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Apples: Organic Production Guide

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This publication provides information on organic apple production from recent research and producer experience. Many aspects of apple production are the same whether the grower uses low-spray, organic, or conventional management. Accordingly, this publication focuses on the aspects that differ from nonorganic practices—primarily pest and disease control, marketing, and economics. (Information on organic weed control and fertility management in orchards is presented in a separate ATTRA publication, *Tree Fruits: Organic Production Overview.*) This publication introduces the major apple insect pests and diseases and the most effective organic management methods. It also includes farmer profiles of working orchards and a section dealing with economic and marketing considerations. There is an extensive list of resources for information and supplies and an appendix on disease-resistant apple varieties.

Contents

Photo: Elderberry Farm and Restaurant

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This publication draws on previous ATTRA publications on apple production written by Richard Earles, Guy Ames, Radhika Balasubrahmanyam, Holly Born, and Rex Dufour.

We recognize the tried-and-true experience of organic orchardists and draw extensively from them in this publication. Special thanks to the farms that agreed to be profiled in this publication: Elderberry Farm and Restaurant, Skaneateles, New York; Hoch Orchard and Gardens, LaCrescent, Minnesota; and Home Acres Orchard in Stevensville, Montana.

Introduction

Apples, *Malus sp.*, are among the most difficult crops to grow organically. They are prone to attack by more pests than perhaps any other crop. Without effective management, the worst of these pests can be devastating—to the fruit, to the grower's spirit, and to the bottom line. To minimize or eliminate chemical inputs while keeping yields and profits sound, the grower must develop a detailed understanding of the orchard as a managed ecosystem. In this regard, there is no substitute for direct observation and experience, along with a willingness to experiment. As the organic market for apples increases, more organic management options are available to growers. This publication will outline many of these options for pest and disease management as well as describe marketing options and enterprise evaluation for organic apples.

A note on terms:

Organic fruit production involves more than simply excluding synthetic pesticides and fertilizers. Benign neglect does not meet National Organic Program standards for production, nor would it satisfactorily manage the numerous pest species that frequent the apple. Organic agriculture is an integrated approach of active and observant management of a farming system. The USDA's National Organic Program (NOP) defines organic production as "A production system that is managed … to respond to site-specific conditions by integrating cultural, biological, and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity."

Included in this publication are references to the organic standards authorized by the USDA's National Organic Program, *www.ams.usda.gov/nop*. Organic producers should verify with an accredited certification agency that their practices and any materials they intend to use are compliant with NOP standards. In addition, if a farmer is planning on marketing internationally, there may be further production and labeling requirements. ATTRA has numerous resources on beginning or transitioning to organic production. See *Guide to ATTRA's Organic Publications* for an overview of these.

This publication touches on some orchard-floor and weed-management options specific to apples. More information on organic weed control and fertility management in orchards is available in ATTRA's *Tree Fruits: Organic Production Overview*. For an introduction to IPM principles and practices, see ATTRA's *Biointensive Integrated Pest Management*.

Geographic and climatic considerations, cultivar selection, the local pest complex, market prices, production costs, and other factors all influence the design and viability of an organic system. Because this publication is national in scope, it can only introduce the most common pest and disease problems and selected organic control strategies. No method presented here will be appropriate for every orchard or every region. The following is a set of guidelines, not prescriptions. The individual producer must try various tools and evaluate them according to efficacy, cost, production, marketing goals, and personal preferences.

What begins as a fragmented pest-by-pest set of tactics must gradually form an overall management plan in which the various strategies work together as much as possible. The publications *Twenty Years of Apple Production Under an Ecological Approach to Pest Management*, by Ron Prokopy, and *The Apple Grower: A Guide for the Organic Orchardist*, by Michael Phillips, are excellent guides for an orchardist transitioning to organic production. The Further Resources section has information on how to obtain these publications.

Obstacles to organic apple production include the following:

- Cultural guidelines for controlling one pest may create conditions that favor another pest.
- Many organic pest-control tactics tend to give highly variable results from location to location and year to year.
- Traditional local support services are often unable to provide much information or guidance.
- The practices may be labor and/or capital intensive.

Apples can be difficut to grow organically. Photo: Howard F. Schwartz, Colorado State University, Bugwood.org

Geographical Factors Affecting Disease and Pest Management

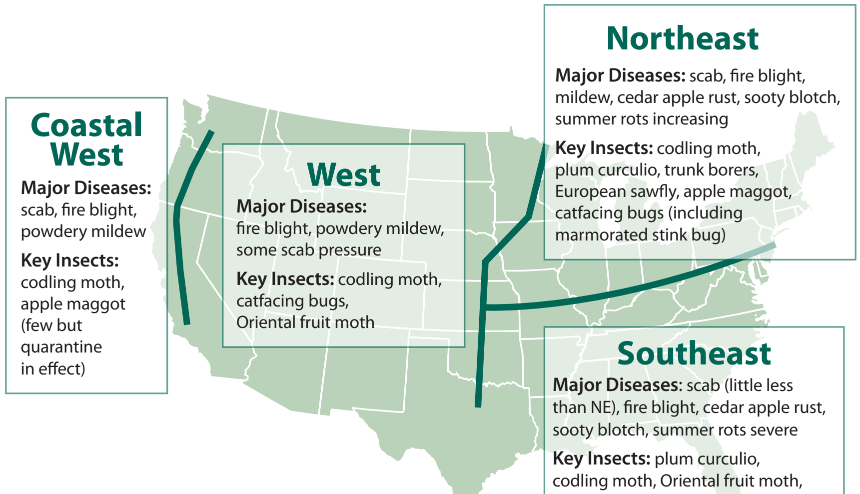
West of the "tree line" (approximately the 97th meridian, a line running roughly from Fort Worth, Texas, to Fargo, North Dakota) a major pest of many tree fruits—the plum curculio—is not present. This fact, coupled with reduced disease pressure, facilitates organic production of apples in much of the West. The many large-scale organic apple orchards in Washington and California are testament to the relative ease of organic apple production in that part of the country.

Eastern growers, on the other hand, must contend with the plum curculio and increased incidence of fungal diseases. Northeastern growers have the apple maggot as an additional major pest. In the Southeast, fruit rots can be especially troublesome. The prognosis for eastern organic apple production is starting to look up, however. Through a combination of innovative pest-management strategies and diligent research, many of the issues associated with organic apple production in the East are beginning to be resolved. Surround, a kaolin-clay-based pesticide, has dramatically changed the face of organic fruit production in the eastern U.S. These control measures are time and management intensive, however, and growers need to account for additional pest-management time and expense in their enterprise budgets. See the Economics and Marketing section for enterprise evaluation and further resources on this matter.

With the comparative difficulties of production in mind, this publication is weighted somewhat toward the eastern apple-pest pressures, though many of the pest-management needs of western growers are also addressed.

Insect and Mite Pests

The codling moth, apple maggot, tarnished plant bug, scale, Oriental fruit moth, various aphid species, trunk borers, leaf miners, leafhoppers, mites, etc. can all be damaging—if not devastating—apple pests. Furthermore, there are always scab, blight, rust, mildew, and a host of other diseases. Heretofore, a problem with apple-pest control in both the East and West was the piecemeal approach that organic growers have been forced to take, especially relative to nonorganic growers.



Common Apple Pests by Region

For instance, mating disruption for codling moth only works on codling moth; *Bacillus thuringiensis* is effective against some lepidopteran species but not hemipterans, coleopterans, etc.; borers necessitate their own separate control efforts; sulfur works reasonably well against rust but not at all against blight; and one cultivar that is resistant to scab may not be resistant to any other disease.

So even though in theory it appeared that apples could be grown organically if all these approaches were employed, it was generally only the most meticulous, energetic, and well-informed growers in the West who were actually making a profit with organic apples. By way of comparison, conventional growers have broad-spectrum insecticides and fungicides, many of which are singly brought to bear against a wide variety of insects and pathogens. The consequences of these broad-spectrum pesticides are now well known, and possibly the most infamous of these is the toxicity to nontarget organisms, including birds, fish, and beneficial insects.

Often, the least-toxic, organic approach to pest control is very pest-specific. This is good for the overall health of the ecosystem and for consumers, but it can greatly complicate pest management for crops like apples, which have multiple pests. Do not be discouraged, though. The interest in organic produce has led to some valuable research on organic apple production in the East. Particle film technology, or Surround WP, is the closest that organic growers have been able to get to a broad-spectrum material for pest control. For more details see the Kaolin Clay section.

Plum Curculio

A plum curculio. Photo: Clemson University - USDA Cooperative Extension Slide Series, Bugwood.org

The plum curculio (*Conotrachelus nenuphar*), a small brownish weevil, is the Achilles heel of organic apple production in the eastern U.S.

This species of snout beetle injures fruit in several ways:

- Scarring from surface feeding and oviposition (egg depositing)
- Internal damage from burrowing larvae
- Premature fruit drop ("June drops")
- Puncturing by adults feeding in late summer and fall

The adult weevils overwinter in woodlots, fence rows, and hedges and move into the orchard during bloom to feed on young flowers. 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 (Berenbaum, 1991).

Table 1: Detecting Plum Curculio in the Orchard

Stage	Timing	Where to Look
Adults	Spring when temperatures exceed 60°F (15.5°C)	In orchard adjacent to hedgerow. Feeding wounds are frequently the first sign of adult presence.
Adults	Late July to hibernation. Temperatures below 60°F (15.5°C)	Same as above.
Eggs	Petal fall and 30 days thereafter	On developing fruit within crescent-shaped oviposition wounds.
Larvae	Early June through mid-July	Within injured, dropped fruit.
Pupae	Mid-July through mid-August	In soil within 25mm (1 inch) of the surface.

Biological monitoring—systematically scouting the orchard to detect the presence or measure the population density of pests—provides critical information for choosing and timing control strategies. Monitoring is more difficult and more labor intensive for the plum curculio than for other insects. Baited traps have not performed well, likely because of competition from fruit trees that also release benzaldehyde. USDA Agricultural Research Service (ARS) scientists have created more-competitive baits based on volatiles released by not just the fruit, but by the entire tree—and specifically by the foliage and woody tissues. In combination with the male-produced pheromone, these novel baits outperformed the standard bait of benzaldehyde and pheromone, even in the competitive environment found within an apple orchard. When benzaldehyde is combined with these new tree-based volatiles and the pheromone, even more plum curculios are captured in traps (Leskey et al., 2005). There is a modified trap design available from Great Lakes IPM (see Resources section) that helps increase the effectiveness of catching the first emergence of plum curculio adults. These traps, called Whalon modified tedder's traps, are 4-feet high and work without bait to give early warning of pest emergence. They work best when placed near target trees that have trunks painted white. One or two traps should be placed under at least 10 whitewashed trees known to have weevil infestations. Since the plum curculio enters the orchard from surrounding habitat such as woodlots, it is especially important to monitor perimeter apple trees at bloom.

Surround WP is a relatively new plum curculio-management option that is explained below. It is labor intensive and expensive to apply, however. New research from the University of Michigan is looking at a "push-pull" method involving heavy Surround application in the center of the orchard and mass trapping using pyramid and screen traps baited with attractants on the outer rows of the orchard. The basic idea behind mass trapping is that removing as many adult plum curculio as possible from the spring population greatly reduces the subsequent generation in number. Dr. Marc Whalon from Michigan State University has seen good results from this method in his preliminary experiments. More on this strategy can be seen in the Michigan State University IPM newsletter listed in the Further Resources section (Grieshop et al., 2010).

Plum Curculio and Orchard Establishment

"Because of plum curculio's preference for maple woodlots as overwintering sites and its low winter survival in other locations, it seems advisable to establish orchards as far removed as possible from maple woodlots. Furthermore, because plum curculio also attacks crabapple, wild apples, pears, plums, cherries, peach, apricot, quince, and hawthorn, apple orchards should be kept away from these trees, and wild host trees should be removed from the surrounding area."

"Sites adjacent to maple woodlots could be made less attractive by planting one or two rows of conifers along the edge to discourage plum curculios from entering the woodlot in the fall. Coniferous leaf litter scattered along the woodlot edge might also repel the plum curculio."

"A stone mulch about 1 foot in radius around the tree trunk with a thick spoiled hay mulch out of the dripline is likely to encourage many predators of plum curculio. Efficient mice guards must be used in conjunction with mulches."

"A diverse array of ground vegetation with small flowers is likely to attract parasitic wasps, which may parasitize not only plum curculio but also many other pests. This would need to be mown during apple blossom to avoid attracting the bees away from the apple pollination. Bare soil in the orchard is probably also unattractive to plum curculio, but its dependence on heavy herbicide use and associated soil erosion makes it an unsuitable solution."—Dr. Stuart B. Hill (1991)

Disking during the pupal period ("cocoon stage") is a method of mechanical control effective for the following production year. The pupa of the plum curculio is very fragile. If its cocoon is disturbed, the pupa fails to transform into an adult. Pupation usually occurs within the upper inch of soil. The most desirable time to begin cultivation for destruction of pupae appears to be about three weeks after the infested fruit starts to drop from the trees. Cultivation should be continued at weekly intervals for a period of several weeks. Cultivation before the curculio

Plum trees planted as "trap trees" could serve as early detectors since the crescent signature appears earlier on the plum fruit than on the apple. Photo: Angus Howitt, Michigan State University

pupates is of little value. If the cocoon is broken before pupation occurs, another cocoon is made by the larvae.

Free-ranging fowl such as chickens, ducks, and geese can be encouraged to scratch for the larvae and adult weevils by mixing poultry feed into the soil under the trees. Another option is to move mobile chicken coops along the edge of the orchard. Dr. Stuart Hill, an entomologist formerly at McGill University, has written that every successful organic orchard he's visited "had several hundred chickens in them as pest control agents" (Berenbaum, 1991).

Rotational grazing of hogs is currently being assessed by researchers at Michigan State University as a means of managing plum curculio and other insect pests through direct removal of larval-infested dropped fruit and soil disturbance. Preliminary results in apples have been very encouraging. Hogs grazing during the "June drop" period have reduced damage by subsequent generations of plum curculio three to five fold. A primary concern if using this approach is that hogs should be removed from the orchard at least 90 days prior to harvest in order to comply with the NOP manure application standards for tree fruit (Grieshop et al., 2010).

Michigan State University research is demonstrating that hogs and orchards go well together. Photo: David Epstein, Michigan State University

Insect IPM in Apples - Kaolin Clay

Surround WP is the commercial formulation of particle-film technology that presents a unique and wide-ranging form of pest control for apples and many other fruits. It is a nontoxic particle film that places a barrier between the pest and its host plant. The active ingredient is kaolin clay, an edible mineral long used as an anti-caking agent in processed foods and in such products as toothpaste and indigestion medicines. There appears to be no mammalian toxicity or any danger to the environment posed by the use of kaolin in pest control.

The spray was developed by Michael Glenn and Gary Puterka of the USDA ARS at Kearneysville, West Virginia, in cooperation with the Engelhard Corporation, which began marketing the product in 1999 on a limited basis. It is now widely used from coast to coast for insect and disease pest-management purposes. Conventional spray equipment can be used. Surround is sprayed on as a liquid, which evaporates, leaving a protective powdery film on the surfaces of leaves, stems, and fruit. Full coverage is important. The film works to deter insects in several ways. Tiny particles of the clay attach to the insects when they contact the tree, agitating and repelling them. Even if particles don't attach to their bodies, the insects find the coated plant or fruit unsuitable for feeding and egg-laying. In addition, the highly reflective white coating makes the tree less recognizable as a host.

The standard Surround spray program for plum curculio and first-generation codling moth starts at first petal fall and continues for six to eight weekly sprays or until the infestation is over. Discontinuing sprays at this point will leave little or no residue at harvest because of rain and wind attrition. If a full-season program is used to suppress later-season threats such as apple maggot, growers will need to use a scrubber/washer to remove any dust remaining on the fruit for fresh market sales. Although this residue is not considered harmful, it might be considered unsightly by consumers. The dust residue is not a problem for processing fruit, however.

Trial applications of Surround spray showed that whereas plum curculio damage was 20 to 30% in unsprayed checks, the areas receiving the particle film had only .5 to1% damage. Dr. Puterka is careful to say that his trials indicate "suppression" of plum curculio damage rather than complete control (Puterka and Glenn, 2005). For the organic grower looking to achieve an economic level of control, the distinction is probably not relevant. What the researcher terms "suppression" in these USDA trials is very close to control—far closer than any other organically suitable option. For the nonorganic grower, kaolin alone will not achieve quite as high a level of control as is ensured by organophosphates. Surround is comparable to organophosphates, however, in that it's a broad-spectrum tool effective against most of the major insect pests of apples.

A field trial using Surround in a certified organic apple orchard that historically had high apple maggot (AM) pressure was conducted in 2002 at the New York State Agriculture Experiment Station. The trial demonstrated that weekly applications of Surround gave excellent control—close to what is achieved with conventional pesticides—of AM damage, regardless of which nozzle was used—hollow cone, 2.4%; air induction, 3.3% (Robinson, 2003). Another trial in North Carolina had similar results (Villanueva and Walgenbach, 2007). Note that the adult life cycle of apple maggot is much later than plum curculio and codling moth. The above-referenced studies started their spray program at fruit set, in late June, and sprayed through mid-August. This schedule would not give sufficient time for the Surround residue to wear off the fruit before maturity and sales, but if you are direct marketing your apples, the presence of residue could be explained to the customer.

Recent studies have shown that application of Surround WP with a hand-held wand spray rig is often superior to application with an air-blast sprayer, simply because it takes more time per tree to achieve a full coat, and this provides better insect control. This may be a viable option for those looking to increase the amount of insect-free fruit produced by their organic orchards (Robinson, 2003). Another field trial in Missouri demonstrated significant control and suggested that the highest and most frequent rate of 50 pounds/acre sprayed weekly generally resulted in the best-protected plots in the orchards. Because a strong and persistent coating seems to be most successful, farmers should maintain a good, even coating on their trees and fruit at all times when a particular targeted pest is present and virulent (Thomas, 2002).

Although at first glance the film may appear to block light, Surround actually increases net photosynthesis and can provide secondary benefits. Surround keeps the tree cool so that photosynthesis can continue longer into the afternoon on hot days after untreated trees have already shut down because of heat stress. In a 2-year study, when sprayed with Surround WP during the first six to eight weeks after petal fall, the cultivar Empire had increased yields and increased red color (Glenn et al., 2001). Growers have reported similar results with Stayman and Gala.

Economics of Using Surround WP in Your Orchard Management System

Most conventional apple orchards will be sprayed about 15 times per season (Thomas, 2002). The labor and machinery cost for this is estimated at $51 per acre per year. For maximum insect and disease control, Surround WP must be sprayed nearly as frequently, so no cost savings are achieved on this count. Costs for chemical insecticides and fungicides are estimated by Rutgers to be $345 per acre in the Northeast. Surround WP averaged $30 per 25-pound bag in a search of agricultural supply companies. If sprayed at the most effective, high rate of 50 pounds per acre at an estimated 15 times per year, it would cost approximately $900 per acre per year. A lower application rate of 25 pounds per acre would cost approximately $450 per acre per year. Many organic orchardists, however, might be more selective with such a product, carefully incorporating it as part of a total integrated pest-management system and possibly using less. For example, a farmer who carefully monitors insect levels in the orchard may spray Surround WP frequently and heavily to combat a target insect when it is most virulent, while spraying lower rates and/or less often when threats are reduced.

The above figures of $345 (conventional chemical), $900 (Surround WP high rate), and $450 (Surround WP low rate) assume a significant loss in Grade 1 apples for the organic farmer, but a price premium for organic apples could compensate for the higher input costs. Probably the most important point to keep in mind is that an effective product such as Surround WP may be able to make the difference in whether organic apple production is feasible (and economical) at all in the East and Midwest (Thomas, 2002).

A study done by Cornell University researchers in 2002 indicated that the approved organic insecticides are about five to six times more expensive than conventional insecticides (Robinson, 2002). Combined with the consideration of increased number of applications and the increased labor involved with them, especially if hand application is utilized, this may result in a very expensive insect-control program. (See Table 2).

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Table 2: Surround Cost Breakdown

Product	Amount	Price/pound	Total average price (25 pounds)	Number of applications	Total cost of Surround/Acre
Surround WP	25 pounds/ acre	1.30/ pound	$32.50	15	$487.50
Surround WP	50 pounds/ acre	1.30/ pound	$32.50	13	$845

Table 3: Efficacy (Percentage) of Particle-Film Formulations Against Key Pests of Apple Other Than Plum Curculio

Formulation[1]	Pests	% Efficacy	Mechanisms	Comments (rate)
M96-018 dust	*Aphis spiraecola* Potch; apple aphid *Tetranychus urticae* Koch; two spotted spider mite *Empoasca fabae* (Harris); leaf hopper *Cacopsylla pyriocola* (L.); pear psylla	50% 50% 50% >75%	Mortality Mortality < Damage Repellence, <Oviposition	Lab (dust@100ug/ cm^2) Lab (dust@100ug/ cm^2) Field (dust@100ug/ cm^2) Field (dust@100ug/ cm^2)
M96-018+MEOH	*Choristoneura rosaceana* oblique banded leaf roller	75%	Mortality, reduced mating success, repellence	Lab and field (3% solids)
M96-018+MEOH, Surround + M03	*Cydia pomenella* (L.); codling moth	53-87%	<damage, <oviposition, and repellence	Lab and field (1.5 and 3% solids) No rate effect

(Puterka and Glenn, 2005)

[1]Formulation and rate: M96-018 dust (hydrophobic film)—100g/ tree; m96-018/MEOH (hydrophobic film)—3% solids, 4% MEOH, 100 gpa; Surround/ MHO3 (hydrophobic film)—also called m97-009/M03—3% solids, 1 pint M03 spreader/ 100 gallons water, 100 gpa; Surround WP—3% solids, 100 gpa.

Insect IPM in Apples - Kaolin Clay continued

A systems approach

Surround will be most effective when used within a well-managed agroecological system combining the most appropriate cultural methods for the specific orchard situation, pest complex, and local climate. Such a system will integrate soil building, habitat for beneficial organisms, and well-tuned nutrient and water management in a preventative pest-management strategy. A healthy soil high in organic matter will have better water- and nutrient-holding capacity. Plants receiving too much or too little of either water or nutrients, particularly nitrogen, are more susceptible to damage by insects and diseases. Good water management, through water-stress monitoring, conserves valuable (and expensive) soil nutrients, reduces contaminated runoff, and saves water. Also, providing habitat for beneficial organisms is like hiring millions of helpers whose sole aim in life is to eat pests. Furthermore, nitrogen-fixing cover crops can do double duty as habitat for beneficial organisms if managed correctly. (See the ATTRA publication *Farmscaping for Biological Control* for more details on this.)

Compatibility

Surround is generally not affected by most other insecticides, miticides, and fungicides. However, the user should test tank-mixes before use. When mixing with other products, make up a small batch and observe slurry and film characteristics. Curdling, precipitation, lack of film formation, or changes in viscosity are signs of incompatibility. Do not tank-mix with elemental sulfur or Bordeaux mixture fungicides. Wettable sulfurs and liquid sulfur products are tank-compatible with Surround WP, according to the Surround WP label.

Note: "Raw" kaolin clay is not the same as Surround WP. We have heard of one grower who bought a train carload of "generic" kaolin clay and killed most of his apple trees. Surround is, at this point in time, the only kaolin product suitable and registered for horticultural use. The kaolin in Surround is processed to a very fine particle size and combined with a sticker-spreader. ***Other forms of kaolin clay are phytotoxic and should not be used under any circumstances.***

Codling moth

A coddling moth. Photo: Whitney Cranshaw, Colorado State University, Bugwood.org

The codling moth entrance hole. Photo: Clemson University - USDA Cooperative Extension Slide Series, Bugwood.org

Codling moth larvae and internal damage. Photo: Clemson University - USDA Cooperative Extension Slide Series, Bugwood.org

The codling moth, *Cydia pomonella*, is present throughout North American apple-growing regions. Prior to the advent of synthetic pesticides, the codling moth larva was the proverbial "worm in the apple." Relatively cold regions may have only one generation of the codling moth, while in the warmest apple-growing areas the codling moth may pass through two to three generations per season. Several organically acceptable controls are available and discussed below. Also see the section on Kaolin Clay.

Among the most effective nontoxic controls for codling moth is mating disruption using pheromones—chemicals naturally produced by insects as a means of communication. During the mating period, female codling moths release pheromones that signal their locations to males. By releasing quantities of these pheromones into the orchard, the grower can confuse and disrupt the moth's mating cycle.

This approach faces two general problems—difficulties with sustaining an even, long-lasting distribution of pheromones throughout the orchard and complications due to the biology and initial distribution of the codling moth. For instance, dispensers can release pheromones too slowly or too quickly, thus allowing mating to occur. Orchard layout is another consideration. For best results, trees should be evenly spaced and of equal heights since treeless spaces and taller trees interrupt the pheromone spread. Cold weather can cause too little pheromone release and hot weather can cause the pheromone to deplete too fast. Since the pheromones actually attract male moths, fruit damage can be worse if pheromone levels drop low enough to allow mating to occur (Quarles, 1994).

Dispensers should be placed as high in the trees as possible, since mating can occur in the air above the dispensers. For pheromone dispensers to be effective, it is important to use them at the recommended rate per acre (Warner, 1996).

An aerosol dispenser, nicknamed the "puffer," which uses a timer to periodically spray pheromone into the orchard air, is an effective dispensing method. These puffers reduce the labor requirement of tying pheromone twist-ties on to orchard trees. Some of the puffers are allowable for use by the National Organic Program. See the Further Resources section for a list of places to obtain pheromones.

For organic growers it will probably not be feasible to achieve adequate suppression using mating disruption alone. Growers in California have significantly improved codling moth control by combining mating disruption with black-light traps. Both male and female codling moths are strongly attracted to black light (Howell, 1997).

Calculating Growing Degree Days

In orchards where codling moth is managed primarily with insecticides (organic or not), pheromone traps, in conjunction with degree days, are used to determine egg hatch and proper spray timing. Use growing degree days (GDD) primarily to time control measures for pests of woody plants. You can also use them to track and predict other events that are synchronized with the accumulation of warmth during the growing season, such as the blooming of some plants.

In a nutshell, growing degree days accumulate any time the average temperature for the day is more than 50° F. For example, if the high for the day was 70° F and the low was 40° F, the average temperature was 55°F, so five GDDs accumulated.

Codling moth has two to four generations each season. Continue to monitor the generations with traps and accumulate degree days until the crop is harvested or populations decline below damaging levels in September. GDD measurements start March 1, and the GDDs for each day are added to the previous total. When the average temperature for the day is below 50°F, it is ignored. It is not subtracted from the total (Cornell Department of Horticulture, 2010). The chart at right, from a Washington State University publication, illustrates how to calculate degree days.

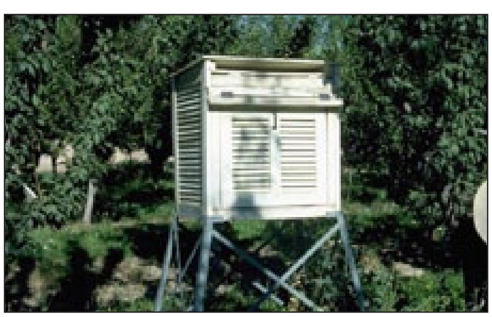
Degree Day Look-up Table for Codling Moth and Peach Twig Borer

Lower threshold: 50°F Upper threshold: 88°F Horizontal cut-off

Maximum temperature \ Minimum temperature	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63	66	69	72	75	78	81
49	0	0	0	0	0	0	0	0	0	0	0	0											
52	0	0	0	0	0	0	0	0	0	0	0	1	2										
55	1	1	1	1	1	1	1	1	1	1	2	2	3	5									
58	1	2	2	2	2	2	2	2	2	3	3	3	5	6	8								
61	2	2	3	3	3	3	3	3	4	4	4	5	6	8	9	11							
64	3	3	4	4	4	4	4	4	5	5	6	6	8	9	11	12	14						
67	4	4	5	5	5	5	5	6	6	6	7	8	9	11	12	14	15	17					
70	5	5	6	6	6	6	7	7	7	8	8	9	11	12	14	16	17	18	20				
73	6	7	7	7	7	8	8	8	9	9	10	11	12	14	15	17	18	20	21	23			
76	8	8	8	8	9	9	9	10	10	11	11	12	14	15	17	18	20	21	23	24	26		
79	9	9	9	10	10	10	11	11	12	12	13	14	15	17	18	20	21	23	24	26	27	29	
82	10	10	10	11	11	11	12	12	13	14	14	15	17	18	20	21	23	24	26	27	29	30	32
85	11	11	12	12	12	13	13	14	14	15	16	17	18	20	21	23	24	26	27	29	30	32	33
88	12	13	13	13	14	14	15	15	16	16	17	18	20	21	23	24	26	27	29	30	32	33	35
91	13	14	14	14	15	15	16	16	17	18	18	19	21	22	24	25	27	28	30	31	32	34	35
94	14	15	15	15	16	16	17	17	18	18	19	20	22	23	24	26	27	29	30	32	33	34	36
97	15	15	16	16	16	17	17	18	19	19	20	21	22	24	25	27	28	29	31	32	33	35	36
100	16	16	16	17	17	18	18	19	19	20	21	22	23	24	26	27	28	30	31	32	34	35	36
103	16	16	17	17	18	18	19	19	20	21	21	22	23	25	26	28	29	30	32	33	34	35	36
106	17	17	17	18	18	19	19	20	20	21	22	23	24	25	27	28	29	31	32	33	34	35	36
109	17	17	18	18	19	19	20	20	21	22	22	23	24	26	27	28	30	31	32	33	34	36	36
112	18	18	18	19	19	20	20	21	21	22	23	24	25	26	27	29	30	31	32	34	35	36	37
115	18	18	19	19	20	20	21	21	22	22	23	24	25	26	28	29	30	31	33	34	35	36	37

To find the total degree days for a day, locate the low and high temperatures and follow the rows to where they intersect. For temperatures between those listed, use the nearest shown. This chart can be duplicated for easy reference in the field.

This degree-day calculator helps to determine where codling moths are in their life cycle. Chart excerpted from **Orchard Pest Management** ***by Vincent P. Jones and Jay F. Brunner.***



Weather monitors such as this help to calculate growing degree days. Photo: Howard F. Schwartz, Bugwood.org

Prior to the development of the mating-disruption system, pheromones were used primarily for monitoring to determine the best timing for spray applications. Degree-day monitoring can also be used to this effect. Since insects are cold blooded, weather monitoring can forecast when an event, such as egg hatch, will occur. This information can be obtained by calculating degree days and can be used to implement control methods, such as pesticide applications or cultural manipulations, so that they are used at the most effective time in the pest's life cycle.

There are several "windows" in the pest's development that, if detected, can greatly increase the effectiveness of control measures. Determination of these critical periods is especially important, since codling moth eggs are fairly resistant to pesticide treatments, and once the eggs hatch, the larvae will quickly enter a fruit and be protected from sprays. While *Bacillus thuringiensis* has shown effectiveness with other moth pests, it is not as effective on codling moth, and additionally can be cost prohibitive. A granulosis virus, originally identified from codling moth, has been shown to be effective for control of early-stage codling moth larvae. This virus was developed for commercial use in Europe and has been used in the United States under the brand name Cyd-X (CMISS, 1998). Degree-day monitoring is necessary to time the application of Cyd-X. Harry Hoch describes his use of Cyd-X in his farm profile on page 13.

The *trichogramma* wasp is increasingly used in U.S. orchards as a biological control organism against codling moth. The wasps can be ordered from insectaries, which ship them as pupae inside parasitized grain moth eggs glued to perforated cards (100,000 *trichogramma* per

Using Farmscaping to Attract and Conserve Beneficial Insects in Your Orchard

Farmscaping is the use of hedgerows, insectary plants, cover crops, and water reservoirs to attract and support populations of "beneficial" organisms—natural predators of crop pests. Because of the inherent ecological stability of a permanent planting of trees, apple orchards are generally more amenable to farmscaping than annual cropping systems are.

Farmscaping concepts can be used to design an agroecosystem that increases plant diversity, confuses pest insects, and disrupts pest life cycles. The goal is to create a more species-diverse environment by providing a variety of habitats (niches) for organisms to exploit. Farmscaping practices will not eliminate pest problems, but they can help reduce pest pressure and, when integrated with cultural control methods, contribute to minimizing the use of chemicals. However, simply using a random selection of flowering plants for farmscaping may favor pest populations over beneficial organisms, so it is important to include only those plants (and planting situations) that best support populations of beneficial organisms.

Ron Prokopy wrote about the management dilemma faced by some farmers trying to implement farmscaping concepts: how to manage a resource that has both positive and negative impacts on crop yield and/or health. To illustrate, Prokopy noted that the presence of brambles in an apple orchard supports significant populations of phytoseiid predatory mites (Prokopy, 1994). However, brambles are important hosts of two major summer diseases of pome fruit: sooty blotch and flyspeck. Should the farmer retain the brambles and gain the positive effect of the mites or reduce disease pressure by eliminating the brambles? This is a good example of the quandaries presented by ecological pest management.

Flowering plants provide various forms of food to beneficials, including nectar, pollen, honeydew (from aphids on plants), and herbivorous insects and mites. A mix of plants such as dill, hairy vetch, spearmint, Queen Anne's lace, buckwheat, yarrow, white clover, tansy, cowpea, cosmos, and zinnias will attract and conserve many beneficials, including trichogramma wasps. It may not be necessary to sow flowers or put much time into planning to take advantage of beneficial-sustaining habitat. When Arkansas orchardist Guy Ames mows the paths between his apple rows, he simply leaves an unmown strip down the middle of each path, where weeds such as Queen Anne's lace, clovers, and vetches can go to flower. He has noticed a marked increase in beneficials in the orchard and enjoys the aesthetic effect of wildflowers blooming among the apple trees.

For further information, including resources and seed suppliers, see the ATTRA publication *Farmscaping to Enhance Biological Control*.

Home Acres Orchard in Stevensville, Montana, plants strips of wildflowers between trees to attract beneficials. Photo: University of Montana Dining Services

card). Each card can be broken into 30 squares, allowing for even distribution in orchards and fields. *Trichogramma* parasitize freshly deposited moth eggs, so release of the adult wasps should be timed to coincide with moth egg-laying. Degree-day monitoring can help determine when egg laying is occurring. *Trichogramma* feed on insect eggs, nectar, pollen, and honeydew. They live much longer and destroy more codling moths when supplied with nectar. Good nectar and pollen sources in and around the orchard, such as borders or strips of unsprayed alfalfa, sorghum, sunflower, corn, clovers, and wildflowers, will increase *Trichogramma* parasitism of pest eggs. Beneficial organisms are not sufficient by themselves to affect a commercially acceptable level of control; rather, they play a potentially potent part in an overall long-range ecological management strategy. Best results are usually observed after three to five years of releases, as the population of beneficials grows.

Sanitation and cultural practices can help reduce codling moth populations. Woodpiles, boxes, and bins can be a major source of reinfestation, so these should be kept away from the orchard. If wooden crates or boxes are discovered to contain codling moth pupal cases, they can be disinfested by scorching with a propane torch.

In smaller orchards, codling moth larvae can also be intercepted as they descend the trunk to pupate in bark crevices, soil, and certain weed stems. Wrap the trunks with corrugated cardboard, which will provide an attractive artificial pupation site. In areas with only one generation of codling moth, remove and burn the cardboard at the end of the season. If there are two or more generations, the cardboard should be removed and destroyed about a month after the first larvae moved down to pupate. To determine the timing of this larval movement, use the degree-day method described above or employ a trap of a 6-inch-wide burlap strip painted with Tanglefoot and wrapped around the trunk just above the cardboard wraps (Dickey, 2009).

Apple Maggot

The apple maggot, *Rhagoletis pomonella*, is another major apple pest, primarily found in the Northeast and the upper Midwest. To monitor adult population levels, red spheres covered with a sticky coating and impregnated with a fly-attracting odor are hung in the orchard. If enough spheres are used, the flies can also be mass trapped. This technique may reduce or eliminate the need for pesticide applications. The spheres are available from several suppliers, including Gempler's, Inc. See the supplier list under Further Resources.

Monitoring for apple maggots can be done with sticky traps or "red spheres." Photo: Whitney Cranshaw, Colorado State University, Bugwood.org

Removing hawthorns and abandoned or neglected apple trees near the orchard should help in reducing fly influx into the orchard. The flies are susceptible to pyrethrum, rotenone, and diatomaceous earth. Also, recent research on Surround particle film has shown it to manage maggot populations within acceptable levels if sprayed shortly after fruit set (late June through August for northern climates). See the section on Insect IPM in Apples - Kaolin Clay.

Oriental Fruit Moth

Usually thought of as a pest of stone fruits, this insect has adapted to exploit apples. This insect was initially limited to the South and Upper South regions of the U.S., but Harry Hoch of Hoch Organic Orchards mentions that it has an increasingly expansive range, having made an appearance in Michigan apple orchards and moved west. It is a direct pest of the fruit, tunneling randomly throughout the flesh (in contrast to the codling moth, which feeds mainly around the seed cavity). Another identifying feature of the fruit moth is that it often feeds on succulent shoot tips. The Oriental fruit moth is relatively easy to control with insecticides, especially if sprays are timed by using commercially available pheromone traps. Unfortunately, due to differing life cycles, the sprays for plum curculio and codling moth do not control the Oriental fruit moth. Sprays for this pest are usually needed later in the season, when they may be disruptive to beneficial insects. A pheromone-based mating disruption system (Isomate-M) has proved effective and is registered for use on apples.

Minor and Induced Pests

All of the aforementioned insects are direct pests of the apple fruit. Most of the so-called minor pests—mites, aphids, scale, leafrollers, and others—feed primarily on the stems and foliage. In general, these pests can be tolerated in much higher numbers than the direct fruit pests, but they can occur in high enough numbers to seriously weaken the tree, resulting in reduced quality and quantity of fruit and perhaps tree death.

Many of these minor pests are "induced" pests—that is, they have achieved pest status because pesticides that were targeted for major pests killed beneficial organisms that would otherwise have kept these minor pests below damage thresholds. Nonselective pesticides—those that affect beneficial and pest organisms alike—whether organic or synthetic, can cause this phenomenon.

Dr. Ron Prokopy's low-spray system is largely based on the supposition that avoidance of nonselective pesticide use during mid and late season will preserve adequate numbers of beneficial organisms, which will control these minor pests. Interestingly, organic growers who have to rely on frequent sprays of nonselective botanical pesticides (especially pyrethrum) may suffer more from induced-pest problems than low-spray growers who are able to stop spraying earlier in the season (Prokopy, 1991).

There are relatively nontoxic ways to control most of these minor pests, should they become troublesome. *Bacillus thuringiensis* is effective against lepidopteran pests such as leafrollers. Oil sprays (dormant and summer types) are effective against mites, scale, and eggs of some other pests. Oils should not be used in conjunction with or within 30 days of sulfur applications, since a combination of the two can cause phytotoxicity (damage to the plants, in this case leaf "burning"). M-Pede insecticidal soap is effective against aphids and mites if coverage is adequate and frequent.

Beneficial mites, ladybeetles, green lacewings, and parasitoid wasps are also commercially available and can be helpful against many of the minor pests. Encouragement of these beneficials can also help to increase these populations naturally. See the section above on Farmscaping. The kaolin clay spray discussed above has also been found to control leafhoppers and leafrollers and to provide significant levels of suppression against mites, apple suckers, stink bugs, and thrips.

Borers

Another important production concern for organic or low-spray apple growers is borer control. There are two species of flatheaded borers that may invade apple trees. *Chrysobothris femorata* is the species endemic to the East. On the Pacific coast, *C. mali* fills a similar niche. Adults emerge from woodland trees in late April through early May and begin laying eggs beneath bark scales on the tree. The graft union is a favorite place for egg deposition.

Upon hatching, the larvae burrow under the bark and feed on the cambium—the layer of tissue just underneath the bark. Development is usually completed in one year, but sometimes two years are required. Photo: James Solomon, USDA Forest Service, Bugwood.org

Maintaining trees in good vigor is important first-line protection from flatheaded borers since a tree in good vigor will be able to drown an invading larva with sap. Drought-stressed trees are much more susceptible to borers; therefore, adequate water is essential.

The roundheaded apple tree borer, *Saperda candida*, attacks the tree near ground level and is therefore harder to exclude using a wrap or paint. As with the flatheaded borer, keeping the tree in good vigor is the first line of defense. Removing serviceberry trees (*Amelanchier spp.*) in close proximity to the orchard may also help because the serviceberry is a preferred host for the roundheaded borer.

Another borer that was initially exclusive to the East, the dogwood borer or *Synanthedon scitula*, feeds primarily on burr knot tissue on clonal rootstocks. Substantial damage from this borer has been found in Minnesota apple orchards, so the pest is expanding its territory. Burr knots are clusters of root initials that develop on the above-ground portion of some rootstocks. Planting so that the graft or bud union is within 1 inch of the soil should inhibit the development of burr knots, thereby preventing dogwood borer attack. Painting exposed burr knots with interior white latex paint is also helpful, but it is not allowed by the National Organic Program standards. Unless the infestation is heavy, dogwood borer damage is generally not as important as that caused by flatheaded or roundheaded apple-tree borers.

For all species of borers, the larvae can be removed from the trunk with a jackknife or piece of wire. Look for signs of borer damage, such as frass mixed with sawdust at the base of the tree and at the pest's entry hole. Because the roundheaded borer may burrow deep into roots, it is important to check routinely (at least twice

Pest Management at Hoch Orchards and Gardens. LeCrecsent, Minnesota

The Hochs have developed a state-of-the art integrated pest-management system in their eastern-Minnesota orchard, using sophisticated monitoring, pest management techniques and beneficial encouragement. These techniques have enabled the Hochs to become certified organic.

Pest monitoring

The Hochs use a weather-data logger that monitors conditions that are favorable to codling moth and plum curculio—the two most difficult apple-insect pests on the farm. Another major pest is apple maggot. Although weather data is not used to time pest control, visual traps are used to both monitor and control apple maggots. The bearing orchards (about 30 acres) are divided into 12 separate monitoring zones. Each zone has its own set of insect traps, so they are able to record pest levels in the different zones on a weekly basis. The zones are then evaluated and treated independently, allowing the Hochs to focus spraying only where pest pressure went above the economic threshold. Through degree-day logging combined with Tanglefoot sticky traps (baited with a pheromone lure), the Hochs are able to time their codling moth sprays exactly when they are needed. For codling moth, they typically spray granulosis virus as a biological control—the trade name is CYD-X; they occasionally use Entrust when pressure is high. Surround WP will also repel the moths, increasing the efficacy of the other products. For apple maggot and plum curculio, they spray neem combined with Surround WP after petal fall.

"I am hoping my control program will not develop resistant codling moth," says Harry. "The use of several products, a biologically balanced environment, and targeted sprays should reduce the chance of resistance showing up here." Taking a holistic approach that includes strong competition with beneficial insects and moth predators helps the pest insect populations stay pretty low. According to Harry, "We only treat a few times per season, and when we do treat, the codling moths don't go much above the threshold levels."

Some blocks never go over the threshold of seven moths trapped per week. "Our high catches are usually between 10 and 15 moths per week; it is not uncommon for conventional growers to trap 30 to 50 moths per week, with some exceeding 70," notes Harry. The Hochs' approach to pest control is to create a balanced environment that keeps populations low and then treat with a soft pesticide to nudge the populations down during their natural peaks.

The data loggers are placed in the tree canopies and downloaded onto a computer. They use the weather data to calculate degree-day units (See the Further Resources section for more information and links to degree-day calculations for your region.) and predict when pests will be hatching and infesting the fruit. They also use this computer modeling to determine when disease pressure is increasing and to plan fungicide application when the pathogens are at their most susceptible phase. They mainly spray lime sulfur for apple scab, especially on the most susceptible varieties. "We spray lime sulfur in a post-infection program, only making an application after it has been verified by the computer model," says Harry. "We are experimenting with different rates of lime sulfur and combining lime sulfur with micronized sulfur. We also use some micronized sulfur in a protectant program on the most susceptible varieties."

Resistant varieties

The Hochs are planting more scab-immune varieties and plan to remove or topwork (graft) the most susceptible varieties with new scab-immune varieties. "Some conventional varieties like Honeycrisp and Haralson do not require a strong fungicide program, while others like Cortland and McIntosh require high levels of fungicide," Harry advises. They plan to phase out the highly susceptible varieties over the next few years.

Encouraging beneficials

The Hochs believe that proper timing of mowing has a big effect on the orchard environment. They create a good home for beneficial insects through alternate-row mowing in the orchards during the growing season. They wait until the mown rows regrow to show signs of flowering before mowing the alternate rows with the long grass. Continual mowing creates a monoculture of grasses, so the Hochs use timed mowing to produce a multilayered diversity of plants that provide pollen and nectar for beneficial insects.

during the growing season (e.g., once in May and again in September) for borers, or they can extend beyond the range of manual removal.

Perhaps the best non-chemical protection from all species of borers is to wrap the bottom 12 to 18 inches of the trunk in window screen (metal, fiberglass, or nylon are all effective). Secure the top with a twist-tie, being certain to loosen and retie it at least once a year. The bottom should be snug against the ground or also secured with a twist-tie.

Diseases

It is important to identify diseases before outlining a management plan. To identify diseases present at a specific orchard site, contact your Cooperative Extension Service or call the ATTRA information line to get contact information for your county.

The OrganicA project based in Vermont is assessing organic disease-management options for apples. Their initial findings show that it is extremely important to examine the surrounding orchard ecosystem and identify sources of disease inoculum. Abandoned apple trees near the two orchard systems studied in this project were providing high levels of disease inoculum, which affected disease-management decisions and disease incidence in the orchards (Berkett, 2009).

Understanding Genetic Disease Resistance

By plant breeders' design or by chance, a plant may exhibit natural heritable resistance to a disease. Because disease-resistant cultivars have become increasingly important as growers try to reduce pesticide use, it is important to understand some principles of genetic disease resistance.

Resistance to a disease can be partial or complete (immunity). Resistance exists on a continuum and may be expressed in terms such as "moderately susceptible," "moderately resistant," "resistant," "very resistant," etc. In some cases, numerical values have been assigned by researchers to represent a given level of resistance. If resistance is strong enough, the grower will not have to spray to control the disease. It is important that the grower understand that medium levels of resistance can be overcome and the plant can suffer some infection, given strong enough disease pressure from high levels of inoculum (disease reproductive capacity) and the proper environmental conditions.

Another principle to understand is that resistance to one disease never implies resistance to any other disease. A given variety may exhibit strong resistance to one disease, yet be highly susceptible to another. A good example of this is the cultivar Prima, which is apparently immune to scab but so susceptible to cedar rust that it will defoliate if disease pressure is high. Growers who intend to forego all sprays for diseases need to be certain to get trees resistant to the diseases present in their areas.

Lastly, the term tolerance is often used interchangeably with resistance. Technically, tolerance refers to the ability of a plant to undergo infection without appreciable losses in growth or yield. A tree in good health will be tolerant to many diseases. For instance, a vigorous tree that suffered a cedar rust infection early in the season may show few signs of that infection later in the same season. The disease resistance/susceptibility of many apple varieties is charted in Appendix 1.

Apple Scab

Apple scab. Photo: James W. Travis, Natural Resource, Agriculture, and Engineering Service.

Apple scab, caused by the fungus *Venturia inaequalis*, is the most serious apple disease worldwide. The pathogen overwinters in dead leaves on the ground. Spores are released during spring rains, landing on and infecting leaves and fruit. Rain, duration of leaf wetness, and temperature determine apple scab infection periods, and the degree of infection depends on a combination of these factors. Infection occurs most rapidly between 55° and 75°F, and leaves or fruit must remain wet continuously for a minimum of nine hours for infection to occur. If initial infections are not controlled, they will give rise to secondary infections later in the season. Primary and secondary infections may occur simultaneously early in the season, depending on weather conditions (Ohlendorf, 2001). If the grower is relying on protective-type fungicides, including all organically acceptable fungicides, trees should be treated whenever there is a chance of primary infection, or, in other words, when the weather conditions favorable to scab infection prevail (Pscheidt, 2009).

Secondary infections begin when summer spores (conidia) develop in lesions on leaf and bud tissues, to be released during wet periods and disseminated throughout the tree. Secondary infections blemish and deform the apples and will also weaken the tree. The number of primary and secondary infections in a year depends on the amount of rain. The warmer the weather, the more quickly conidia development follows primary infection (ranging from 18 days at 31º-40ºF, to seven days at 71º-75ºF). Fortunately, good scab-infection prediction and management programs are available. The equipment necessary to monitor and detect infection periods includes a leaf-wetness meter, a rain gauge, and a temperature recorder (Grove, 2009). These instruments are available at most agricultural supply stores.

The use of scab-resistant varieties is the best long-term strategy for organic growers to pursue since such trees eliminate the necessity of applying fungicides. See Appendix 1 for a list of scab-resistant varieties.

Apple scab can be controlled on susceptible varieties by timely sprays with fungicides. For the organic apple grower, there are three commonly used materials: sulfur, lime-sulfur, and Bordeaux mixture. Bordeaux mixture is copper sulfate plus lime. All of these sulfur-containing fungicides can cause damage to the foliage or blossoms if used incorrectly, so heeding label cautions is important. Recent research in the Netherlands demonstrated that potassium bicarbonate (the trade name is Armicarb) and potassium phosphonate (Resistim), when applied in combination with sulphur, were very effective at controlling the fungus—demonstrating better efficacy than copper in some cases (Heijne, 2006). All these fungicides are effective against scab spores, but have to be applied before spores have a chance to germinate. For the treatment to be effective, the trees must be sprayed or dusted diligently before, during, or immediately after a rain, from the time of bud break until all the spores are discharged. If these primary infections are prevented, there will be less need to spray for scab during the remainder of the season (Agrios, 2005). If primary infections do develop, spraying will have to be continued throughout the season.

In most areas, applications of fungicides—in this case, sulfur products—are based on the phenological development of the trees. Spraying begins in the spring when a period of rain is sufficiently long at the existing temperature to foster an infection. Spraying is then repeated every five to seven days, or as rainfall dictates, until petal fall. With protective-type fungicides such as sulfur, it is important to ensure that new tissues on rapidly expanding young leaves and fruit are always covered with fungicide during an infection period.

Because the scab fungus overwinters on fallen apple leaves, growers can largely eliminate the primary scab inoculum and control the disease by raking and destroying (burying, burning, or composting) the fallen leaves. Results from a two-year on-farm experiment showed that leaf-litter removal reduced the apple scab inoculum and prevented further development (Gomeza et al., 2007).

Other approaches to reducing or eliminating the primary inoculum might include anything that would hasten the breakdown of the fallen leaves. There is evidence that earthworms aid in scab control by speeding the breakdown and incorporation of fallen leaves (Heijne, 2006).

Fall fungicide applications also have shown promise for primary scab control. One of the major problems with using sulfur compounds is phytotoxicity, but this concern could be largely circumvented by spraying in late autumn (after harvest but before leaf fall) when it is not very important if the leaves are damaged. Research with other fungicides has proven the basic efficacy of this approach.

Neem has demonstrated some efficacy in managing scab, but not at the same levels as lime sulfur (Berkett, 2009). Other unconventional approaches to scab control that show some promise include a variety of plant extracts and even compost tea (Cronin, 1996).

Fire Blight

Fire blight symptoms on foliage include sudden dieback, blackened leaves, and a characteristic crook at the top of the infected branch.

The advanced stages of fire blight cause a bacterial ooze as seen in this picture. Photos: TJ Smith, Washington State University

Fire blight is caused by the bacteria *Erwinia amylovora*, which can be transmitted by bees, aphids, and other insects, as well as by wind and rain. Warm, wet conditions foster the bacteria's reproduction and spread within and among trees, and large numbers of new infections can occur within minutes after rain or heavy dew hits. Fire blight will be a problem only in years when the weather is conducive to its spread. Affected branches wither and turn black or brownish black, as if scorched. Most branch tips, once infected, wilt rapidly, taking on the characteristic shape of a "shepherd's crook." Having gained entry to the tree through blossoms or lush new growth, the bacteria spread internally through the stems and begin to work toward the roots. In resistant varieties, the bacteria rarely invade beyond young wood. (See Appendix 1 for information on resistant varieties.) Under the bark, the bacteria form a canker where they will overwinter, surviving to infect more trees the next year.

Once infection has occurred, there is no spray or other treatment—beyond quickly cutting out infected limbs—that will minimize damage. Sprays of agricultural-grade streptomycin and tetracycline have been the standard commercial control since the 1950s, applied at early bloom to prevent infection. These products are allowed for organic production for the purposes of managing fire blight only. If you intend to use them, you must document in your Organic System Plan the indications of fire blight. Bordeaux mix and other copper formulations sprayed at green-tip stage are organic options that provide some protection from infection. For best results, these should be applied to all the trees in a block, not only the blight-susceptible varieties (Stelljes and Stenf, 1998). Streptomycin is currently being petitioned to the National Organic Standards Board to be allowed for use post-infections for both blossom infection and trauma blight prevention. This is pending, so it currently is not allowed for use in organic production, but it is effective if used in combination with a blight-modeling program.

The antagonistic bacteria *Pseudomonas fluorescens* (Blight Ban A506) is commercially available to prevent colonization of the blossoms by *Erwinia amylovora* during bloom. BlightBan is a formulation of the bacteria *Pseudomonas fluorescens*, strain A506. *P. fluorescens* is a non-pathogenic competitor with *E. amylovora*, and as such does not directly kill propagules of *E. amylovora*; rather, it occupies the same sites that *E. amylovora* would, provided it gets there first. Therefore, in order to be effective, BlightBan should be applied to newly opening flowers multiple times or applied in combination with streptomycin (*P. fluorescens*, strain A506, is resistant to streptomycin).

By itself, BlightBan may provide 50% suppression, but research indicates that fire blight suppression is best when streptomycin and BlightBan are combined (Elkins et al., 2007). Using the two together can reduce the amount of streptomycin sprayed each year, which may help to protect the antibiotic's effectiveness. (In some

Fire Blight and Pruning

Whether to cut out and how to cut out active blight infections during the growing season is a subject of continuing debate. We recommend a very aggressive cutting of all branches that show symptoms, but only when the incidence and distribution of infections is light and the job can be completed quickly. More vigorous pruning of fire-blight-affected branches should occur in the winter.

The Cornell IPM Program recommends scouting for and pruning out the yellow-orange shoots characteristic of canker blight infections one to two weeks after petal fall. Pruning out new shoot blight infections as they appear can also help limit disease spread, but will be most effective if practiced rigorously during the first few weeks after bloom. This is particularly useful when blossom blight is well controlled and canker blight infections are thus the main source of inoculum for disease spread during the summer. Pruning will do little to slow disease spread if delayed until a large number of infections are visible (Wilcox, 1994).

When blight is moderate to heavy, the success of even the most well-intentioned cutting effort is questionable. In such cases, the focus should be on removing infections high in the tree, those that threaten the central tree stem, and removing severely damaged trees quickly. While the bacteria are often present in healthy tissues far ahead of visible symptoms, high levels of reserve carbohydrates in living bark tissues deny the pathogen water and limit symptom development. Cutting through such colonized but symptomless branches breaches this natural defense and induces the formation of cankers around wounds, even where both bark surface and pruning shears have first been sterilized with bleach or alcohol.

"To avoid new cankers around cut sites, make cuts during the growing season only into two-year-old or older wood and at least 4 to 5 inches short of the next healthy branch union, leaving an "ugly," naked stub. Cankers that form around the cut can be removed during the regular dormant pruning effort when the temperature is too cold to allow the bacteria to form another canker. Failure to follow this "ugly stub" procedure can actually increase the number and distribution of inoculum sources in the orchard that will fuel yet another epidemic the next season" (Steiner, 1996).

western apple-growing areas, *E. amylovora* has developed resistance to streptomycin.) BlightBan cannot be used in combination with copper sprays. BlightBan is manufactured by NuFarm; to find a sales representative near you, see the Further Resources section.

A computer software program called Maryblyt is available to help guide growers in timing antibiotic sprays. It is generally used in apple- and pear-growing regions in the upper Midwest, the Northeast and mid-Atlantic states. A grower enters daily minimum and maximum temperatures, rainfall, and stage of blossom development, and the program predicts infection events and symptom development for most phases of fire blight. However, growers need to know that Maryblyt may over or underestimate the severity of fire blight because of many factors that are not accounted for in the program. Despite these deficiencies, growers have succeeded fairly well in using Maryblyt to time antibiotic applications. Further information on the Maryblyt program is available at the Kearneysville, Virginia, Experiment Station website, *www.caf.wvu.edu/kearneysville/Maryblyt/index.html* (Strang, 2004).

A rule of thumb is to spray just before rain or heavy dew is expected during bloom, when the average temperature is 60ºF or higher, and to repeat in four days if these conditions persist. "Routine" sprays in the absence of wet, warm conditions are often unnecessary. Furthermore, overuse of streptomycin should be avoided because of the danger of inducing resistance in the pathogen population. It is important to remember that streptomycin is not effective against the "shoot blight" phase and should never be used when symptoms—"burned" branch tips—are present (Strang, 2004).

Proper sanitation is the most important measure for controlling fire blight once it has infected a tree. During the winter all blighted twigs, branches, and cankers should be cut out about 10 cm below the last point of visible infection and burned. After each cut, the shears should be dipped in alcohol or a strong bleach or Lysol solution—1 part household bleach or Lysol to 4 parts water—to avoid transmitting the disease from one branch to another. Lysol is less corrosive than bleach to the metal parts of the pruners. Fire blight development is greatly favored by the presence of young succulent tissues. Where fire blight is a problem, cultural practices that favor moderate growth, such as low fertilization and limited pruning, are recommended.

Powdery Mildew

Powdery mildew is primarily a foliar disease, but it can affect fruit if the infection is severe. Some apple varieties, such as Braeburn, are so susceptible that infection curls, distorts, and discolors leaves. In such cases, photosynthetic capacity is reduced, and tree vigor and health suffer.

Areas where spring and summer humidity are high are most likely to foster powdery mildew problems. There are resistant varieties (see Appendix 1), and mildew can be controlled with the copper and sulfur fungicides aforementioned. The critical period for powdery mildew control is from about "tight cluster to pink" through "first" or "second" cover (Ellis, 1992). Baking soda formulations have also shown promise for managing powdery mildew. For more information on this, see the ATTRA publication *Use of Baking Soda as a Fungicide*.

Cedar Apple Rust

The fungus that causes this disease moves back and forth between eastern red cedars (actually junipers, not true cedars) and apples, so it can be a major problem where eastern red cedars are endemic. In order to complete its life cycle, this fungus must spend part of its life on eastern red cedar; therefore, it is theoretically possible to eliminate the disease by eliminating the cedars within a given area. However, the spores can be windborne for over one mile (Mackenzie et al., 2008), so eradication of the disease in this manner is often impossible or impractical. Nonetheless, if cedars are not too numerous on a given site, their removal around the immediate orchard vicinity can certainly reduce the inoculum reaching the apple foliage. In addition, there are many rust-resistant apple varieties. Only a few varieties, most notably Golden Delicious and its progeny, are susceptible to the point of defoliation (see Appendix 1). Many fungicides are effective against rust, including the sulfur-and-copper compounds, which are approved for organic production as a last resort in your organic pest-management plan. If the grower is observant, he or she may be able to time sprays to coincide with the springtime appearance of orange gelatinous "horns" on the galls on the cedar. This bizarre-looking structure is actually the fruiting stage of the fungus. The "horns" release the spores that infect the apple trees.

The Summer Rots

Where summers are warm and humid (including most of the eastern U.S.), the summer rots—black rot, bitter rot, and white rot—can be problematic. In general, these rots are more pervasive in the Southeast than elsewhere, but one or more of them can become a problem in almost any area if the particular growing season is conducive.

For control in organic orchards, growers should emphasize cultural techniques for suppression of the causal organisms of these rots. Such techniques would include pruning out diseased wood, removing fruit mummies, pruning for light penetration and air circulation, and avoiding poor sites. A study in Hungary recently demonstrated that removal of dropped fruit from the orchard floor resulted in a significantly lower brown rot disease (caused by *Monilinia fructigena*) incidence on fruit in the tree on all cultivars. According to the researchers, drop removal may be useful as a rot-management practice in apple orchards (Holb and Scherm, 2007).

There are several varieties that demonstrate some resistance, or at least a low degree of susceptibility, to the fruit-rot organisms (Biggs, 2003). Appendix 1 shows which varieties are most resistant to fruit-rot organisms. Some cultivars that have been reported to be especially prone to at least one of the summer rots include Liberty, Empire, King David, Priscilla, Golden Delicious, Freedom, Wolf River, Rome Beauty, Jonathan, Blushing Gold, and Sir Prize. Other cultivars

Arkansas grower Guy Ames has noted that in a 3-acre orchard with more than 30 cultivars, unsprayed and largely neglected for 10 years, the earliest cultivars—Williams Pride and Pristine—and some of the latest cultivars—like Arkansas Black, Enterprise, and Winesaps—were the only apples that weren't devastated by the summer rots in wet summers. "To me this suggests 'escape' rather than resistance," Ames surmised. "Among all the other, mid-season cultivars, some were more susceptible than others—like Empire, which was completely wiped out in wet years—but all were badly affected."

that seem to suffer little from the summer rots include Stayman, Dayton, Gala, Melrose, and Fuji (Biggs, 2003).

A number of biological controls have demonstrated effectiveness against post-harvest rot organisms and are labeled for fruit-rot organisms in general. See the ATTRA *Ecological Pest Management Database* for a list of products.

For post-harvest fruit rots, cultural controls are best combined with a biological antagonist such as *Bacillus subtilis* or *Trichoderma viridi*. To help prevent these rots, harvest fruit at optimum maturity, sanitize harvest bins, use handling methods that avoid damaging the fruit, and remove damaged or rotting fruit from the storage facility (Rytter and Travis, 2008).

Sooty Blotch and Fly Speck

These two fungal diseases are almost always found together even though they are distinct from one another. The effects of both diseases are almost purely cosmetic but can render the fruit unsalable in the conventional marketplace (Ellis, 2008).

As with the fruit-rot diseases, there appears to be little resistance to sooty blotch and fly speck, per se. However, these diseases are less apparent on darker fruit, whereas yellow fruit seems to emphasize the problem. Also, very early ripening cultivars, such as Williams Pride, Pristine, and Priscilla, generally escape sooty blotch and fly speck simply by virtue of their earliness. Planting early maturing, dark-red apple cultivars can therefore reduce the damage caused by sooty blotch and flyspeck.

For the organic orchardist, pruning to maintain adequate air flow through the canopy is very important. In a recent experiment on managing sooty blotch and flyspeck in Wisconsin, researchers found significantly less incidence of the complex with regular pruning, due to better air flow and spray coverage (McManus, 2008). Various species of *Rubus*, including blackberries and raspberries, are major reservoir hosts for sooty blotch and fly speck. If you produce these berries on your farm, it is advisable to plant them far away from the orchard or on the other side of a windbreak or hedgerow (Babadoost, 2005).

Potassium bicarbonate (KHCO3) is a new, moderately effective fungicide for control of sooty blotch and fly speck. Potassium bicarbonate is more effective as treatment for control of other apple diseases, particularly powdery mildew in organic orchards (Babadoost, 2005). On-farm research in Wisconsin demonstrated that an amino acid combination of dl-methionine and riboflavin, freshly mixed and supplemented with sodium dodecyl sulfate and a trace amount of copper sulfate, controlled the complex as well or better than the standard sulfur spray. The potassium bicarbonate treatment was also effective against both diseases, but it did not perform as consistently as the methionine-riboflavin treatment (McManus, 2002).

A post-harvest soak for 5 minutes in a 5 to 10% bleach solution in water has shown effectiveness for sooty blotch control. This treatment is time consuming, and would not be approved by the National Organic Program, but it may be effective for small orchards wanting to employ biointensive pest management.

Orchardist Guy Ames said he experienced little or no consumer resistance to apples with sooty blotch and fly speck when he marketed them at the Fayetteville Farmers' Market in northwest Arkansas. He attributes this mostly to the fact that he provided taste samples to his clientele, and taste then became the primary purchasing motivation. If buyers asked about the sooty appearance of the apples, he explained that the fungi are completely superficial, do not hurt the apple or the consumer, and would otherwise have to be controlled by fungicide sprays up to harvest. He found that most customers were completely reassured by his explanation and expressed appreciation of his ecological growing methods.

The Rootstock Factor

Apples can be grown on a variety of rootstocks, which can be divided into seedling and clonal (genetically identical) types. Clonal types can be further divided by size into dwarf, semi-dwarf, and semi-standard.

As well as seedling rootstocks, there are currently about eight clonal apple rootstocks in common commerce, designated (in order from the most dwarfing to the least dwarfing) M.27, M.26, M.9, B.9, Mark, M.7, MM.106, and MM.111. Each has its respective strengths and weaknesses, many of which relate to pest control. Geneva rootstocks developed at the Cornell University Geneva Research Station have recently been commercially released and are available at select nurseries throughout the U.S. Their performance varies depending on size. See the Further Resources section for a specific description of each commercially available rootstock and information on distribution.

Generally speaking, the smaller the tree, the easier it is to spray, and the fewer pesticides that are needed. However, dwarfing rootstocks are not without significant pest problems. For example, M.27, M.26, and M.9 are quite susceptible to fire blight. M.27, M.26, and MM.106 are susceptible to phytophthora root rot. All of the size-controlling rootstocks except those with the "MM" designation are susceptible to wooly aphids. Most seedling rootstocks are also susceptible to wooly aphids, but they are more tolerant of wooly aphid feeding damage than the more-dwarfing rootstocks.

Furthermore, there appears to be a general correlation between intensity of dwarfing and non-pathogenic disorders such as chronic nutrient deficiencies or toxicities. As an example, all rootstocks the size of Mark and smaller are susceptible to apple measles, a manganese toxicity problem. Fortunately, most nutrient problems related to dwarfing can be addressed with careful attention to soil fertility and pH.

Borers can be a problem for any rootstock, but the more vigorously growing rootstocks (the larger ones) have considerably more tolerance for damage than less vigorous stocks. If allowed to become drought stressed, dwarf trees are much more susceptible to serious damage from borers than are larger trees. This is one reason why dwarf trees require more frequent watering than larger trees.

Matching the right rootstock to your management plan (especially considering pest control, site, and water availability) is a very important decision that could ultimately make the difference between success or failure. We recommend consulting with your county Cooperative Extension for rootstocks that work well in your region and with your orchard plan.

Mammal and Bird Pests

Mammals are often overlooked by the beginning orchardist as significant orchard pests, but deer and voles—the two most important mammal pests—can easily put a young orchard out of commission in one short season. Fruit-eating birds are usually more troublesome on small fruits (grapes and berries) but can cause serious economic damage to apples. Many serious orchardists invest in a good deer fence to prevent deer from eating succulent young apple shoots. For more information on managing deer in an orchard, see the ATTRA publication *Deer Control Options*. For information on controlling mammal and bird pests, see the ATTRA publication *Tree Fruits: Organic Production Overview* and ATTRA's *Organic IPM Field Guide.*

Thinning

Thinning blossoms to allow the fruit to reach full size is an important consideration in apple production. Many organic growers thin manually, but this can be time consuming for a larger-scale orchard. Recent research in New York state showed positive results using an organically approved lime-sulfur product to conduct thinning. This product is even allowed for a wide window of application—full bloom to post petal fall (Robinson, 2002).

Weed and Orchard Floor Management

Weeds are often controlled organically with tillage. Although this method can be effective, there is often a flush of weeds after mechanical tillage, and there is always a risk of damaging shallow tree roots. In recent years, living and dead mulches have been applied to orchard systems as a weed control, with mixed results. In a 2004 study done by Washington State University on mulching systems in organic orchards, living mulches were effective at competing with weeds, but they also competed with the trees, causing a reduction in yield in some locations. As with insect- and disease-pest management, a combination of tactics is most effective for weed management in the organic orchard.

Another equally important objective of orchard-floor management is providing natural sustaining fertility to the trees (Vossen and Ingals, 2002). Organic orchardists are required by the National Organic Program to monitor and improve soil quality. They typically rely on tillage for both weed control and incorporation of fertility amendments. However, as a few more growers each year are beginning to use mulches, particularly on low-performing parts of the orchard, they are reporting favorable results.

Growers are most interested in obtaining nitrogen from an on-farm source via legumes. Most growers use cultivation equipment between the rows. In a SARE-funded research grant on orchard-floor management and soil quality, the Wonder Weeder, a ground-driven rolling cultivator with a spring blade that works between the trees, was most effective after three years of cultivating two times per year. This research project in Washington state also demonstrated effective weed suppression with wood chip mulch between the rows; however, this may be cost prohibitive for larger orchards (Cogger and Granatstein, 2007).

One regularly used living-mulch example is a combination of perennial orchard grasses and legumes. Planting subterranean clover into established orchards can provide mulch, fertilizer, between-row ground cover, and beneficial insect habitat. This clover reseeds itself in early summer and dies back during the hottest part of the growing season, leaving a relatively thick, weed-suppressive mulch. This system is used in apple and peach orchards in Arkansas and for a variety of orchard crops in California but not where winter temperatures regularly drop below 0° F (Stasiak, 1990; Finch, 1983). Subterranean clover can provide habitat for such beneficial insects as ladybeetles, syrphid flies, big-eyed bugs, soft-bodied flower beetles, and other predators. The ATTRA publication *Tree Fruits: Organic Production Overview* has an extensive section on organic fertility and weed management on the orchard floor.

There has been research demonstrating that grazing hogs in organic orchards can help with fertility needs, pest management, and keeping down weeds. In fact, in a recent study, grazing hogs

Orchard-Floor Management—Pam Clevenger and Kurt Welborne. Home Acres Orchard, Stevensville, Montana

When Pam Clevenger and Kurt Welborne began growing apples in rural western Montana in 1990, there were lots of produce farms but no organic tree fruit production in the area, though historically lots of apples were grown in the region. Pam and Kurt say there is definitely a demand for organic fruit, but marginal growing conditions are the biggest limitation.

The region may experience hard early frosts, hard late frosts, or extended periods of warm weather in January. They are dependent on snowpack for irrigation, and in a dry year their irrigation water may run out in early August, when temperatures are often over 90° F. Since the weather is particularly hard on new trees, they use only semi-dwarf rootstock, the roots of which are more effective at foraging for water and withstanding high winds.

Pam and Kurt grow about 20 varieties of apples, three varieties of Asian pears, six varieties of European pears, and three varieties of apricots. They also grow tart cherries and plums for their own use. They say the Asian pears have extra boron demands but otherwise are trouble free compared to apples. The pear trees are interspersed among the apples, which they believe helps keep their insect and disease problems down.

They also use wildscaping, particularly around the perimeter of the orchard. The wildscaping has enhanced pollination, but also increased the number of birds that feed on apples.

For codling moth, Pam and Kurt rely primarily on Spinosad, a biological control, along with pheromone emitters for mating disruption. They spray Bt several times in the spring for leaf rollers. They have brought in lacewings in past years to help control aphids, but now there seems to be a strong resident population that pretty much keeps the aphids in check. They use copper and lime sulfur for fire blight and scab.

Home Acres Orchard in Stevensville, Montana, interplants wildflowers between the apple rows to encourage beneficial insects and pollinators. Photo: University of Montana Dining Services

The soil has an alkaline pH and is low in nitrogen, sulfur, boron, and zinc. Pam and Kurt have experimented with different fertility treatments over the years, including alfalfa pellets and feathermeal. Last summer they cut hay from their own pastures and mulched their trees with a mixture of clover, alfalfa, and grass. They add sulfur regularly to the soil and spray boron, calcium, and zinc.

Interestingly, despite following organic practices, Home Acres Orchard is no longer certified organic. Pam and Kurt have joined with other growers in the region to form the Montana Sustainable Growers' Union, which promotes its products under its own Homegrown label. They still get a premium price for their fruit and market their products through two farmers markets, a local natural food store, and the Western Montana Growers Co-op.

Overall, says Kurt, "Some years you're lucky, some years you're not," and they note there are lots of rewards that aren't monetary.

on alleyways in an organic orchard demonstrated improved weed management and a reduction in pests (Epstein and Koan, 2009).

Economics and Marketing

Just as geography plays an important role in pest management, it also is important in determining the feasibility of commercial-scale organic apple production. Organic growers in the eastern half of the country must realize that they are likely to face higher production costs than growers in the West. Management of the plum curculio has become easier with kaolin clay-based pesticides, but the costs of the commercial formulations of this product are higher than conventional pesticides (approximately $300 to $400 per acre higher). A marketing option for plum curculio-damaged apples is cider and other processed goods; however, these require expensive processing and storage equipment and, therefore, bring a lower net return than fresh fruit. It may be possible for the small grower to receive a high enough price to cover costs of production by relying on direct marketing. However, in the East, the difficulty and expense of growing apples organically makes it extremely unlikely that the grower can compete with the large supply of more cheaply produced organic apples from the West in any but the most limited local markets.

Holistic Management and Orchard Planning

The vagaries of the market and the intrinsic complexities of organic and low-spray management demand that the grower, whether beginning apple production or rethinking an existing orchard, take special care in planning ahead and monitoring results. Holistic Management is a simple decision-making framework that incorporates values-based goal setting, the appropriate use of tools, financial planning, land planning, biological planning, and careful monitoring of effects. All these aspects are managed as a whole unit. First, the "whole" is defined by forming answers to underlying questions, such as "Why am I farming? What do I mean to accomplish? What kind of world do I want for my grandchildren?" By developing principles based on these deeper considerations, the grower develops a powerful guidance system for making specific choices later on.

Holistic financial planning often seems to turn conventional financial planning on its head. One key distinction is that profit is planned before any expenses are allocated. Once the profit is allowed for, expense dollars are allocated sequentially where they will do the most good. This approach helps the grower avoid a common mistake that can be fatal—allowing expenses to nearly equal the planned gross income, leaving very little room for profit. For more information, request the ATTRA publication *Holistic Management: A Whole-Farm Decision Making Framework*.

The University of California *Organic Apple Production Manual* details costs of production for organic apples as roughly $5,700 per acre. When organic premiums were available and yields ranged from 10 to 20 tons per acre (depending on variety), net returns ranged from $2,000 to $6,000 per acre for fresh-market organic apples. Total accumulated three-year returns for Northern San Joaquin Valley organic Granny Smiths were equivalent to conventional returns, and Central Coast organic Granny Smith production consistently outearned conventional production over three years (Swezy, 2000).

Elsewhere, a University of Idaho survey of 22 organic apple growers in the Northwest indicated that their costs averaged $3,747 per acre (Higby et al., 2007). (See Table 4 below.)

Table 4: Per-Acre Production Costs from Northwest Organic Apple Growers Surveyed.

Number of observations	22
Average labor cost per acre	$1626
Average pest control per acre	$398
Average fertilizer cost per acre	$252
Average total cost per acre	$3747

A recent publication from Cornell University, titled *A Growers Guide to Organic Apples*, provides a list of costs of production based on a four-year trial of organic Liberty apple production in New York state. The trial showed that "costs—especially the greater labor needs and higher costs for fertilizers and pest control products—make organic apples generally more expensive to grow than conventional or integrated apples, especially under the intense and complex pest pressures typical of Northeastern orchards. Organic pest control materials also tend to be sprayed frequently (sometimes two or three times per week), further increasing labor, fuel, and machinery costs." Cost information from this publication appears in Table 5. The authors used data collected from a recent four-year trial to develop this table. It summarizes some of the production-related costs for Liberty apples in a mature high-density orchard in New York. Because Liberty is a disease-resistant cultivar, disease-control costs were relatively low (Peck and Merwin, 2010).

The price premium for organic apples continues, but it is difficult to predict the stability of the

Table 5: Direct Production-Related Costs for Managing a Liberty Apple Orchard	
Adapted from Peck and Merwin, A Growers Guide to Organic Apples. 2010.	
Costs	**$/acre/yr**
Machinery Operation	
Tractor + Airblast sprayer	93
Tractor + Wonder Weeder (three cultivations per year)	13
Applying chicken manure compost (once every three years)	24
Total machinery costs	**130**
Materials	
Dormant spray (copper and Stylet oil)	47
Insecticides	233
Kaolin clay	143
Pheromone mating-disruption ties (for codling moth and oriental fruit moth)	181
Fungicides	17
Adjuvants	11
Thinning chemicals (liquid lime sulfur and Crocker's fish oil)	150
Foliar fertilizers	75
K-Mag (Sul-Po-Mag)	94
Chicken manure compost (applied once every three years)	16
Total material costs	**967**
Labor	
Tractor airblast spraying	102
Chicken manure application (applied once every three years)	22
Cultivation	17
Hand hoeing	72
Hanging pheromone ties	24
Hand thinning	347
Harvesting	1,222
Total labor costs	**1,806**
Grand Total	**2,903**

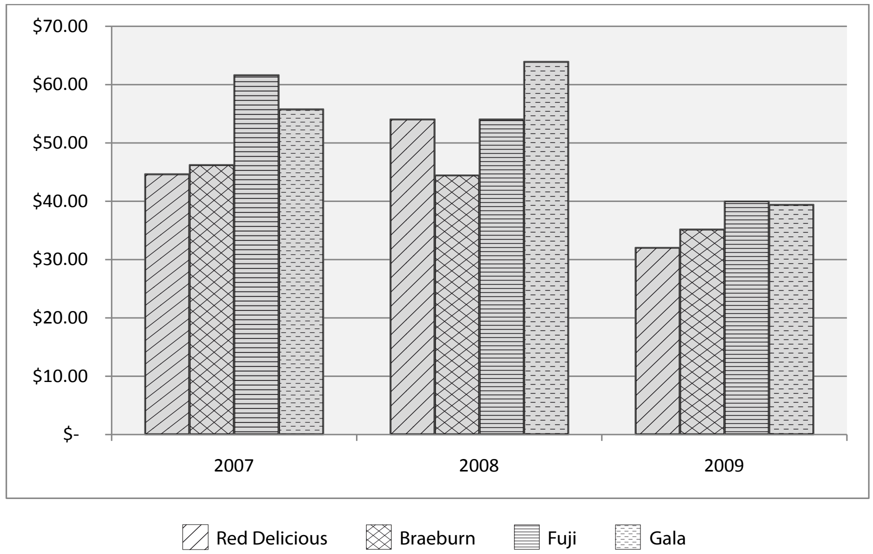
premium as more organic apples come into production (Swezy, 2000). From data gained over 10 years in Washington state, the U.S. leader in organic apple production, the premiums were 50 to 90% in good years and 20 to 40% in poor years (Granatstein, 2007).

In 2008, 488.2 million pounds of organic apples were raised on more than 20,000 acres in the United States (ERS, 2009). According to the Organic Production Survey, more than 1,150 farms raised organic apples. Washington state was the largest producer of organic apples in 2008, with a crop valued at $118.9 million. California was number two in the United States, with a crop valued at $6.5 million. These rankings should not come as a surprise given the geographical constraints to organic production discussed in this publication.

Wholesale Marketing

Wholesale apple markets do offer a price premium (See graph on page 24), but the demand for organic apples in grocery stores may soon level off (Warner, 2007). Matt Miles, an organic marketing specialist with L&M Companies, predicts that the exceptional returns growers have been receiving for wholesale organic apples are likely to adjust to a level that's still profitable for growers on most varieties and these lower prices will likely increase demand. Wholesale apple growing requires close attention to packing standards and post-harvest monitoring for continuous supply. If you are selling to a packing house, packing and marketing fees should be included in your enterprise analysis. Harold Ostenson of Stemilt Growers, Inc. encourages growers to convert newest varieties that bring a good return on both conventional and organic markets to organic production, rather than converting an ailing orchard (Warner, 2007). He encourages growers to take unprofitable blocks or those with old strains of Gala or Fuji and graft them over to the latest varieties while transitioning them to organic. Consumers are interested in new and heirloom varieties. Ostenson suggests that growers need to consider not only the differences in organic and conventional markets but also the varieties that consumers want to buy.

Organic Apple Wholesale Prices



The prices are per carton tray pack (100 count). This graph is based on information from the USDA Economic Research Service, Organic Wholesale Price data sets 2007-2009.

Elderberry Farm

Lou and Merby Lego own a diversified farm in central New York state. They have about seven acres in apples, with about 500 trees. Lou Lego comments, "We planted apples early on because we thought it would be something other local farms might not have and because we both loved apples and cider."

Photo: Elderberry Pond Farm and Restaurant

They have 90 varieties of apples and have selected them for specific purposes. Some varieties are used just for culinary applications: pies, sauces, etc. These include Duchess, Pound Sweet, Bramley's Seedling, Wolf River, Smokehouse, and Goldrush. About four varieties, including Golden Russet, Winesap, and Cox Orange Pippin, are used primarily for cider. The rest are for eating raw or for drying. Their best drying variety is Esopus Spitzenberg, and their best eating variety might be Honeycrisp or another favorite, Pristine.

They market their apples and Asian pears through farmers markets and a country store and restaurant located on their farm. "We find that there is a significant advantage to marketing directly on the farm. There is less loading and hauling time spent. On the down side is the fact that the farm must be maintained in a condition suitable for visitors throughout the season," says Lou.

"The restaurant has had a great benefit to the farm business," Lou adds. Since the addition of their on-farm restaurant, most of the farm output sells through the restaurant. Many people who visit the restaurant become farm customers, and if it were not for the restaurant attracting them, they would never have visited the farm. The regulars at the farm store are already interested in local, sustainable agriculture, but those coming to the restaurant are often unaware of where their food comes from. Elderberry Farm has also started a number of classes in growing and cooking from the garden, and they are always amazed at who attends.

The Legos sell cider at their farm store and at the farmers market as one of their value-added enterprises.

Photo: Elderberry Pond Farm and Restaurant

"The thing I think we have learned over the years is that diversification in both markets and crops is important to success. One or two crops or even one or two classes of crops can be risky. Some years our vine crops are a disaster, but the orchards are spectacular. Other years the deer eat all the beans, but the tomatoes and potatoes are perfect. Diversification is a form of crop insurance as well as a natural scheme for crop pest and disease protection. In markets… diversification is key to intercepting a wide range of customers." – Lou Lego, Elderberry Farm

Direct Marketing

Direct marketing of apples will bring a price premium over the wholesale price, but it will also require more one-on-one interaction with your consumer. One benefit of this time investment is that consumers are generally more forgiving of cosmetic flaws in apples when they can talk to the grower. Agritourism is a common direct-marketing tool that many orchards employ. However, it is important to consider your farm location, goals, and insurance costs before starting such a venture.

Cider and Processed Apple Products

A common strategy for organic and low-spray growers who have a high percentage of culls is to integrate processed apple products into a marketing plan. Not only will cider, preserves, and other processed products enable the grower to sell otherwise unmarketable apples, but they may even add to the profit margin through "value-added" marketing. Producing these products will require special equipment. In addition, the U.S. Food and Drug Administration currently recommends all cider-processing facilities (regardless of size) have a Hazard Analysis Critical Control Point plan. To find recommendations from the FDA to processors and state regulatory agencies, see the Further Resources: Marketing section. Processing apples into unpasteurized cider is under increasing scrutiny, so we encourage you to contact your state department of agriculture to determine your state's regulations for processed products before investing in equipment.

It is important to have alternative outlets for the "less than perfect" fruit, says Jim Koan of Almar Orchards near Flushing, Michigan. His organic culls go into a cider mill for hard cider. The cider is distributed throughout the country (Hanson, 2007). Hard cider is a growing value-added market in the U.S. A University of Iowa study examining the potential of using cull apples for hard cider describes few national processing markets (Holtz-Clause, 2003). The biggest potential is through local markets.

The prudent small grower in the East should retain a niche market strategy focusing on retail sales. By carefully developing this type of market, the grower can maintain an adequate profit margin while personally connecting with and educating customers on the advantages of his or her apples (fresher, fewer sprays, greater variety choice, locally grown, etc.). For more information and ideas along these lines, see the ATTRA publications *Direct Marketing* and *Farmers Markets: Marketing and Business Guide*.

Conclusion

To many interested in sustainable agriculture, apple orcharding perhaps symbolizes two extremes: either an Eden-like permanent agriculture—an arboriculture where trees yield their perfect fruits without labor or coaxing—or a Faustian bargain with the agrichemical companies where everything good and natural has been sold out for a cosmetically perfect poisoned apple. Both images have attracted people to the idea of organic apple orcharding—the first for its simple, idyllic appeal and the second for the challenge of reforming the current conventional production system.

As is often the case, reality falls somewhere between these two extremes. Agriculture is necessarily an imposition on nature, and apple orcharding is no exception. Such tools as pheromones, new biorational and biological pest controls, and a better understanding of disease and pest life cycles are providing opportunities to manage organic orchard systems successfully.

Whether or not an organic apple orchardist can build an economically and ecologically sustainable business is dependent on many factors, not the least of which is self-education. Because of the many potential pitfalls, it is highly recommended that the aspiring organic orchardist consult appropriate texts, journals, Cooperative Extension specialists, and—most important—other orchardists for additional information. The following references and resources should be helpful in this regard. See also ATTRA's *Tree Fruits: Organic Production Overview* and its resource list.

Appendix 1: Disease Resistant Apple Varieties

By Guy Ames, NCAT Horticulture Specialist

There are several important considerations to keep in mind when using the following chart.

First, disease resistance is rarely absolute, and it is usually described in relative terms (e.g., susceptible, moderately susceptible, resistant, etc.). To further complicate matters, different researchers use different rating scales to describe disease resistance/susceptibility. For example, some published studies use a numerical scale (usually 1-10), while others use more absolute measurements, such as the number of fire blight lesions on a leaf or the centimeters of shoot tissue affected by fire blight. For the purpose of compiling this chart, it was necessary to convert these different systems into a uniform rating scale. I alert the reader to this fact and apologize to the researchers for any liberties I have taken with their work.

Second, the occurrence of disease is dependent on three factors (the "disease triangle"): a susceptible host, a suitable environment, and the presence of the disease-causing pathogen. For example, alternaria leaf blotch is a disease that appears to be limited to parts of the southeastern United States. Other regions either do not have the pathogen or present an environment unsuitable to the disease. As another example, cedar apple rust does not occur where the eastern red cedar does not grow, for the pathogen is dependent on the eastern red cedar to complete its life cycle. Cedar apple rust resistance is therefore unimportant in the whole of the western United States.

Also note, as a corollary to the disease-triangle notion, that the environment can affect the expression of a disease in terms of its virulence. In other words, mildew in Virginia may be much worse than mildew in Kansas, though mildew could be found on apple trees in both places. This is occasionally reflected in the following chart by the occurrence of conflicting entries for the same disease on the same cultivar. For an example, see the entry for fire blight on Jonafree. (Differing environmental factors are probably not responsible for the discrepancies between some entries for Priscilla. See the note below the chart.)

The numbers behind some entries refer to the published source of that information, cited below in the References section. Where entries are not accompanied by a reference number, the entry is based upon my own or other apple growers' observations. (Much of the information for white rot and black rot was originally compiled from growers and research by Brenda Olcott-Reid.) I believe that most of these observations will hold true for most growers under most conditions, but it is possible that what a grower took to be "resistance" was in reality a simple "escape."

On the other hand, if an unreferenced entry reads "s" or "vs" ("susceptible" or "very susceptible"), the grower probably observed a bona fide infection—it's hard to say a cultivar has any resistance to scab if you're looking at apples warped and cracked by scab. In other words, if a "negative" is a lack of disease and a "positive" is an observation of disease, a false negative is more likely than a false positive.

Where there is a blank for a cultivar under a specific disease, there was not sufficient information to make an entry.

Disease Key:	Resistance Rating Key*:
ALB = alternaria leaf blotch CAR = cedar apple rust FB = fire blight MIL = mildew SCAB = scab BR = black rot/bitter rot WR = white rot	vr = very resistant r = resistant mr = moderately resistant ms = moderately susceptible s = susceptible vs = very susceptible

***r/mr: May show symptoms, but probably will not require sprays.**

ms: Sprays may be necessary in bad conditions.

s: Sprays are probably necessary where disease is present.

vs: Sprays are necessary where disease is known to be prevalent.

*There may be two Priscillas in circulation. Descriptions of disease resistance and fruit characteristics vary widely among researchers and growers, adding credibility to the notion that somehow two genetically distinct trees are both going by the name Priscilla.

Disease-Resistant Apple Varieties							
Variety	**ALB**	**CAR**	**FB**	**MIL**	**SCAB**	**BR**	**WR**
Akane	mr (1)	vr (11)	mr (7)	mr	ms	r	mr
Anna		ms	r	s	mr		s
Arkansas Black		r	mr	r	ms	r	r
Arkansaw		r	r	r	r	r	mr
Ashmeads Kernel		mr	vr	r (6)	ms	r	mr
Astrachan			r (4)				
Baldwin			s (4)		s (6)		
Barry			vs (4)				
Beacon			ms (4)				
Ben Davis			r (4)				
Beverly Hills			s (4)				
Black Gilliflower			vs (4)				
Blairmont		s	vr	r	mr	r	mr
Blushing Golden		r (11)	ms (7)	r (6)	s (6)		
Braeburn	mr (1)	vs	s	vs	s		
Bramley's Seedling		s	r	r (6)	r (6)	r	mr
Britegold		s (10)	r (12)	r (10)	vr (10)		
Brown Russet				r (6)	r (6)		mr
Buckley Giant			vs (4)	r (6)	r (6)		
Chehalis		s	mr	mr	r	mr	s
Cox's Orange			ms (4)				
Crimson Beauty			vr (4)				
Daniels		vr	r	mr	ms	r	mr
Dayton		ms	mr	mr	vr (9)	ms	mr
Delcon			r (4)				
Delicious		r (8)	vr (4)				
Delicious, Red	s (1)			r (6)	s (6)		
Detroit Red			r (4)				
Discovery				vr (6)	s (6)		
Dorsett Golden			ms (4)				
Ein Shemer			s (4)				
Empire	ms (1)	r (8)	r (4)	s (8)	s (6)	s	
Enterprise		r (10)	r (10)	r (10)	vr (10)	r	
Fameuse			vr (4)		s (6)		
Firmgold	ms (1)						
Florina		r	r		vr (5)	mr	
Freedom		vr (3)	mr (3)	mr (2)	vr (10)	s	s
Fuji		r (11)	vs (7)	r	s (6)	r	mr
Fuji, Red			ms (7)				
Fyan			s (4)				

Information to interpret this chart is in the Disease Key on page 26 and the Appendix 1 References on page 31.

Variety	ALB	CAR	FB	MIL	SCAB	BR	WR
Gala		ms	ms	mr	s	s	ms
Gala, Fulford	mr (1)		ms (7)				
Gala, Red	ms (1)						
Gala, Royal	r (1)		ms (7)				
Gala, Scarlet			mr (7)				
Gala, Spur (Go-Red)			vs (7)				
Gala, Stark			ms (7)	r (6)	s (6)		
Ginger Gold	r (1)						
Golden Delicious	r (1)	vs (8)	vr (4)	r (6)	s (8)		
Goldrush		vs (10)	r (10)	r (10)	vr (10)		
Golden Russet		s (11)	ms	r	r	s	s
Grandspur	r (1)						
Granny Smith	r (1)	vr (11)			s (6)		
Gravenstein			vs (4)	r (6)	vs (6)		
Grimes			r (4)				
Grove			r (4)	r (6)			
Haralson		mr	r (4)		s		mr
Hawaii		r	vr	mr	s (6)	ms	ms
Holly				vr (6)	s (6)		
Honeygold				r (6)	s (6)		
Horse			s (4)				
Hudsons Golden Gem		s	r	r (6)	r (6)	r	mr
Idared			vs (4)	s (6)			
Irish Peach			r (4)	r	r		ms
James Grieve			vs (4)				
Jefferis		s	r	mr	r		s
Jerseymac		vr (11)	s	vs (6)	vs (6)		
Jonadel			r (4)				
Jonafree		s (3)	mr(3)vs(7)	r (2)	vr (10)	r	mr
Jonagold	r (1)	s	ms (7)	s	s		
Jonagram			s (4)				
Jon-A-Red	ms (1)						
Jonathan		s (11)	vs (4)				
Jonathan,Double Red	mr (1)						
Kidd's Orange Red			r (4)				
King David		r	ms	r	r	ms	mr
King Luscious			s (4)				
Lawspur Rome	mr (1)						
Liberty		vr (3)	r (3)	s(2) r(6,7)	vr (6)	mr (8), s	mr
Limbertwig		r	mr	r	mr	r	mr
Lodi			vs (4)		s (6)		

Information to interpret this chart is in the Disease Key on page 26 and the Appendix 1 References on page 31.

Variety	ALB	CAR	FB	MIL	SCAB	BR	WR
Loriglo	mr (1)						
Lurared	ms (1)						
Lysgolden	r (1)						
MacFree		vr (3)	mr (3)	s (2)	vr (8)	s (8)	mr
Macoun			mr (4)	s (6)	s (6)		
Maiden Blush			r (4)				
Maigold				r (6)	s (6)		
Mammoth Black Twig			ms (4)				
McIntosh		vr (8)	r (4) s (8)	s (2)			
McShay		vr	ms	mr (9)	vr (9)		s
Melba			r (4)	r (6)			
Melrose		vr	r (4)	s (6)	s	r	mr
Moira		r (10)		s (10)	vr (10)		
Mollies Delicious			r (4)		s (6)		
Mother		ms		r (6)	r (6)		
Murray		r (10)	r (10)	r (10)	vr (10)		
Mutsu	mr (1)	s(8)vs(11)	s (4)	vr(6)vs(8)	vs (8)		
Nittany	r (1)						
Northern Spy		s (8)	vs (4)	s (8)	s (8)		
Nova Easygro		vr (3)	mr (3)	r (2)	vr (8)	mr (8)	
Novamac		r	r	ms (10)	vr (10)	mr	mr
Novaspy					vr (13)		
Nured McIntosh	ms (1)						
Nu Red Rome	r (1)						
Orleans		r	mr	mr	mr		ms
Ozark Gold	r (1)		mr (7)	r (6)			
Paragon			r (4)				
Pink Pearl			vs (4)				
Priam					vr (9)		
Prima		vs (8)	mr (3)	r (2) s (8)	vr (8)	r	s
Priscilla*		r (10) s (3)	vr (3)	s (2) r (6)	vr (6)	r (8)	s
Raritan		vr (11)					
Redcort		vr (11)					
Redfree		vr (3)	mr (3)	ms (2) mr	vr (9)	s	ms
Red Fuji	ms (1)						
Red June			s (4)				
Red Yorking	ms (1)						
Richelieu					vr (13)		
Rouville					vr (13)		
Roxbury Russet		r	ms (4)	r	mr		ms
Shamrock		vr (11)					

Information to interpret this chart is in the Disease Key on page 26 and the Appendix 1 References on page 31.

Variety	ALB	CAR	FB	MIL	SCAB	BR	WR
Sinta		s (11)		r (6)	s (6)		
Sir Prize		s (3)	ms (3)	s (6)	vr (6)	r (8)	
Smokehouse			r (4)				
Smoothee	r (1)	s (3)	mr (3)	s (2)			
Snow			r (4)				
Spartan		r (8)	r (4)	r (8)	ms (6)		
Spencer			vr (4)		s (6)		
Spigold		vs (11)	vr (4)	s (6)			
Spitzenberg, Red			s (4)		s (6)		
Stark Earliest			s (4)				
Stark Splendor				vr (6)	s (6)		
Stark Summerglo				r (6)	s (6)		
Stark Summer Treat				r (6)			
Starkspur Winesap	r (1)						
Stayman	r (1)	r	mr (4)	ms	ms	r	ms
St. Edmunds Pippin		r	mr	r	mr	r	ms
Steele's Red			vs (4)				
Stirling				r (6)	r (6)		
Summer Pearmain			ms (4)				
Summer Rambo			s (4)				
Summer Treat	r (1)						
Tangier				vr (6)			
Thompkins King		ms	s (4)	mr ms(6)	mr		
Toko				r (6)			
Trent		r (10)	r (10)	ms (10)	vr (10)		
Turley			r (4)				
Twenty Ounce			vs (4)				
Tydeman's Early				r (6)	r (6)		
Tydeman's Red			vs (4)				
Ultragold	r (1)						
Wagener			s (4)				
Wayne			s (4)				
Wellington			vr (4)				
Whetstone			ms (4)				
Williams Pride		vr (3)	r (3)	ms (2)	vr (9)	r	mr
Winesap	r (1)		r (4)				
Wolf River			vs (4)	r (6)	r (6)		
Wynooche		r	ms	mr	vr		mr
Yates		r	r			r	r
Yellow Belleflower			r (4)				

Information to interpret this chart is in the Disease Key on page 26 and the Appendix 1 References on page 31.

Variety	ALB	CAR	FB	MIL	SCAB	BR	WR
Yellow Delicious	r (1)						
Yellow Newtown			ms (4)				
Yellow Transparent			vs (4)				
Yorking			s (4)				

Information to interpret this chart is in the Disease Key on page 26 and the Appendix 1 References below.

*There may be two Priscillas in circulation. Descriptions of disease resistance and fruit characteristics vary widely among researchers and growers, adding credibility to the notion that somehow two genetically distinct trees are both going by the name Priscilla.

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Further Resources

Publications and periodicals

ATTRA Publications

Tree Fruits: Organic Production Overview
Organic Farm Certification and the National Organic Program
Biointensive Integrated Pest Management
Farmscaping to Enhance Biological Control
Notes on Compost Teas
Biodynamic Farming & Compost Preparation
Direct Marketing
Farmers' Markets: A Marketing and Business Guide
Organic Marketing Resources
Holistic Management: A Whole-Farm Decision Making Framework
Biorationals: Ecological Pest Management Database (Available online only at *www.attra.org/attra-pub/biorationals*.)

Books

Beers, Elizabeth, et al. 1993. Orchard Pest Management: A Resource Book for the Pacific Northwest. Good Fruit Grower. Yakima, WA. 276 p.

This guide has good life-cycle illustrations and excellent photographs. A "must" resource for commercial apple growers in the Pacific Northwest. Insects and other arthropods are covered; diseases, etc. are not. Available for $35 (plus $3.50 postage and handling) from:

Good Fruit Grower
105 South 18th Street, Suite 217
Yakima, WA 98901
800-487-9946
www.goodfruit.com

Note: OPM Online is based on the book "Orchard Pest Management: A Resource Book for the Pacific Northwest" and can be accessed at the following link:
http://jenny.tfrec.wsu.edu/opm

Braun, G. and B. Craig (eds). 2008. Organic Apple Production Guide for Atlantic Canada. 3rd edition. Agriculture and Agri-Food Canada, NS, Canada.

This publication mainly discusses insect and disease pest management for Eastern Canada. Available in print from:

Nova Scotia Agricultural College
P.O. Box 550
Truro, NS B2N 5E3 Canada
902-893-7256
Fax: 902-896-7095
oacc@nsac.ca
www.organicagcentre.ca/Docs/OrganicAppleProd08_e.pdf

Edwards, Linda. 1998. Organic Tree Fruit Management. Certified Organic Associations of British Columbia, Keremeos, B.C., Canada. 240 p.

Full of the real-life experiences of organic growers. It might be especially helpful for questions regarding organic fertility management. For Northwest only.

Available from: Certified Organic Associations of British Columbia for $19.95 for COABC members and $25.95 for nonmembers.

202 3002 32nd Ave.
Vernon BC V1T 2L7 Canada
250-260-4429
Fax: 250-260-4436
office@certifiedorganic.bc.ca

Ellis, Michael. 1992. Disease Management Guidelines for Organic Apple Production in Ohio. Ohio State University, OARDC, Wooster, OH. 33 p.

This publication is exactly what it says in the title: guidelines (not a systematic, calendar spray approach) and only for diseases, not insects. It is not *a comprehensive guide to organic production in Ohio. Available free of charge from the contact below. A web version is available too, at:* www.caf.wvu.edu/kearneysville/organic-apple.html

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330-263-3700
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Howitt, Angus H. 1993. Common Tree Fruit Pests. Michigan State University, East Lansing, MI. 252 p.

A few pictures are fuzzy, and a few major pests (at least for organic and low-spray growers) are inexplicably absent (e.g., roundhead and flathead borers), but it is still a useful resource, especially for eastern growers. To order, send a check for $10, payable to Michigan State University, to the following address. Specify publication No. NCR63.

Michigan State University
Bulletin Office
10-B Agriculture Hall
East Lansing, MI 48824-1039
517-355-0240

Jones, A. L. and H. S. Aldwinkle (eds.). 1990. Compendium of Apple and Pear Diseases. American Phytopathological Society, St. Paul, MN. 100 p.

A very comprehensive guide to all the things that can afflict your trees and crop. Excellent color plates. To order send $37 (plus $5 shipping and handling; MN residents add applicable tax) to:

American Phytopathological Society
3340 Pilot Knob Road
St. Paul, MN 55121-2097
800-328-7560

Page, Steve and Joe Smillie. 1995. The Orchard Almanac. 3rd edition. AgAccess, Davis, CA.

Using a seasonal format, the authors provide an easy-to-use, understandable approach to both low-spray and organic apple production. One of the best guides for the East. Available from online book sellers for $16.95 (plus shipping and handling).

Peck, Gregory and Ian Merwin. 2009. A Growers Guide to Organic Apples. NYS IPM Publication No. 223. Cornell University Department of Horticulture.

A comprehensive guide for Eastern growers. Complete with several illustrations and photos of apple insect and disease pests and organic management options.

Available online at the following link: www.nysipm.cornell.edu/organic_guide/apples.pdf

Peterson, Brooke A. (ed.) 1989. Intensive Orcharding. Good Fruit Grower, Yakima, WA.

Guide to growing apples in high-density systems using dwarfing rootstocks. Currently out of print. May be available through interlibrary loan. A used-book seller search showed very high prices for this book (over $100,) so an interlibrary loan is advisable to see if the purchase is worth it.

Phillips, Michael. 2005. The Apple Grower: A Guide for the Organic Orchardist, Revised and Expanded Edition.

This definitive guide to growing apples wisely, naturally, and with gentler impact on the Earth covers all the cultural points of apple growing. Michael's advice has already made The Apple Grower a classic among small-scale growers and home orchardists. Anyone serious about succeeding with apples should consider adding this updated edition to their bookshelf.

Chelsea Green Publishing
P.O. Box 428
White River Junction, VT 05001
800-639-4099
www.chelseagreen.com

Swezy, Sean. 2000. Organic Apple Production Manual. University of California, Oakland, CA.

This manual reviews the organic apple industry, including trends in production and markets, supply and price, and state and federal regulation and certification. It covers orchard management, disease and pest management, harvest and post-harvest operations, marketing considerations, and economic performance for areas in the West. It also has good additional resources.

Division of Agriculture & Natural Resources
Communication Services-Publications
6701 San Pablo Ave.
Oakland, CA 94608
800-994-8849
http://anrcatalog.ucdavis.edu/ApplesPearsStoneFruits/3403.aspx

Whealy, Kent. 2009. Fruit, Berry and Nut Inventory. 4th edition. Seed Saver Pubs., Decorah, IA.

Descriptions of various fruit cultivars in U.S. nursery trade. Available from the publisher for $30 (plus shipping and handling).

Seed Savers Exchange
3076 N. Winn Road
Decorah, IA 52101
563-382-5990
www.seedsavers.org

Periodicals

American/Western Fruit Grower
Meister Publishing Company
37733 Euclid Ave.
Willoughby, OH 44094
afg.circ@meistermedia.com
800-572-7740
www.growingproduce.com/subscribe
$19.95/ year

Good Fruit Grower
105 South 18th Street, Suite 217
Yakima, WA 98901
800-487-9946
www.goodfruit.com
$35/ year

Fruit Growers News
Great American Publishing
P.O. Box 128
Sparta, MI 49345
616-887-9008
http://fruitgrowersnews.com
$12/ year

Organizations and Associations

North American Fruit Explorers
1716 Apples Rd.
Chapin, IL 62628

Two of NAFEX's finest services to its membership are the operation of fruit and nut interest groups and special consultants in various fields. They have a quarterly publication titled Pomona.

Membership is $19/ year
www.nafex.org/AboutNafex.htm

Upper Midwest Organic Tree Fruit Growers Network
A network of growers and others sharing information and encouraging research to improve the organic production and marketing of tree fruit in the Midwest, and representing the interests of growers engaged in such.
www.mosesorganic.org/treefruit/intro.htm

Holistic Orcharding Network
An online network of growers that share sustainable fruit-growing techniques with an emphasis on orchard soil health.
http://grou.ps/groworganicapples/home

Web resources and Email Lists

General resources

AIM (Apple Information Manager) is a collaborative Extension and research effort of the Universities of Vermont, Maine, New Hampshire, Massachusetts, Connecticut, and Rhode Island. Excellent weather resources and IPM decision-making tools for New England orchardists. Archived and current Extension and research newsletters and publications. Grower and Extension contacts. Searchable.
http://orchard.uvm.edu/uvmapple/pest/

Kearneysville Tree Fruit Research and Education Center, West Virginia University. Keys to pest identification, with great photographic images of insects and disease symptoms. Lots of useful information for fruit growers in the mid-Atlantic region. Online newsletters and publications archived. This is also the location to download the MaryBlyt program mentioned in the publication.
www.caf.wvu.edu/kearneysville

Lost Nation Orchard Seasonal Checklist, by Michael Philips
www.groworganicapples.com/organic-orcharding-articles/home-orchardist.php

The Mid-Atlantic Regional Fruit Loop, a cooperative effort bringing together information from fruit professionals in Maryland, Michigan, New Jersey, New York, North Carolina, Pennsylvania, Virginia, W. Virginia, and USDA/ARS.
www.caf.wvu.edu/kearneysville/fruitloop.html

The OrganicA Project is a multidisciplinary, multistate project that incorporates available knowledge and information to build an interactive community of growers, researchers, and educators for the exchange and generation of information and knowledge to enhance the adoption of organic practices and to improve the competitiveness of organic apple producers.

They have an email list serve. To subscribe, send an email to *listserv@list.uvm.edu* and place the subscribe command, "subscribe organica First Last" in the body of the message. Replace the "First Last" with your name. Here is an example that uses a list name of folkmusic: subscribe folkmusic Joe Smith.

The Virtual Orchard is a forum for research and Extension projects dealing with sustainable commercial apple production and marketing issues. Includes up-to-date news on issues affecting apple growers. Searchable.
www.virtualorchard.net

The Virtual Orchard also has an email list forum to foster exchange of information between university researchers, Extension agents and specialists, students, commercial apple growers, wholesalers/brokers, retailers, and direct marketers of apples.
www.virtualorchard.net/applecrop.html

Information on Rootstocks

New York State Agricultural Experiment Station Rootstock Fact Sheet
A fact sheet which includes a description of all commercially available rootstocks.
www.nysaes.cornell.edu/hort/breeders/appleroots/Factsheets/FSAccess.htm

All About Apples: Rootstocks
This is a comprehensive overview of all the commercially available rootstocks and a short description of each one, sorted by size.
www.allaboutapples.com/backyard/rootstock.htm

Disease Management Guidelines for Organic Apple Production in Ohio, by Michael Ellis
This online Extension publication is exactly as the title suggests—guidelines only for diseases, not insects. You can order a hard copy free of charge (see above under Books).
www.caf.wvu.edu/kearneysville/organic-apple.html

Growing Degree Days Information

Growing Degree Days. Cornell Gardening Resources.
www.gardening.cornell.edu/weather/gdd.html

Phenology web links:
(1) Sequence of Bloom, Floral Calendars, What's in Bloom;
(2) Birds, Bees, Insects and Weeds, by Steve Diver, 2002
www.attra.ncat.org/attra-pub/phenology.html

Economics and Marketing Web Resources

Input/Output analysis of organic apples versus conventional apples in Washington State:
http://enviro.lclark.edu:8002/rid%3D1241221293171_1070554029_1265/chart%2520inputs.pdf

Food and Drug Administration. 2005. Guidance for Industry: Letter to State Regulatory Agencies and Firms That Produce Treated (but not Pasteurized) and Untreated Juice and Cider.
www.fda.gov/Food/GuidanceComplianceRegulatoryInformation/GuidanceDocuments/Juice/ucm072508.htm

Organic Apples. Agricultural Marketing Resource Center. Iowa State University.
www.agmrc.org/commodities__products/fruits/apples/organic_apples.cfm

Other Projects and Organizations

Michigan State University Organic Apple Program
Information based on the findings from the research at the Clarkville Horticultural station including soil management, pest management and economics.
www.organicfruit.msu.edu

IPM Institute of North America, Inc.
1914 Rowley Avenue
Madison, WI 53726
608-232-1410
Fax: 608-232-1440
info@ipminstitute.org
www.ipminstitute.org/index.htm

Nurseries to Obtain Rootstock and Trees

Bear Creek Nursery
509-732-6219
bearcreektrees@gmail.com
www.bearcreektrees.com/index.html

Raintree Nursery
800-391-8892
customerservice@raintreenursery.com
www.raintreenursery.com

Stark Bros.
800-325-4180
info@starkbros.com
www.starkbros.com

St. Lawrence Nurseries
315-265-6739
trees@sln.potsdam.ny.us
www.sln.potsdam.ny.us

Pest-Management Supplies and Resources

Organic Management of Plum Curculio. Matt Grieshop, Mark Whalon, David Epstein, John Wise, and Larry Gut. May 2010. Fruit Crop Advisory Team Alert. Michigan State University Integrated Pest Management Resources.
http://ipmnews.msu.edu/fruit/Fruit/tabid/123/articleType/ArticleView/articleId/2530/Organic-management-of-plum-curculio.aspx

MARYBLYT Fire blight-Forcasting Software
This validated fire blight forecasting software is offered free of charge to growers, county agents, extension specialists, private consultants, and researchers. The software is offered without support (they do not answer questions on software installation issues or program mechanics). The software is available to download at: www.caf.wvu.edu/kearneysville/Maryblyt/index.html.

IPM Technologies
4134 N. Vancouver Ave.
Suite 105
Portland, OR 97217
888-476-8727
www.ipmtech.com

Scentry Biologicals, Inc.
610 Central Avenue
Billings, MT 59102
406-248-5856, 800-735-5323
Fax 406-245-2790
scentry@imt.net
www.scentry.com
A leader in pheromone technologies for more than 20 years. Offers Scentry traps and lures and NoMate mating disruption products.

Agriculture Solutions LLC
PO Box 141
Strong, ME 04983
207-684-3939
info@agriculturesolutions.com
Source of Isomate and other organic apple-pest management supplies.

Suttera
20950 NE Talus Place
Bend Oregon 97701
541-388-3688
866-326-6737
www.suterra.com
Manufactures Checkmate CM, delivery system that automatically dispenses pheromone for mating disruption of Codling moth for the entire growing season.

TRÉCÉ, INC.
PO Box 6278
Salinas, CA 93912
831-758-0204
Fax 831-758-2625
custserv@trece.com
www.trece.com

A leading producer of pheromone-based insect monitoring systems, including Pherocon and Storgard product lines.

Gempler's
P.O. Box 328
Belleville, WI 53508
800-382-8473
www.gemplers.com/tech/ilures.htm

Great Lakes IPM
10220 Church Rd., NE
Vestaburg, MI 48891
800-235-0285
www.greatlakesipm.com

Nufarm (Manufactures of Blightban)
800-345-3330
www.nufarm.com/USAg/BlightBanrA506

Rincon-Vitova Insectaries, Inc.
800-248-2847
bugnet @ rinconvitova.com
www.rinconvitova.com/index.htm

General Agriculture Supplies

Peaceful Valley Farm Supply
P.O. Box 2209
Grass Valley, CA 95945
916-272-4769
www.groworganic.com

Superior Ag Products
Yakima, WA 98908
509-966-9681
(no website)

Wholesale Agricultural Products

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

Monte Package Company
800-653-2807
www.montepkg.com

Apple boxes, bags, and cider supplies.

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Notes

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NCAT Agriculture Specialists
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Robyn Metzger, Production

This publication is available on the Web at:
www.attra.ncat.org/attra-pub/apple.html
or
www.attra.ncat.org/attra-pub/PDF/apple.pdf

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