. 1998. 162 p.
Illustrated how-to book that helps to identify natural enemies to control pests with a combination of cultural, physical, chemical, and biological controls. ($35.00)

IPM in Practice: Principles and Methods of Integrated Pest Management
Publication 3418. 2001. 296 p.
A comprehensive, practical field guide developed for setting up and carrying out an IPM program in any type of crop or landscape. ($30.00)

Seasonal Guide to Environmentally Responsible Pest Management Practices in Peaches and Nectarines
Publication 21625. 2006. 8 p.
This handy full-color guide takes you through the year based on the stages of peach tree growth with an easy-to-understand approach to environmentally friendly pest management in peaches. It indicates the best times to monitor specific pests and, when available, gives treatment thresholds and appropriate pesticides to use. This easy-to-use decision guide is packed with information to help peach and nectarine growers make environmentally responsible pest management decisions year-round without decreasing their yields or increasing their reject levels. Based on research and results from the University of California and the Stone Fruit Pest Management Alliance.

Selected titles from American Phytopathological Society:

APS Press
3340 Pilot Knob Road
Saint Paul, MN 55121-2097
800-328-7560

651-454-7250
651-454-0766 FAX
aps@scisoc.org
www.shopapspress.org

Compendium of Stone Fruit Diseases
1995. 128 p. 168 color images ($49)
www.shopapspress.org/41744.html

Diseases of Orchard Fruit and Nut Crops-CD Rom
2002. 500 full color images ($79)
www.shopapspress.org/disoforfruit.html

Selected titles from North Central Regional Extension: Available through Michigan State University

MSU Bulletin Office
10-B Agriculture Hall
Michigan State University
East Lansing, MI 48824-1039
517-353-7168 FAX
http://web2.msue.msu.edu/bulletins/mainsearch.cfm

Diseases of Tree Fruits in the East, NCR 045. 116 p. ($10)

Common Tree Fruit Pests, NCR 063. 252 p. ($10)

From Natural Resource, Agriculture, and Engineering Service (NRAES):

NRAES
152 Riley-Robb Hall
Ithaca, NY 14853-5701
607-255-7645
607-254-8770 FAX
nraes@cornell.edu
www.nraes.org

Mid-Atlantic Orchard Monitoring Guide
NRAES-75. 1995. 361p. 322 color images.
www.nraes.org/publications/nraes75.html

Titles from Good Fruit Grower:

Good Fruit Grower
105 South 18th Street, Suite 217
Yakima, WA 98901
509-575-2315
800-487-9946
509-453-4880 FAX
www.goodfruit.com

Orchard Pest Management: A Resource Book for the Pacific Northwest
1993. 276 p. Published by Good Fruit Grower. ($35).

Organic Tree Fruit Management
1998. 240 p. Published by Certified Organic Associations of British Columbia. ($38).

Web-Based Resources

Virginia Fruit Web Site: Virginia Stone Fruits
www.ento.vt.edu/Fruitfiles/VirginiaPeachSite.html
This site presents current information on peach research, as well as peach pest management.

University of California Fruits and Nuts Research and Information Center
http://fruitsandnuts.ucdavis.edu
This is the portal for information on all of the University of California's fruit and nut research.

2007 North Carolina Peach and Nectarine Disease and Pest Management Guide
http://ipm.ncsu.edu/peach/NCGuide.pdf
This PDF publication from North Carolina State University is available online and provides evaluations of the effectiveness of different cultural and fungicidal controls for a range of peach diseases and pests, as applied during each stage of the growth cycle.

Penn State College of Agricultural Sciences' Pennsylvania Tree Fruit Production Guide
http://tfpg.cas.psu.edu/37.htm
A guide to conventional peach production, addressing site selection, cultivars, planting, and pruning.

West Virginia University Index of Fruit Disease Photographs, Biology, and Monitoring Information
www.caf.wvu.edu/kearneysville/wvufarm8b.html#PEACH
This portion of the Mid-Atlantic Orchard Monitoring Guide Web Site for Tree Fruit Pathology furnishes photos that can be used to help identify diseases on leaves and fruit.

Organic Control of Peach Brown Rot in California, USA
www.agroecology.org/Case%20Studies/brownrot.html
The Agroecology Web site from UC Santa Cruz includes a case study on Carl Rosato's organic peach orchard in Oroville, California.

Insect and Disease Control On Peaches, Apricots, Nectarines, and Plums
http://entowww.tamu.edu/extension/bulletins/b-1689.html
This Texas A&M online extension bulletin includes a spray schedule for peaches and contains information on pesticide toxicity.

Appendix I. Hypothetical Pest Control Calendar for an Eastern Organic Peach Grower

Disclaimer: The following is a set of guidelines, not a list of prescriptions. Geographical/climatic considerations, cultivar selection, the local pest complex, market prices, production costs, and other factors will all influence the design and viability of any system. Reducing chemical input and foregoing conventional calendar spray schedules will require the orchardist to develop an understanding of the orchard agro-ecosystem. In this regard, there is no substitute for direct observation and experience, along with a willingness to experiment. ***This is a hypothetical, not a proven, system.***

Dormant season:

- Remove/destroy sources of brown rot inoculum (wild plums, old pruning piles, etc.)
- Prune; remove and destroy mummies and diseased limbs
- Perform maintenance on orchard equipment
- Check for scale on limbs and trunk; spray dormant oil on warm day if warranted
- Order spray materials, traps, etc.
- Spread compost or other organic fertilizer materials late dormant season
- Apply liquid lime sulfur for leaf curl (may be applied in the fall after 90% of the leaves have fallen or in the spring before the buds swell)

Inspect trunks for borer damage (gum mixed with frass) and manually remove trunk borers. Paint trunks with interior white latex OR (better) wrap trunks with screen for borer control.

Pink:

- Deploy traps for plum curculio monitoring
- Spray first micronized sulfur spray for brown rot (blossom blight phase)
- Scout for tarnished plant bug (TPB), green peach aphid (GPA), plum curculio (PC); spray with Surround or PyGanic* (see note) if necessary (but don't spray insecticides during bloom)

Bloom:

- Spray micronized sulfur for brown rot and scab (repeat as necessary due to rain wash-off)
- Use NO insecticides during bloom

Petal Fall:

- Spray micronized sulfur for brown rot and scab (repeat as necessary due to rain wash-off)
- Apply Surround or PyGanic for TPB, GPA, and PC (important: PyGanic is only effective for one to two days, so diligent scouting for next four weeks is necessary and repeat sprays as necessary; Surround is only as effective as the coverage—repeat as necessary to keep trees covered for next three to four weeks OR until PC trap catches approach zero OR fruit diameter exceeds one inch)

Shuck Split/Shuck Fall:

- Spray sulfur for brown rot and scab (repeat as necessary to maintain cover on plant surfaces)
- Apply Surround or PyGanic for PC, etc. (see Petal Fall note above)
- Add foliar nutrients if necessary (as per test or last year's experience) to this and subsequent sprays
- Begin trap monitoring for Oriental fruit moth (OFM) and peach tree borer (PTB)

First cover spray (one to two weeks after shuck split):

- Spray sulfur for brown rot (drier, hotter weather will allow for longer intervals between sprays)
- Discontinue Surround after fruit is one inch in diameter (to avoid residue at harvest)
- Use PyGanic or other OMRI-approved insecticides as scouting indicates for PC, TPB, etc.
- Deploy OFM mating disruption as traps or last year's experience indicate
- Monitor PTB traps
- Thin fruit (to approximately one fruit per six- to eight-inch limb) and remove any damaged fruit
- Cultivate shallowly under trees to destroy PC pupae

Second cover spray (two weeks after First Cover) and thereafter:

- Spray insecticides only as scouting/trapping indicate for minor pests (leaf rollers, mites, etc.)
- Discontinue Surround after fruit is one inch in diameter
- Make sure PTB controls in place (interior white latex or screen on trunks)
- Use sulfur as needed for brown rot up to pre-harvest (as temperatures approach and exceed 85°F, need for

spray decreases AND danger of sulfur burn on leaves increases)

- Cultivate shallowly under trees to destroy PC pupae
- Continue hand thinning fruit (one fruit per six- to eight-inch limb), removing any damaged fruit

Post Harvest:

- Spread compost or manure as soil tests, foliar tests, or tree performance indicate but not later than September
- Clean up behind borers (frass at base of tree indicates borer invasion)
- Avoid broad-spectrum insecticides (e.g., PyGanic), but otherwise protect from any serious pest threats as scouting indicates (e.g., Bacillus thuringiensis sprays for leaf rollers, light oils for mites, etc.)

**Note:* PyGanic is currently the only OMRI-approved insecticide (Surround is not technically an insecticide) that can provide a commercial level of control over the plum curculio. However, overreliance on any single insecticide (or insecticides with the same mode of action) is likely to lead to the development of insect resistance to the insecticide and/or non-target pest outbreaks.

Appendix II. Bacterial Spot Susceptibility Rating

[z]R = resistant. Control only needed under high disease pressure.

S = susceptible. Control usually needed where disease is prevalent.

HS = highly susceptible. Control always needed where disease is prevalent. These cultivars should receive first priority when control is called for.

Peach cultivar	Bacterial spot susceptibility rating[z]	Peach cultivar	Bacterial spot susceptibility rating[z]
Ambergem	R	Loring	S
Autumn Lady	HS	Madison	S
Babygold5	HS	Maybelle	S
Belle of Georgia	R	Mayflower	R
Biscoe	R	Monroe	S
Blake	S	Raritan Rose	S
Brackett	HS	Redbird	R
Candor	R	Redhaven	S
Cardinal	R	Redskin	S
Cherryred	R	Richhaven	S
Coronet	S	Rio Oso Gem	S
Cresthaven	S	Shippers Late Red	HS
Dixired	R	Southhaven	R
Earlired	S	Southland	HS
Early East	HS	Springold	HS
Early Sunhaven	S	Sullivan Elberta	HS
Elberta	HS	Summercrest	S
Erly-Red-Fre	R	Summergold	S
Gemmers Late Elberta	HS	Summerqueen	S
Golden Jubilee	S	Sunhaven	S
Hale Harrison Brilliant	HS	Sunhigh	HS
Halehaven	HS	Sweet Sue	HS
Harrow Beauty	S	Triogem	S
Harrow Diamond	S	Tyler	S
Jefferson	S	Washington	S
Jerseyland	HS	White Hale	HS
Jerseyqueen	S		
Keystone	S		
Late Sunhaven	S		

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Notes

Notes

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