Organic Matters

ATTRA's *ORGANIC MATTERS* SERIES

CONSIDERATIONS IN ORGANIC APPLE PRODUCTION

By Guy Ames, NCAT Agriculture Specialist, July 2001

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Introduction: A Tale of Two Systems

As in real estate, economic success in organic apple production depends on location, location, location. Time has shown that there are significant differences in strategy and potential for production systems in the eastern and western United States. Though progress is still being made in the development of certifiable organic materials that lower the hurdles to organic apple production in the East, there are still some major stumbling blocks that grant the competitive edge to western organic apple producers. Moreover, given current marketing trends in organic foods, probably only the most committed and talented grower-marketers in the East will be able to turn a meaningful profit growing organic apples. As Dr. Ian Merwin of Cornell University attested at the First National Organic Tree Fruit Research Symposium (Grand Junction, CO, May 31-June 1, 2001):

> At present, it is extremely difficult and prohibitively expensive to produce organic tree fruits in eastern North America, even with a substantial market premium. There are few successful certified organic tree fruit growers in this region, and no marketable pome or stone fruits with sufficient resistance to limit arthropod pests without pesticides. Growers have also found it difficult to market the more disease resistant tree fruit varieties in competition with mainstream varieties…
>
> Considering [the] pest management advantages in combination with the western states' more centralized packing and marketing operations, lower climatic variability and risks, cheap water and transportation, and a history of regional cooperation in support of research and marketing—there is little question that fruit growers of the western US will have a substantial advantage nationally in developing and servicing the expanding market for organic fruits.

In a nutshell, the dichotomy underlying the two systems is this: in the West, where the largest production areas (eastern Washington) are essentially irrigated desert, there are relatively fewer—far fewer—pests while, in the East, production is complicated by a plethora of pathogens, arthropod pests, and weeds. The reason for this difference is, of course, rainfall. East of the "tree line," an imaginary meridian defined by a line running between and beyond Forth Worth, Texas, and Lincoln, Nebraska, there is generally enough rainfall to support tree growth. It's not the trees, *per se*, that are the problem; it's the climate that supports the trees. The higher humidity and rainfall directly foster disease and weed problems, and the abundance of biomass supports greater insect and mite populations.

The exception to this proves the rule. California apple production is scattered among several relatively distinct climatic zones. In one of those areas, the North Coast, winters and springs are mild and wet, and summers tend to be foggy. In this location, the fungal disease scab is much more problematic than it is in the drier San Joaquin and Sierra Foothills apple production areas. To extrapolate, New England, which is much wetter yet than the California North Coast region, has an even greater problem with scab, requiring as many as 10–12 sprays for control compared to the North Coast's 3–4.

And nowhere in the West do apple growers yet have to tangle with the plum curculio.

East Is East, West Is West ….

The organic movement seems to be at an ironic and awkward crossroads in regard to apple production in this country. The roots of the movement stressed small-scale, locally-produced, and chemical-free food. However, the larger economic system, within which the organic food industry exists, inevitably rewards efficiency of scale, and among "green" consumers, only the most hard-core and best educated bio-regionalist-types are going to pick the predictably uglier, eastern organic apples over the cosmetically near-perfect western organic apples, especially when the latter are apt to be cheaper! Given the current trend towards consolidation in the organic food industry, this hypothetical green consumer probably won't even have a choice.

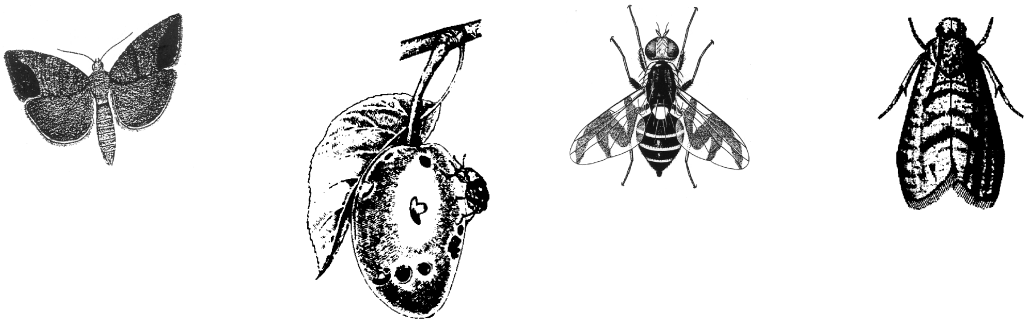
The truth is that organic production of apples is a *fait accomplis* in the West. Western growers are moving beyond the basic challenges of pest management They are now asking questions about fruit thinning, nuances of orchard floor management and fertility, and how to deal with predicted overproduction (!); meanwhile, in the East the few remaining organic growers are struggling for anything resembling market share in the new organic market economy, hoping that Mother Nature will allow them a crop at all, and working at their "real" jobs that allow them to pursue their farm fantasies.

Despite the progress outlined in the rest of this report, outside of a miracle silver bullet and/or fuel prices that truly inhibit transcontinental transport of produce, eastern organic apple growers will stay afloat only through aggressive micro-niche marketing efforts (farmers' markets, on-farm sales) and/or processed (value-added) products such as hard cider, jellies, etc.

Finally, the western organic fruit industry is ably supported by research and extension. The recent publication of the University of California's *Organic Apple Production Manual* is testimonial to this fact. In Washington, the Tree Fruit Commission and the Center for Sustaining Agriculture and Natural Resources represent grower- and public-funded institutional support for organic fruit growers. Similar support is ongoing at Oregon State University and Colorado State University. Stemilt, Cascadian Farms, Gerber Products and other private concerns augment this support. Though more research is always welcome and needed, it's a fact that the research and extension community is on-board or rapidly getting on-board in western states. Moreover, there are regional, public institution-led efforts like the area-wide codling moth mating disruption programs that benefit conventional and organic growers alike.

With these factors in mind, this publication is weighted somewhat toward the unanswered needs of eastern growers, though many of the research needs of western growers are also addressed.

Multiple Pests: No Silver Bullet, Just a Scattergun



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. Furthermore, there is always scab, blight, rust, mildew, and a host of other diseases. Heretofore, a problem with the organic approach to pest control in apples, be it East or West, was the piecemeal approach, especially relative to conventional growers, that organic growers have been forced to take.

For instance, mating disruption for codling moth only works on codling moth; ryania (not currently available) works on codling moth and Oriental fruit moth but not much else; *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; one cultivar that is resistant to scab may not be resistant to any other disease; and so forth.

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* that were actually making a profit with organic apples, and then only when the market began providing the price premium for organic after the Alar scare of 1989. (Western organic growers, unlike eastern growers, could produce apples that were cosmetically near-identical to those grown by conventional growers, and, for better or worse, the appearance standard set by conventional growers is the one that consumers have grown accustomed to.)

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 toxicity to non-target organisms—the broad spectrum broadened to include birds, fish, beneficial insects…and humans. 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 with multiple pests. Before particle film technology (see below), it seemed highly unlikely (and maybe not even desirable) that organic growers would ever have a broad-spectrum material for pest control.

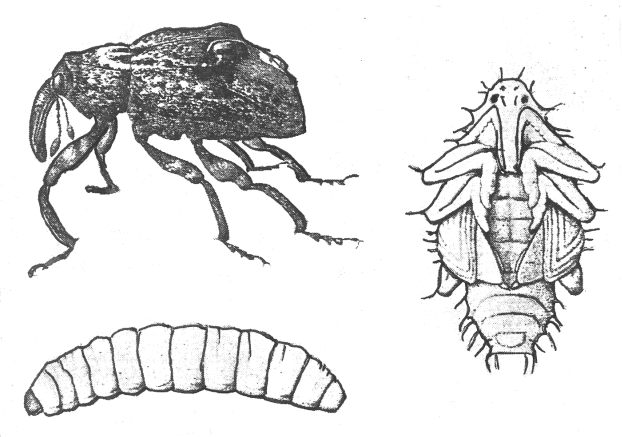
Plum Curculio: The Snout-nosed, Hump-backed, Pimpled Nemesis

Up until just a couple years ago, the plum curculio (PC) seemed to be the chief spoiler of organic aspirations for eastern apple growers. While there were various organic methods and materials that either delivered or promised adequate control of the other pests and diseases, the plum curculio seemed to thumb its snout at every organic method brought to bear against it.

The PC is a weevil (family Curculionidae, order Coleoptera) native to most of the apple production areas in the eastern U.S. (and it is indeed snout-nosed, hump-backed, and pimpled, not to mention ill-mannered). Perhaps the main reason it is not endemic elsewhere is the adult PC's need to overwinter in leaf litter and plant debris, a need readily satisfied in the woods surrounding most eastern orchards and in the weed- and grass-littered floors of the orchards themselves.* Before the advent of modern agricultural pesticides, growers kept the PC somewhat in abeyance by burning orchard floors and neighboring forest floors and/or by periodic cultivation (plowing) of the orchard. The latter practice disrupted the PC by turning up and exposing the pupae (larvae pupate in mid-summer right in the orchard). However, both burning and plowing can and often did have profoundly deleterious effects on the soils of eastern orchards.

The PC feeds on and lays eggs in the developing fruit of many plants, both native and introduced. The adult feeding is problematic, but it's the egg-laying, leading to larvae in the fruit, that is the real problem. Without some effort at control the PC can put worms in more than 90% of a developing apple crop (1)!

The Rodale Institute in the mid-1980s turned its research guns on the PC, with only modest results (2). Using the best methods these committed researchers could muster, they were only able to reduce the PC damage to around 50%—still too high for economical production.



* Dr. Mark Whalon of Michigan State University has very recently found the PC in two isolated western cherry-producing areas, one in Utah and one in Montana. He theorizes that these were accidental and isolated introductions by humans. He is, however, conducting trapping to try and determine the limits of PC in the West. Personal communication, June 27, 2001.

Particle Film Technology: "As Close to a Silver Bullet as We'll Ever Get"

Then Surround™ came around. In West Virginia in the 1990s, Drs. Gary Puterka and Michael Glenn of the USDA's Agricultural Research Service began experimenting with various "inert" materials, including clays, for disease suppression in apples. Though consistent disease suppression was elusive, the researchers noted reduced insect damage. After some refinements, the USDA ARS, in cooperation with the Engelhard Corporation, came up with a product based on kaolin clay—the same clay in many toothpastes and Kaopectate™—that demonstrated consistent control or suppression of almost all the major and minor apple insect pests, including the plum curculio. There appears to be no mammalian toxicity or any danger to the environment posed by the use of kaolin in pest control. Engelhard began marketing Surround in 1999, and the Organic Materials Review Institute officially recognized Surround as "organic" in 2000.

Surround is a wettable powder which leaves a white, protective, powdery film on the surfaces of leaves, stems, and fruit. Although at first glance the film may appear to block light, Surround actually increases net photosynthesis, and can provide secondary benefits to the trees' overall health. 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 two-year study, 'Empire', when sprayed during the first six to eight weeks after petal fall, had increased yields and increased red color. Growers have reported similar results with 'Stayman' and 'Gala'. A Michigan State study reported increased return bloom where Surround had been used the previous season. Growers in hot areas benefit from significant reduction in sunburn damage to fruit, often 50% or greater.

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 unrecognizable as a host.

So far, in controlled settings (university or USDA trials) Surround has shown control of leafrollers and leafhoppers; suppression of mites, codling moth, PC, stink bugs, apple maggot, and thrips; reduced heat stress, fruit drop and sunburn; greater return bloom; and improved color in certain cultivars. One Arkansas grower remarked that, though it didn't control diseases, "it's probably as close to a silver bullet as we'll ever get."

Note that Surround generally *does not kill the pests!* This is the key to why it can be both a broad-spectrum pest management tool ("pesticide" is really not an appropriate moniker for this stuff) without harming non-target organisms. It doesn't even really hurt the pests! No wonder the typically staid, academic *Journal of Economic Entomology* refers to particle film technology as "a new paradigm for pest management" (3).

The standard Surround spray program for plum curculio and first-generation codling moth starts at first petal fall and continues with 6–8 sprays, applied at roughly one-week

intervals 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. However, the dust residue is not a problem for processing fruit.

Trial applications of the spray showed that where plum curculio damage was 20–30% in unsprayed checks, the treatments receiving the particle film had only .5–1% damage. Dr. Puterka has speculated that in areas where PC pressure is especially heavy (for instance in unsprayed trees in northwest Arkansas which can suffer in excess of 90% damage), shortening the recommended spray interval from 7–10 days to every 5 days might provide the levels of suppression obtained in the trials (4).

Dr. Puterka is careful to say that his trials indicate "suppression" of PC damage rather than complete control, but 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 organic option.

Grower Testimonial: "It's Like Christmas"

Maryland grower Eric Rice, one of the first orchardists to use the kaolin spray, is hopeful that the product will help him boost the percentage of select grade fruit from 50% to 70% of his apple crop. He expresses optimism about Surround's effectiveness against insects like the plum curculio, codling moth, leaf rollers, mites, and aphids. "It doesn't bother beneficials," he says, adding that the ladybugs and other predators continued to thrive in the rich groundcover of clover and grass. Trials at the Rice orchard have shown over 90% control of the "big ones"—codling moth, plum curculio, and apple maggot. While Surround has also had a positive effect on fungal diseases like sooty blotch, fly speck, and fire blight, Rice cautions that it is not a panacea. It has had no effect on apple scab, a disease that often poses a bigger problem to growers than insect pests. (Initial research with kaolin focused on its potential for disease suppression, but the results were inconsistent.)

Although reluctant to make "overly aggressive claims" about the product, Rice says that Surround is far more useful than any other organic tools available on the market. The only disadvantage he cites is the necessity of washing the clay off the fruit after harvest. Referring to the uniformly white appearance of the trees after spraying, Rice says, "It looks like Christmas. People who drive by sometimes stop to inquire if something is wrong."

At this time, Surround seems to be roughly comparable in relative cost to the commonly used organophosphate insecticides and cheaper than current organic controls. Of course, there are variables that make this a tentative statement: relative pest pressure and rainfall, for example, influence how many sprays of Surround must be made in a season.

Surround's efficacy does not seem to be affected by most other pesticides; however, Surround should not be tank-mixed with sulfur or Bordeaux mixture fungicides as clumping and settling out of the materials can occur. Conventional spray equipment can be used, though it is important that the sprayer is equipped with paddles or some form of agitation as the material will tend to precipitate out of suspension. Full coverage is important, so a fan-type sprayer that blows the leaves around is beneficial. Surround does not appear to clog spray equipment as some growers initially feared.

Combine Surround with other available organic pest controls, and the insect and mite problem suddenly looks solvable in the East and easier for the West. Multiple applications because of rain wash-off is a problem for the East, but the researchers have some ideas for that obstacle, too. All in all, it's very promising. It's been a long time coming, but it still is probably not enough, at least not yet. Eastern organic apple growers' focus on adequate controls for the PC—the clearest danger—may have obscured the seriousness of some of the other major problems.

Blight Plight and Rot Rut

Eastern apple growers face a plethora of disease problems—fireblight, scab, black rot, white rot, bitter rot, cedar rust, to name a few. Half of the diseases that afflict the East don't even occur out West, and if they do, they cause far less damage than in the East. For instance, in almost all but the coldest apple growing regions in the East, the summer rots—especially bitter rot—can be absolutely devastating in a warm, wet season unless fungicides are used. In contrast, looking in California's *Organic Apple Production Manual*, you won't even find entries for these rots, not even in the "Minor Diseases" section.

Of course, for years organic growers have employed the mineral fungicides sulfur and copper—singly, combined, and in various formulations—for disease control, but there are many drawbacks. Some formulations are hard on equipment, and some are hard on beneficials, including earthworms and other soil organisms. To top it off, these mineral fungicides have very little efficacy against some diseases—the rots, for instance— and to be efficacious against diseases they can control, they may have to be applied 15–20 times per season in rainy climates (compared to 2–3 sprays in California's North Coast growing district)!

Seek, and Ye Shall Find

If there is solace to be taken, it is this: the more we look for organic and least-toxic controls, the more we find. The Alar scare of 1989, the Food Quality Protection Act of 1996, and general public concern over pesticides in the food system (often expressed as consumer willingness to pay a premium for organic food) have prompted intense searches for ecologically sound approaches to pest management in apples. Though we have not yet found answers to every pest control problem, the progress is very promising.

In the realm of plant disease control, there are several avenues that are yielding results. For the purposes of discussion, these avenues will be labeled genetic resistance, induced resistance, microbials, and biorationals.

Genetic Resistance: Breeding for Disease Management

Genetic resistance to a particular disease or diseases can be obtained through sexual recombination—be it by chance in nature or by deliberate crosses made by conventional plant breeders—or it can be obtained through genetic engineering, a methodology that is officially eschewed by organic growers (see box below).

Conventional plant breeding is a time-honored way to incorporate genes for resistance into apples. Some of the older heirloom apples have, by happenstance, some resistance to some diseases. However, the products of modern breeding efforts have garnered most of the attention in this arena. Cultivar names like Liberty, Freedom, Williams Pride, Goldrush, et al., are now relatively well known to orchardists, if not to consumers…and therein lies the rub—or one of the rubs. It may easily take 20 years from the first controlled crosses to the point that a breeder feels that a candidate plant can become a named cultivar. If the public doesn't accept that apple because of color, flavor, shape, or who-knows-what, then those efforts and those years may seem "down the drain" to the breeder *and* to the institution that supported the work. As a consequence of this situation, very, very few of the land-grant universities still fund apple breeding programs. In fact, the only programs still active in making new crosses are at Cornell and Purdue, and both of these are threatened.

As intimated above, there is at least one other "rub" to breeding for resistance. Again because heritability in apples is complex, it's very difficult to deliberately incorporate resistance to more than one disease at a time into a commercially acceptable apple. As a consequence, a cultivar with near immunity to scab might be horribly susceptible to cedar apple rust, blight, and/or summer rots.

Gene Jiggering

One thing that is particularly interesting (and admittedly tempting to some) about genetic engineering is the ability to quickly "transform" an already popular, profitable cultivar to be resistant to a disease. For instance, gene jockeys are currently showing progress in making 'Gala' significantly resistant to fireblight by engineering in a gene from a moth! For whatever long-term danger this might represent, such work at least appears to deliver what early promoters of genetic engineering promised: quickly obtained disease or insect resistance that would lead to a reduction in pesticide use. In contrast, conventional breeding techniques to incorporate resistance take a very long time, and are restricted to closely related organisms (e.g., wild apples vs. moths) as sources of resistance-coding genes. Moreover, because of the complex inheritance of traits in apples, retaining the valuable horticultural characteristics of a specific cultivar (e.g., Gala) through the breeding process is practically impossible.

Induced Resistance

One of the most interesting things to occur in phytopathology in the last two decades is the confirmation of the widespread existence of "induced resistance" in plants—the ability of a single plant to *respond* to a pest challenge by creating a general defense mechanism. Although the existence of induced resistance has been known for some time, researchers long maintained that the absence of a central nervous system in plants meant that, in general, individual plants could not react to attack in its lifetime with, for instance, the production of antibodies such as in mammals. Rather, said the conventional thinkers, plant resistance to pests occurred at a genome level, over time, and by natural selection. Furthermore, the resistance mechanisms triggered by pathogen or herbivore attack were relatively specific to that pathogen or herbivore. Therefore, a given plant either had some form of resistance at the time of attack or it did not. The few apparent exceptions were simply yet-to-be-explained anomalies.

However, it now seems that the exceptions *are* the rule. Resistance to plant pathogens, insects, and mites has been demonstrably induced by challenging plants with non-toxic to mildly toxic microbes and chemicals, plant extracts, compost extracts, and even by mechanical means (abrasion with sand, etc.). For instance, cucumbers have been made resistant to cucumber anthracnose by exposure to extracts from spinach and rhubarb leaves; coffee plants were resistant to leaf rust after exposure to *Bacillus thuringiensis*; and potatoes became resistant to potato scab after foliar sprays of benzoic and picolinic acid.

In all these cases, researchers know it is induced resistance rather than a direct antagonistic effect of the substances on the pathogens because the substances are washed off before the plants are exposed to the pathogen. What scientists have discovered is that exposure of certain plants to certain substances elicits general plant defense mechanisms such as the production of protective phytoalexins or thickening of cell walls. However, there is (or was? See below!) no single agent that consistently elicits significant protection in a broad range of crop plants.

In the early 1990s, researchers at Cornell discovered that the causal organism of fireblight (the bacterium *Erwinia amylovora*) releases a protein, dubbed harpin, which triggers a "hypersensitive response" in a broad range of plants. The commercial product has been named Messenger™.

The EPA, which has labeled Messenger for use on apples, says:

> When the harpin protein is applied to a plant, it is recognized and activated by a receptor system located on the leaf surface. This binding by the harpin receptor triggers a series of signals and internal reactions that stimulate the induction of a systemic acquired resistance (SAR), analogous to the immune response in mammals. SAR induced by harpin, however, is a much broader response, giving the plant long-lasting resistance to a broad range of fungal, bacterial and viral diseases, while simultaneously stimulating growth and enhancing yields. Harpin protein does not directly kill the disease organism or insect pest. Instead, it sends a "message" to the plant to mobilize its defense mechanisms, thus the product's name, Messenger. Because harpin is a natural elicitor of plant systemic immunity, its use in the field results in a natural, plant-directed response that does not upset the balance of normal plant physiological mechanisms. (5)

So far, the manufacturer, Eden Biosciences, is not claiming protection from specific diseases or pests; however, it is claming larger fruit; better color; earlier, more uniform maturity; improved internal quality and shelf life; and reduced post-harvest disease. Research on pome fruit is ongoing.

As of this date (June 27, 2001), OMRI (Organic Materials Review Institute) has not received a request from Eden Biosciences to register Messenger as organic. It would seem a good fit, yet perhaps this product is a bit too manipulated to pass OMRI muster. Still, something like it—maybe a de-clawed *Erwinia*—would be organic enough to pass and still elicit the desired plant response. Now, wouldn't that be something: organic orchardists spraying the fireblight organism for disease control?

Microbials: Germs of an Idea

Beauveria bassiana, an entomophagous fungus, and *Bacillus subtilis*, a bacterium capable of suppressing a wide range of fungi, are two examples of microbial products that have a good chance of surviving in the marketplace because of their broad spectrum of activity. Both are now commercially available and are discussed in the **Selected Abstracts** section that follows.

There are other "microbial antagonists" out there in various pipelines and in various stages of development, but most are, in their turn, effective against a single or narrow range of pests. There are three problems with these specific biocontrols. One is simply a practical problem for orchardists: more things to juggle in an already complex farming system. If an organic orchardist can just as safely and just as cheaply (or almost as cheaply) apply a broad-spectrum pest control product to manage multiple pests, he or she is apt to do so.

The second problem is a tad more theoretical and (therefore?) more interesting. It seems to be a general rule in nature that the more specific the mode of action of a plant protectant—whether it be genetic, chemical, or biological—the more easily and quickly the pest develops a way around it. Among chemical pesticides, the sterol-inhibiting fungicides are notorious for this. In plant genetics, monogenic resistance to nematodes in soybeans has led to a constant battle between plant breeder and nematode as race after new race of nematode develops to overcome the latest source of resistance. In biological control (really the same as genetic), the history of life itself can almost be written in terms of the co-evolution of hosts and pests: the host evolves a biochemical defense mechanism for a pest; the pest learns to de-toxify it; the host tweaks the defense and gains a temporary advantage; the pest tweaks in turn; *ad infinitum*. One of the problems with these specific approaches is that they tend to put great selective pressure on the pest precisely because they are initially so effective; only the resistant genotypes survive to replicate, and soon there is a new resistant race. In contrast, a general mode of defense—such as an actual physical barrier, e.g., thicker leaf cuticle or a layer of clay on the fruit—may put very little selective pressure on the pest (individuals may not even be killed, just forced to go elsewhere to eat).

Thirdly, a product or technique that works against multiple pests or on multiple crops is obviously going to have an advantage in the marketplace over products with more limited uses. The big chemical companies operate by this rule, of course. It's not economical to produce a plant protectant, however safe or organic it might be, if the market is too limited.

All of which is to say, many new entries among the microbials, because of their specificity and regardless of their apparent efficacy, will probably not survive long in the marketplace. Some, like *Beauveria bassiana* and *Bacillus subtilis,* may have a broad enough applicability to grant them longevity.

Inert Biorationals: Oil on the Water

Soybean oil, jojoba oil, other vegetable oils, fish oil, and refined petroleum- or paraffin-based oils all either are, will be, or could be used in organic orcharding. There's really nothing new here except, possibly, *how* some of them are being used. For decades the primary use of such oils was to smother scale, mite eggs, etc. during tree dormancy. Then advances in technology allowed the use of the more refined oils during the growing season to help control a few more arthropod species. Now, more and more oils have been found to control some diseases. Powdery mildew, not a terribly devastating disease for most cultivars, seems to be controlled by any number of oils (I'm wondering now what kind of oil *won't* control powdery mildew). Unfortunately, as of yet, none of these oils promise significant control for the truly devastating diseases such as scab, blight, and the summer rots.

Some of the oils have also been included in bloom thinning experiments. Research in China indicates that vegetable oil emulsion can be an effective crop load management tool. More details on this research are provided in the **Selected Abstracts** section.

Narrowing the Gap—Getting (More) Ideas from "Conventional" Agriculture

Agriculture is in such flux, it's becoming difficult to call any part of it "conventional." This is especially true for pest management and even more so for pest management in tree fruits. Easily the big story in this regard is mainstream agriculture's movement *toward* organic. Because of factors mentioned earlier, all agriculture is headed toward the least-toxic methods of pest control. And mainstream pesticide research is finding many of its answers in nature. For instance, the abermectin insecticides and parasiticides were first isolated from soil actinomycetes. As another example, the new, apparently very safe, strobilurin fungicides were discovered in European strobilurin mushrooms. In both cases, the active compounds were isolated, characterized, and ultimately synthesized in the lab.

As synthetic compounds, such materials are not accepted in organic production. But it's not too hard to imagine this research taking a step back (or sideways?) and becoming more natural and less synthetic. *Bacillus thuringiensis* is produced in large-scale commercial culture. Would it be possible to produce mycelial mats of strobilurin mushrooms and make simple watery extracts for disease control? Maybe not, but might there be other ways to take advantage of some of the advances being made in so-called conventional agriculture and adapt them to organic agriculture? Of course, it's all just pipe dreaming of the highest order without commercial incentive for the pest control industry. But, wait! We're getting that kind of clout now! Hmmm.

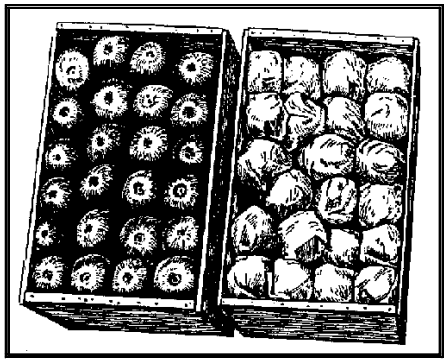
Econ. 101: Supply & Demand—The Organic Premium is Slipping

The "Alar incident" of 1989 prompted prices for organic apples to rise as high as $60 for a 20-pound box. Prices did not stay that high for long, and by the end of the year organic apples were selling for only 25–30% more than conventionally grown apples. Also in 1989, a University of California study (6) concluded that premium prices, not cut-rate production costs, represented the best hope for profits in organic apple production. Dr. Roberta Cook, one of the authors of the study, cautioned that supply is rapidly catching up with demand and that growers should not leap into production based on perceptions of lower input costs and guaranteed premiums.

Twelve years later, Cook's predictions appear to have come true. Supply of organic apples has increased dramatically and seems set to continue increasing. Whether growers in the West will have access to premium prices at the wholesale level is becoming increasingly uncertain. Those premiums are rapidly shrinking to near zero, according to Dan Cheatham, a buyer for the Whole Foods chain (7).

The number of organic apple growers in Washington was projected to increase from 74 in 1998 to 114 by 2001 (8), with organic apple production in the state expected to triple in roughly the same time period (9). Some industry experts believe that the number of acres being converted to organic production will lead to an oversupply of organic apples, depressing prices. According to a USDA-FAS study on Washington organic production (9), domestic demand for organic apples "is fast reaching the saturation point," and the authors recommend developing the export market, where growers will face increasing competition from countries such as China. In 1997, China produced nearly four times as many apples as the U.S., and China is predicted to produce 40% of the world's apples by 2005 (10).

Given this market situation, any potential organic apple producer needs to carefully consider the economics of production in his or her area before making any investments. 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.



Conclusion: East is East, and West is Best?

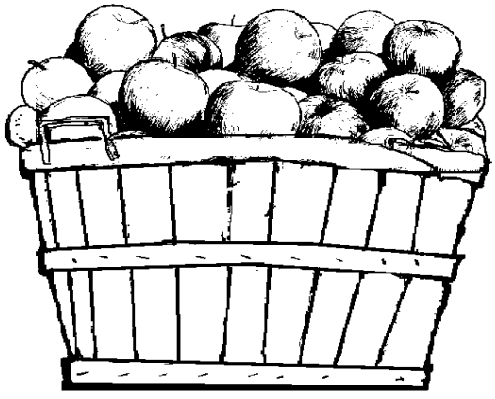
While western growers and researchers are refining their organic production system and talking about how to deal with surplus production, eastern growers and researchers still have very serious production obstacles to overcome.

Would-be organic growers in the eastern half of the country must realize that they are likely to face production costs at least triple those faced by growers in the West. Management of the plum curculio alone is a very serious economic and logistical problem, even with the new kaolin clay technology.

In addition to the plum curculio, a host of other pests and insects make organic apple growing in the East difficult at best, and costly for sure. While slightly damaged apples can be used for cider and other processed goods, these require expensive processing and storage equipment, and cider usually brings a lower return than fresh fruit. Obviously, the organic grower would have to receive premium prices to recoup the higher production costs.

The prudent small-scale, organic grower in the East should retain a niche-market strategy focusing on retail sales. By carefully developing this type of market, the grower may be able to maintain an adequate profit margin while personally connecting with and educating customers on the advantages of his or her apples (fresher, greater variety choice, locally grown, etc.).

In the West, organic production is certainly easier due to climate and a supportive infrastructure, but profitability is a crucial issue for the whole apple industry right now, organic or not. The small premium that exists now will get smaller if too many growers enter the game…unless demand can keep pace or exceed a larger supply. A Chinese-born-and-educated researcher now with the USDA in Washington, Zhiguo Ju (11), maintains that China (the looming giant in world apple production) does not have a climate amenable to organic production and that Washington, therefore, should be able to maintain a competitive advantage in the world organic apple market. Perhaps, then, the best thing we could do for western growers is prioritize funding for research (e.g., health benefits of apples, especially organic apples) and programs (e.g., advertising and education campaigns to disseminate information on the benefits of organic) with the purpose of increasing consumer demand for organic apples.



Selected Abstracts: Research Relevant to Organic Apple Production

Introductory Notes: As emphasized from the beginning of this report, there is a significant difference between the eastern and western U.S. in regards to pest management in apples, and pest management is the key to organic apple production. This difference is reflected in the amount and types of information available to growers, East and West. Western growers will find significant support from university-based research and extension (including publications relevant to organic growers). In the East, university research and extension has concentrated on integrated pest management (IPM), which, as a rule, reduces but doesn't eliminate synthetic pesticide use. Most of the information on organic apple production in the East has been and continues to be grower-generated. ***NOTE:*** **It is very important that eastern growers and would-be growers do not rely on information from the West for the planning or operation of eastern organic orchards.**

A Scent-Based Trap for Codling Moth Which Attracts Males AND Females:
A synthetic version of the female codling moth sex pheromone has been available for 30 years and provides the basis both for monitoring and mating-disruption systems. This pheromone attracts only males. Now, USDA researchers have discovered and isolated a fruit scent from pear that is as effective as the sex pheromone, *and* attracts females. "Attracting females directly would allow growers to eliminate the females and their unlaid eggs and to monitor mating cycles more precisely." Trece, Inc., of Salinas, California, in cooperation with the USDA, is pursuing commercial development.

Stelljes, Kathryn. 2001. Fruit perfume lures female codling moths. Agricultural Research. Vol. 49, No. 6. June. p. 10–12.

Researchers:
Douglas M. Light, USDA-ARS Plant Protection Research Unit, Western Regional Research Center, 800 Buchanan St., Albany CA 94710; phone (510) 559-5831, e-mail <dlight@pw.usda.gov>.

Alan L. Knight, USDA-ARS Yakima Agricultural Research Laboratory, 5230 Konnowac Pass Rd., Wapato, WA 98951; phone (509) 454-6566, e-mail <aknight@yarl.ars.usda.gov>.

BlightBan™ Use Guidelines: As many growers have already learned by now, BlightBan (a formulation of the bacteria *Pseudomonas fluorescens*, strain A506) is, by itself, not much better than the conventional sprays of streptomycin at combating fireblight. Like strep, the practical use of BlightBan—which outcompetes the bacterium that causes fire blight to *prevent* infection—involves making sprays at just the right time. Too early and the flowers that need protection won't be open; too late and the fireblight-causing bacteria are already there and can't be stopped. Recommendations are application at 20% bloom, again at full bloom, and once more at two weeks past full bloom.

Source: Midwest Biocontrol News, <http://www.entomology.wisc.edu/mbcn/rev603.html>.

Granulosis Virus for Codling Moth Works in Combo with Mating Disruption: The codling moth granulosis virus (CMGV) is hardly new, having been discovered by Louis Falcon of UC Berkeley in the 60s, but research continues. Over the past decade, grower interest seems to have faded with the promise of control via mating disruption. However, as some situations (e.g., high initial codling moth populations, uneven-sized trees, etc.) militate against control with mating disruption, the importance of having other primary or supplemental organic controls has become apparent.

In New Zealand, "export quality" harvests were obtained by combining mating disruption and one spray of CMGV in organic orchards. In one orchard, damage was reduced to 0–1% in year two and 1–4% in year three. In a second orchard, previously sprayed with a conventional program and having a large initial population of codling moth, the population was also controlled combining the two methods.

One spray of CMGV was used per season. CMGV is highly specific to codling moth and is applied with conventional airblast sprayers. Timing of the spray is very important as it breaks down quickly in sunlight. The spray must be applied when the young caterpillars are hatching and boring into apples. Careful monitoring indicates the best time to apply the CMGV spray. One spray costs approximately $130 per hectare.

Source: <http://www.hortnet.co.nz/publications/science/clwater.htm>.

Granulosis Virus for Codling Moth Works, Depending on Conditions: In parts of Canada where the climate is cool and there is only one generation of codling moth, CMGV needs to be applied only once or twice per year for good fruit protection. However, in warmer areas with a longer growing season, codling moth populations tend to be higher and larval activity occurs over a longer period of time, necessitating several applications. Six or seven applications were made in some Ontario orchards to keep fruit damage below 4%. As in previous studies, the virus was not consistently as good as chemicals at keeping codling moth damage at low levels.

Jaques, R. P., J. M. Hardman, J. E. Laing, R. F. Smith and E. Bent. 1994. Orchard trials in Canada on control of Cydia pomonella (Lep.: Tortricidae) by granulosis virus. Entomophaga 39: 281-292.

Hand Thinning Yields Extra Pest Control Benefit: At least in Quebec, hand thinning of fruit clusters to a single fruit reduces damage from oblique-banded leafroller (OBLR). The effect was consistent over seven cultivars. Manual thinning was twice as effective as chemical thinning for limiting OBLR damage, and was also superior in increasing fruit diameter and weight in this study.

Grossman, Joel. 2000. ESA Conference—Part 8. IPM Practitioner. October. p. 14

Researcher:
Charles Vincent, Ag & Agri-Food Canada, 430 Gouin Blvdl, Saint-Jean-Sur-Richelieu, Ouebec, Canada J3P 3E6.

Mycotrol O™ Bioinsecticide for Many Apple Pests: *Beauveria bassiana* is an entomopathogenic fungus that is effective against a broad range of insects including tarnished plant bugs, leafrollers, aphids, thrips, and more. In most trials, *B. bassiana* provided control equal or superior to conventional insecticides. Its use is approved on all agricultural crops, it can be used up to the day of harvest, and it is labeled as organic by OMRI. It is most effective when used at early stages of insects' life cycles, so combining with scouting is recommended. Because it is a fungus, it should not be tank mixed with fungicides.

Grossman, Joel. 2001. ESA 2000 Annual meeting—part one. IPM Practitioner. February. p. 15–16.

Manufacturer's website: <http://www.mycotech.com/products/mycotrolo.shtml>.

Serenade™ for Disease Control: Serenade, a strain of the bacterium *Bacillus subtilis*, has proved effective against a broad range of fungi, including those which incite scab and mildew, as well as the bacterium that causes fireblight. In university-sponsored trials, it out-performed conventional fungicides and antibiotics against mildew and fireblight. It was not quite as effective as conventional fungicides in combating scab, but was still vastly better than the untreated controls. It has not yet been tested on the various summer rots.

Serenade should be considered a protectant with little or no curative activity. It inhibits attachment of the pathogen to the host, stops the pathogen from growing, and induces systemic acquired resistance (similar to Messenger). It is certified organic by OMRI.

Quarles, Bill. 2001. Serenade biofungicide. IPM Practitioner. February. p. 10.

AgraQuest, Inc. website for technical information and trial results: <http://www.agraquest.com/prod_frames.html>.

Oil for White Apple Leafhoppers: Oil treatments (Orchex 796—not registered with OMRI) gave significant control of white apple leafhoppers and inhibited egg-laying, with six sprays more effective than three. Perhaps some of the summer-weight oils that are OMRI-registered would be as effective.

Grossman, Joel. 2000. ESA Conference—Part 8; Oil for apples. IPM Practitioner. October. p. 14.

Vegetable Oil for Bloom Thinning: When applied in a 4% solution during early bloom, a vegetable (corn) oil emulsion was effective in thinning crop load in both 'Delicious' and 'Fuji' apples. Two applications, one at first bloom and the second at 50% bloom, were effective in reducing fruit set in Fuji by about 75%.

Unlike some other thinners being tested (e.g., lime sulfur, pelargonic acid), the sprays did not result in any fruit russet at harvest. Nor was there any reduction in return bloom; in fact, return Delicious bloom was increased by 32%.

Though the research was conducted in China, the primary author/researcher is now with the USDA-ARS Tree Fruit Research Lab in Wenatchee, WA.

Ju, Zhiguo and Yousheng Duan. 2001. Vegetable oil emulsion for organic fruit production. p. 33–35. In (Informal proceedings of the) 1st National Organic Tree Fruit Research Symposium, May 31–June 1, 2001, Grand Junction, CO. (These *informal* proceedings were published for symposium participants; a formal proceedings is in process and will be issued by the American Society for Horticultural Science sometime in 2002.)

Contact:
Zhiguo Ju, USDA, ARS Tree Fruit Research Lab, 1104 N. Western Ave., Wenatchee, WA 98801. Email: <Ju@tfrl.ars.usda.gov>.

The *Ladurner* Mechanical Hoe: "One of the most interesting new developments on the market": Developed initially by a Swiss organic orchardist, this device is being manufactured by the Ladurner Company in Southern Tyrol. In the words of Swiss researcher Franco Weibel:

> The results are convincing, even in situations with dense growth and on heavy soils, i.e., conditions under which it is difficult to hoe but which are common in fruit production.
>
> The hoeing is carried out by two rotors with three tines each. The front rotor, which is slightly smaller, is controlled by a sensor wand and works precisely around tree trunks and stakes. All soil moving parts are attached to a side-mounted arm moving parallel to the tramline. This floating position with lever arms of minimum length and within view of the driver allow for optimum guidance and control of tillage depth and straight driving. Quality has its price which in this case is Euro 12,500. However, the machine will only have to be used between four and six times a year, so the Ladurner mechanical hoe is perfect for co-op use.

Weibel, Franco. 2001. Weed control in organic orchards. p. 13–20. In: (Informal Proceedings of the) 1st National Organic Tree Fruit Research Symposium, May 31–June 1, 2001, Grand Junction, CO. (These *informal* proceedings were published for symposium participants; a formal proceedings is in process and will be issued by the American Society for Horticultural Science sometime in 2002.)

Organic Shown to Be Most Sustainable of Three Production System Types: Scientists from Washington State University examined three different production systems—organic, integrated, and sustainable—and concluded that the organic system ranked first in environmental and economic sustainability, the integrated system second and the conventional system last.

Perhaps the biggest news from this study was the prestige of the messenger; it was published in *Nature*, widely considered the premier academic journal for the biological

sciences. This should make it useful to activists looking for research to influence public policy decisions.

Reganold, John P., Jerry D. Glover, Preston K. Andrews, and Herbert R. Hinman. 2001. Sustainability of three apple production systems. Nature. No. 410. p. 926–930.

Contact:
John Reganold. E-mail: <reganold@wsu.edu>.

Paper Mulch Coated with Vegetable Oil Biodegrades…But Slowly: USDA researchers in Illinois have shown that coating shopping bag-weight, brown, kraft paper with soybean oil can extend its useful life as a mulch for up to 13 weeks, compared to 2.5 weeks for untreated mulch. No commercial product is yet available, but a patent has been approved and further field trials are underway.

Articles:
<http://www.goodfruit.com/archive/May1-01/cursplt.html>.

Brown, Greg. 2001. Coated paper mulch offers biodegradable alternative. Fruit Grower News. July. p. 18–19.

Resources in Print

1st National Organic Tree Fruit Research Symposium, May 31–June 1, 2001, Grand Junction, Colorado. Informal Proceedings.

From the cover: "The results in these informal symposium proceedings are preliminary. The papers within are only to be used for symposium discussion and information by conference participants. They are not reviewed and will be followed by a peer reviewed formal proceedings."

In other words, unless you have connections, you cannot get a copy of these "informal" proceedings. Yet this document does exist and is filled with research and experience related to organic orchard floor management, crop thinning, nutrition, and pest management.

Participants came from across the country, Europe, and New Zealand and included growers, researchers, and representatives of industry. Colorado Organic Crop Management Association, Colorado State University, Organic Farming Research Foundation, American Society for Horticultural Science, Gerber Products, Dr. Rick Zimmerman, and Pacific Biocontrol sponsored the event.

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

Very slick, professionally done book. 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 $35.00 (plus $3.50 postage and handling) from:

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

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

Not as slick and professional as some, but full of the real-life experiences of organic growers. Might be especially helpful for questions regarding organic fertility management. For Northwest only. Available for $38.00 (plus $3.50 postage and handling) from Good Fruit Grower (see previous item).

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. Still, lots of good information for Eastern growers. Available **free of charge** from the address below. A web version is available too, at:*

http://www.caf.wvu.edu/kearneysville/ organic-apple.html

C & T Department
OSU/OARDC
1680 Madison Ave.
Wooster, OH 44691
330-263-3700
e-mail: martin.881@osu.edu

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 $10.00, 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 pathogens that can afflict your trees and crop. Excellent color plates. Though there is life-cycle and other relevant information that impacts control, it is not primarily a control guide. To order send $37.00 (plus $5.00 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**. Third edition. AgAccess, Davis, CA. 154 p.

Using a season-by-season 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 Fertile Ground Books for $16.95 (plus $2.50 shipping and handling book rate, or $5.00 UPS; CA residents add applicable tax).

Fertile Ground Books
P.O. Box 2008
Davis, CA 95617-2008
800-540-0170
http://www.agribooks.com

Phillips, Michael. 1998. **The Apple Grower: A Guide for the Organic Orchardist**. Chelsea Green Publishing, White River Junction, VT. 242 p.

To date, the best guide for strictly organic growing in the East, but that's not to say that it provides perfect or easy answers for all the considerable challenges in the East. In fact, it was published before the market availability of Surround, so nothing about this technology is mentioned. Phillips is hoping to convince his publisher a second edition is necessary in order to add in this and other information. Available from the publisher for $35.00 (plus $6.00 shipping and handling; VT residents add applicable tax).

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

Swezey, Sean L., Paul Vossen, Janet Caprile, and Walt Bentley. 2000. **Organic Apple Production Manual**. University of California Agriculture and Natural Resources Publication 3403. University of California, Oakland. 72 p.

The first of its kind: a manual for organic apple producers from a land grant university. Together with the companion UC publications IPM for Apples & Pears and Commercial Apple Growing in California, it's hard to imagine a better published information base for current or would-be California organic apple production. The foundation is a body of experience and scientific research conducted in California, not extrapolated from research – anecdotal or scientific – from elsewhere in the country. For information on ordering, contact:

University of California
Agriculture and Natural Resources
Communication Services – Publications
6701 San Pablo Ave., 2nd Floor
Oakland, CA 94608-1239
Tele: 800-994-8849 or 510-642-2431

Related ATTRA Publications

Organic and Low-Spray Apple Production
Overview of Organic Fruit Production
Insect IPM in Apples: Kaolin Clay
Organic Certification
Biointensive Integrated Pest Management
Farmscaping to Enhance Biological Control
Compost Teas for Plant Disease Control
Biodynamic Farming & Compost
Direct Marketing
Organic Marketing Resources
Holistic Management

All available free by calling (800) 346-9140.
Or go to the website <http://www.attra.org/>.

Web Resources

http://orchard.uvm.edu

UVM Apple Orchard site (University of Vermont). "Extension and research for the commercial tree fruit grower in Vermont and beyond." Horticulture, IPM, weather, archived newsletters, searchable, links, e-mail newsletter.

GROWER-AIM is an e-mail discussion group for New England apple growers. To subscribe, send an e-mail to listserve@list.uvm.edu *with the subscribe command as the first line of your message along with the list name and your first and last names (example: subscribe grower-aim Henrietta Somebody.) Once you are on you may send a message to everyone on the list by sending an e-mail to:* <grower-aim@list.uvm.edu>.

http://orchard.uvm.edu/AIM/default.html

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://www.caf.wvu.edu/kearneysville

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. Links.

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

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.

http://www.virtualorchard.net

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.

http://fruitsandnuts.ucdavis.edu/app2.html

Links to all sorts of apple information.

http://axp.ipm.ucdavis.edu/PMG/ r4100211.html

University of California Statewide IPM Project. UC Pest Management Guidelines—Apple.

http://www.msue.msu.edu/vanburen/ organasp.htm

Organic Apple Spray Program. Michigan State University Extension's suggested spray schedule for organic apple production in Michigan. Written by Mark Longstroth, District Extension Horticulture and Marketing Agent.

http://www.caf.wvu.edu/kearneysville/organic-apple.html

Disease Management Guidelines for Organic Apple Production in Ohio, by OSU's Michael Ellis. This Extension publication is exactly what it says in the title – guidelines (not a systematic, calendar spray approach as in the MSU publication above) and only for diseases, not insects. You can order a hard copy free of charge (see above under Books).

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4) Gary J. Puterka. 1999. Interview with author.

5) http://www.epa.gov/oppbppd1/PESP/publications/vol3no1.htm#New%20Pesticides

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9) Zygmont, Janise. June 29, 1998. Observations on Washington state. Organic Perspectives. USDA-FAS Online. <http://www.fas.usda.gov/htp/organics/98-07/organics.htm#whashingtonState>.

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11) Zhiguo Ju, USDA, ARS Tree Fruit Research Lab, 1104 N. Western Ave., Wenatchee, WA 98801. e-mail: <Ju@tfrl.ars.usda.gov>.

Acknowledgements:

Special thanks are due to ATTRA Program Specialist Richard Earles, participant in the 1st National Organic Tree Fruit Research Symposium (2001), and to ATTRA Program Specialist Holly Born for information on marketing and economics.

By Guy K. Ames
NCAT Agriculture Specialist
July 2001

**For more information on sustainable agriculture,
call ATTRA at 1-800-346-9140 or visit our website:
http://www.attra.ncat.org**

The ATTRA Project is operated by the National Center for Appropriate Technology under a grant from the Rural Business-Cooperative Service, U.S. Department of Agriculture. These organizations do not recommend or endorse products, companies, or individuals.