

This bulletin from the Sustainable Agriculture Network (SAN) outlines how to use ecological principles to control pests on your farm. Read on to learn about successful strategies and consult the more comprehensive resources listed on page 20.

CONTENTS

Ecologically Based Systems at Work, 3

Ecological Principles for Managing Pests, 5

Applying Ecological Principles to Manage Pests, 6

Strategies and Practices for Reducing Pest Pressures, 10

Resources, 20

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A Whole-Farm Approach to Managing Pests



Growing rye between vineyard rows suppresses weeds — both by smothering and by producing allelopathic substances that inhibit weed germination — and attracts beneficial insects such as lady beetles to this vineyard in Monterey County, Calif. Photo by Chuck Ingels.

BEFORE STEVE GROFF TOSSED OUT HIS CONVENTIONAL PEST controls in favor of a more comprehensive, ecologically based strategy, his 175-acre Pennsylvania vegetable farm attracted a parade of pests.

Now he plants a winter cover crop of hairy vetch and rye and lets it grow 5 feet tall. Each spring, he knocks it down with a rolling chopper, then transplants his tomatoes into a thick mulch. Growing annual cover crops became a cheaper and more effective way to control the pests that plague vegetable growers.

“I have yet to use any insecticide for Colorado potato beetle. They don’t like the cover crop mulch,” he says. In addition to adding nitrogen and organic matter to the soil, the cover crop mulch also seems to stall early blight by keeping disease organisms from splashing up onto the plants.

“It’s working for us,” says Groff—and it’s just one of the fistful of tools he uses to stymie pests.

Neither Groff’s farm nor any other will ever be entirely pest proof. But by completely rethinking his

Opposite: New Hampshire vegetable grower Eero Ruuttila uses a mix of hairy vetch and rye cover crop mulch to crowd out weeds in his valuable tomato plots. Top: Living rye and vetch; bottom: killed and shredded as mulch. Photos by Eero Ruuttila.

farming practices from top to bottom, he has made his system much more resilient and resistant to pests.

Like Groff, producers across the country are changing their pest management practices to move toward whole-farm strategies based on ecological principles to control troublesome insects, weeds and diseases. Recognizing the importance of many tactics rather than just one deceptively easy fix, researchers, too, have begun testing new, comprehensive ways to control weeds, diseases and insect pests.

Their intent mirrors what early advocates of integrated pest management (IPM) believed—that a single approach is a poor substitute for a system-wide strategy to control pests. The ecological focus they emphasize goes beyond current IPM practices, mimicking nature as

much as possible in an industry that disturbs the landscape in the process of growing food and fiber. This evolving breed of researcher seeks to control pests in ways other than with expensive, “easy-fix” chemicals that have unknown impacts on natural resources and human health. Instead, they are creating whole systems that rely on diversity and soil health to keep pests at bay.

A whole farm ecological approach calls for rethinking management practices to design an improved system that integrates ecological pest management into other aspects of crop and soil management. Controlling pests should be linked to soil organic matter management, soil nutrient management, tillage and efforts to lessen compaction, as well as creating field boundaries, borders and buffers designed to protect waterways.

Jim Bender, Weeping Water, Nebraska

When it comes to meeting the challenges of operating a large farm without chemical pesticides, Nebraska farmer Jim Bender wrote the book—literally. He has worked 650 acres of mixed grains and legumes, and about 100 head of cattle, in the eastern part of the state since 1975. After eliminating his use of chemicals almost 15 years ago, he published a 160-page book on the subject.

Future Harvest: Pesticide-free Farming is part cautionary tale, detailing Bender's early, nearly disastrous attempt to shift from chemical dependence. The bulk of the book, however, focuses on how to do the job right.

Today, Bender is a thorough practitioner of intensive crop rotation, cover cropping, soil building, and topsoil retention. He aims to return his soil and waterways to prime condition and make natural weed and pest

control an easier prospect with each year.

“The objectives are to alternate sod-based crops with row crops, weed-suppressing crops with those without that characteristic, crops susceptible to specific insects with those that are not, and soil enhancing crops with those that do not enhance soils,” says Bender, who grows milo, wheat, soybeans, turnips, alfalfa and clover hay, and corn and sorghum for feed.

A typical rotation begins with a soil-building crop such as a clover or alfalfa. He follows with either corn or sorghum, and then with soybeans. (He also might precede the corn with soybeans depending on soil test results). The beans are followed by wheat or oats, then he plants a cover of turnips, clover hay, or more alfalfa.

He also allows his cattle to forage after harvest, knowing they will help in at least two respects: The manure they leave behind adds to soil fertility, and their consumption of seeded stalks missed during harvest means fewer opportunities for this year's crop to germinate as next year's weeds.

The various aspects of Bender's organic regimen appear to work together seamlessly. One crop that helps the soil gives way to another that will help suppress weeds in the following crop. The rotations help disrupt the life cycles of pests and weeds, making it difficult for them to establish. Cattle cycle through his fields, further displacing potential weed infestations. Finally, his cover crops, along with his discontinued use of pesticides, help attract beneficial insects that further reduce the risk of pest outbreaks.

The farm does not run on autopilot, however. Bender's cattle follow a rotational grazing pattern that calls for intensive management as well as good strong fences, and lots of them. Fences require maintenance, but the work pays off.

“Livestock is the linchpin that makes everything else fall into place on my farm,” he says. “I can't imagine a large organic operation without animals.”

In addition to their foraging though harvested fields, his cattle reduce the need to mow his grassed waterways. They also serve as an economic buffer. In lean times, Bender can sell more beef than normal. If a cash crop is ruined by infestation, he can always replant with a forage crop that not only gets used for feed, but also acts to repel the pest.

Labor remains a big part of the operation. Even with

the suppressive qualities frequent rotations bring, Bender is on a tractor often, dragging a spring tine harrow, a rotary hoe, or running a shovel cultivator to keep weeds in check.

It's an intricate and maybe even intimidating system in the sheer number of factors and options Bender considers. But he doesn't apologize for the level of detail. Instead, Bender hopes his book will convince others that it's possible to operate a large Midwestern grain and cattle farm without using chemical inputs.

“You have to really want to do it; that's what ultimately makes it successful.” Bender says. “And I hope more and more farmers will reach that point, because the way they're farming now just isn't working.”

Ecologically Based Systems at Work

Producers from as far away as Georgia and Oregon say they want to emulate Groff's system. Groff, whose combination of no-till, cover crops and rotations has eliminated many pest problems, manages the farm as a whole rather than as individual fields.

"Mother Nature has given us incredibly powerful tools," says Fred Magdoff, a soils professor in the Department of Plant and Soil Science at the University of Vermont, who likes to repeat entomologist Joe Lewis' strong and simple message: "Let's learn how to use them."

Across the country, researchers are finding that whole-farm, ecological systems work.

- ✦ In Pennsylvania, 80 percent of apple growers now rely on the black ladybird beetle to control European red mites. Using chemicals very judiciously and applying only those that the beetle can tolerate, producers have saved millions of pounds of pesticide.
- ✦ Cotton, when attacked by beet armyworm larvae, releases volatile chemical cues that attract the parasitoid *Cotesia marginiventris*, a natural enemy of the armyworm. Leaving habitat for the parasitoid aids the natural system.
- ✦ Along ditch banks in Michigan, three times more ground beetles are harbored by native switchgrass filter strips than by soybean fields. These beneficial insects can remove up to 4,000 cutworms an acre and as many as 40 weed seeds per square foot per day. A single female field cricket sheltered by a grassy strip can eat more than 240 pigweed seeds in 24 hours.
- ✦ In Oregon, an integrated cover crop and strip tillage system is reducing tractor trips in vegetable crops from eight to one and confining herbicide application to 12-inch bands. Among the results: 60 percent less herbicide use, 95 percent weed control in the untreated areas between rows and higher yields.

For the past 50 years, most farmers have relied on pesticides as their main tool to protect their crops from pests. Wielding pesticides like a big hammer, they pounded back menacing insects, nematodes, weeds and diseases. Then they watched the pests return — braced by pesticide resistance and paired with serious outbreaks of what were once minor pests.

"It's picked up so much speed that we can't sustain it anymore," says Lewis, an entomologist with USDA's Agricultural Research Service. "Relying on high inputs has become unprofitable. When you just can't make a living or a profit anymore, you have to take a serious look at redesigning the farming system so you can work with its built-in, renewable strengths."





A Growing Problem

Corn grown in hairy vetch mulch allowed 83 percent fewer annual grass weeds than corn grown in unmulched soil, according to research conducted at USDA's Agricultural Research Service in Beltsville, Md. Photo by John Teasdale.

Opposite: A beneficial stinkbug preys on a Colorado potato beetle larva, helping this potato plant retain leaves. Photo by Eleanor Groden.

The key weakness of “big hammer” management is a philosophy that ignores basic ecological principles. Reacting to complex pest problems with one tool eventually fails because it does not consider problems as symptoms of a system whose intricate natural controls have collapsed.

“No matter whether that single tactic is chemical, biological or physical, if it kills 99 percent of a pest population, the few surviving pests will find a way to avoid it or resist it,” says Doug Landis of Michigan State University’s Department of Entomology and Center for Integrated Plant Systems. “That’s what natural selection is all about.”

Organisms find ways to adapt to new environments or toxic materials. Over the years, a succession of chemical “big hammers” has reaped unintended environmental impacts, unnecessary human safety risks, unwanted expense, unwelcome problems with secondary pests and unnerving surges in pest problems.

From 1965 to 1990, as conventional pest control intensified, estimated crop losses from insects, diseases and weeds increased from about 35 percent to 42 percent worldwide. That suggests conventional approaches are not effective in many situations.

In Eastern states, corn and soybean growers have watched at least 10 species of annual weeds become resistant to triazine herbicides. Now, in no-till systems,

producers use four to five different herbicides to control the weeds once stopped by atrazine. Similarly, the costly Colorado potato beetle has become resistant to many pesticides.

In the South, growers battling boll weevils soon needed about 20 insecticide applications a year to control both the weevils and all of the secondary pests—including bollworms, aphids and spider mites—that arose after the pesticides killed beneficial insects.

“As managers of cotton production, we hadn’t made all of those connections until we took the primary pest—the boll weevil—out of the picture,” says Lewis. “The boll weevil was like a little, yapping terrier: It only took a couple of dollars an acre to treat it. The problem was that when we treated the boll weevil, the little dog woke up the big one.”

In the Midwest, growers have watched corn rootworm develop resistance to [organochlorine] soil insecticides. Even the more environmentally friendly single-tactic of rotating corn with other crops has produced corn rootworm populations that can over-winter for two or more years or lay eggs to avoid control by rotation.

Resistance to sulfonyleurea herbicides in Russian thistle and to diclofop in Italian ryegrass has left wheat growers in the West struggling to find alternatives—only five or 10 years after the herbicides were first used.

Ecological Principles for Managing Pests

Plants Have Natural Defense Systems

Most of think that plants are defenseless. In fact, they use a variety of natural defense mechanisms to counter attack by pests. Not only can healthy plants out-compete a pest by growing rapidly, but they also produce chemicals to slow insect feeding or inhibit bacterial or fungal infection. Some plants emit chemical "help" signals that call natural enemies – such as beneficial insects – to their aid. It's important to realize that farmers can manage crops to maximize their defenses.

What Makes a Plant Susceptible to Pests?

While you cannot change a pest's basic character, you can adjust management practices to decrease a crop's vulnerability. Understanding what makes a crop susceptible to pest attack is critical to devising management strategies that reduce crop losses, pesticide use and associated costs.

Monoculture plantings are more susceptible to pest pressure than mixed stands. Specialized disease-causing organisms and plant-feeding insects are less likely to bother crops that grow amid other types of plants. Not only does a pest find it more difficult to locate its preferred host in a mixture, but the pest's natural enemies are often more abundant or effective. Conversely, large fields of single crops create an ideal environment for pest attack. When crops are genetically uniform, as most modern varieties are, the opportunity for pest damage is greater still.

Plants under stress from drought, a lack of nutrients, soil compaction, or other factors are more vulnerable to pests such as aphids. Practices that promote the growth of healthy plants — ones that are able to better compete with pests or protect against them — are key to minimizing pest problems on the farm.

Understanding a Pest's Strengths and Weaknesses

More than 100,000 species of insects, plants, vertebrates, nematodes and microorganisms inhabit any given farm. Only several dozen are potential problems. Fewer than a dozen pests will feed on or crowd out crops in a given year.

Pests generally succeed by adapting to the specific food, water, shelter and light conditions in a particular farming system. They explode into major problems only

when the factors that naturally keep them under control are limited or missing. By recognizing the needs and abilities of a pest, and by designing a system that works against its preferences, you can reduce pest numbers and pest-inflicted damage. "The laws of nature demand that we look at the whole system," says John Teasdale, a weed scientist with USDA's Agricultural Research Service in Beltsville, Md. "To control any individual organism, we need to understand how it relates to the ecosystem in which it operates."

Many pests have impressive abilities to reproduce often and disperse widely. Although these "hit-and-run" pests face competition from other organisms or attacks by enemies, they thrive by rapidly colonizing new habitats before their competitors or antagonists arrive. Summer annual weeds such as redroot pigweed, insect pests such as aphids and many diseases share such characteristics. Annual monoculture cropping systems — subjected to the repeated disruptions caused by tillage, planting, herbicide applications, cultivation and harvest — open many inviting habitats for "hit-and-run" pests.

Other pests are "stand-and-fight" types. Better adapted to the difficulties of competition and to withstanding attacks by their enemies, they thrive in long-term perennial systems. These pests, such as perennial weeds, often live for a long time. Pests like the soybean cyst nematode go through dormant stages and wait for the right opportunity to establish. While they may produce fewer offspring than "hit-and-run" types, "stand-and-fight" pests invest more energy into the care of those offspring. Expect a "stand-and-fight" weed such as quackgrass to have large seeds, tubers or rhizomes. They compete vigorously, squelching their opponents' growth in one-on-one competition.



Plants react with pest defenses, such as:

- *producing chemicals in tissue to slow pest feeding*
- *emitting chemical signals to attract beneficial insects*
- *increasing extrafloral nectar to feed beneficial insects*

Applying Ecological Principles to Manage Pests

Wield Many Little Hammers

Incorporating pest controls at many different stages and limiting pests' abilities in many small ways are the foundation of ecological pest management. Production systems that use ecological principles to imitate nature, along with multiple tactics and the right information, can:

- strengthen individual impacts of strategies when used together,
- reduce the risk of crop failure by distributing the burden of crop protection across many tactics,
- minimize environmental disruptions and threats to human health,
- slow the rate at which pests adapt or evolve resistance to a given management tactic because that tactic is used less frequently, and

- reduce operating costs and improve profitability by minimizing the need for purchased inputs.

Cotton research headed by Joe Lewis at ARS in Georgia has shown that, like Steve Groff's vegetable system, combining minimum tillage with cover crops and cover crop mulch creates enough biological diversity to stymie pests. Comparing tilled fields to fields planted using conservation tillage following a winter cover crop like vetch, winter grains or clover, researchers found that beneficial insect populations increased. In fact, overall seasonal densities of certain types of carabid beetles and spiders in the "conservation" fields were a full 14 times higher than in the conventional fields.

Input costs were nearly identical, but average yields in the conservation fields were about 100 pounds higher than conventional yields. Moreover, net returns were \$60 per acre higher in the conservation plots.

Terry Pepper, O'Donnell, Texas

Drought has brought challenging times for west Texas cotton grower Terry Pepper. But thanks to membership in an organic cotton cooperative, he is able to keep a lighthearted approach.

"The drought is so bad, any boll weevil who wanders this way better be packing a lunch," he quips.

Pepper, who farms 1,400 acres near O'Donnell, Texas, about 200 miles west of Dallas, is coping better than most. He and his wife, LaRhea, manage a growers' cooperative they helped establish a decade ago. Even if his yields are down, many of the other 30 members have had sufficient rain or irrigate. That means they will have enough cotton in the fall for clients such as Patag-

onia, the outdoor clothing manufacturer, and Esprit clothing.

Pepper also has some assurance that once the rains return to his part of the highlands, he'll go back to bringing in his regular yields of about 600 pounds per acre. That's because he has learned how to grow cotton without synthetic inputs, even in semi-arid territory, and even under pressure from pests like the weevil, beet armyworms and aphids.

"All I need is rain," he says. "Everything else I can pretty much keep ahead of."

It wasn't always that way, not for Pepper and not for the 50-year history of cotton production in west

Texas. Both Peppers' grandparents used herbicides. After a time, though, diligent farming practices and a flair for thrift led even conventional area farmers to reduce their dependence on chemicals. Pepper says weed control in particular was not overwhelmingly difficult in the highlands for the same reason that raising a good crop can be — limited rainfall.

"Our families learned how and when to cultivate, and pretty soon they found they could get by with single applications of a pre-emergent herbicide most years."

It wasn't that much of a leap, then, for Pepper himself to decide to try doing without even that initial application, and then to forego

synthetic pesticides and fertilizers too, about 10 years ago.

The system he has devised for controlling weeds and pests includes mechanical cultivation, cover crops, frequent rotations and attracting beneficial insects, as well as purchase and release of pest predators on an as-needed basis.

It's a lot of work for Pepper and his family, including such onerous, time-consuming tasks as hand-hoeing. "I get my two boys out in the field and get it hand-hoed in a day," he says. Getting it done, and done at the right times during the season, keeps weeds in check.

Pepper also credits his cover crops and the sandy

loam soil of the highlands with keeping weed pressure to a minimum. The soil responds well to green manure and has improved quickly in the years since he began setting a third of his acreage aside each season for a cover crop.

Corn is his cover of choice. He plants it in strips throughout his cotton fields, where, in the fiercely hot weather of August, it is usually stunted and produces only small, insignificant ears. Pepper shreds it late in the season, leaving the residue on the ground to hold moisture, suppress weeds and add organic matter.

Corn cover also helps attract beneficial insects such as ladybugs and lacewings, Pepper says. They eat the

Improve Management of the Disturbances Created by Agriculture

Agricultural disturbances such as tillage, harvest, and fertilizer and pesticide application all can provoke pest problems, but you can avoid stimulating pests at the wrong time. For example, till fields before final seedbed preparation to stimulate weed germination, then cultivate before planting to lower the density of weeds infesting a crop.

Leaving some undisturbed areas on a farm can help maintain the balance between beneficial and pest organisms. Many predators and parasites that attack

crop pests thrive in the less-disturbed areas provided by hedgerows, weedy borders, woodlots and riparian buffers on the farm; in grassed alleyways in orchards and grassed waterways in field crops; and even in the small areas left between crop rows by zone tillage. Small sites allow natural enemies to persist and migrate into crop fields to keep pest populations in check.

In a research project in the Southeast, ground beetles, field crickets, ants and field mice were important weed seed predators within a low-input, no-till cropping system in which soybeans were grown in a surface mulch of wheat straw. Over five weeks in the fall, the

Cotton no-tilled into winter wheat stubble, such as this crop approaching harvest on Max Carter's farm in Coffee County, Ga., contained significantly more beneficial beetles and spiders than tilled fields compared in a USDA-Agricultural Research Service study. Photo by Joe Lewis.



aphids that can do a lot of harm to cotton. He is also helped by a parasitic North American wasp called *Bracon mellitor*, which feeds on beet armyworm and boll weevil larvae. When he feels the need, he purchases small shipments of a Central

American wasp called the *Catolaccus Grandis* to combat weevil infestations.

He says these efforts are usually enough to guarantee a healthy crop and to continue improving both his soils and his bottom line. CottonPlus organic cotton,

after all, is commanding about 90 cents a pound compared to about 37 cents a pound for conventional. Prices like that are icing on the cake for Pepper when he thinks about all the other benefits he's recognizing from his decision

to grow cotton without synthetic inputs. Now all he needs is one wholly natural input to return him to peak production.

"If we get a little rain," he says, "I can grow the best organic cotton you've ever seen."



Applying compost, depicted in this SARE-funded project evaluating organic soil amendments to Maine potato fields, builds a healthier plant through healthier soil — and may suppress soil-borne diseases. Photo by Greg Porter.

weed seed predators removed more than double the number of seeds from the no-till system compared to an adjacent conventional tillage system.

Include Perennial Plants in and Near Fields

Perennial plants—such as fruit trees, grassed waterways, trees growing along stream banks, or forage grasses and legumes harvested for hay—offer many advantages:

- their roots are more extensive and longer lasting than those of annual crops,
- much more than annual crops, they support communities of diverse soil organisms that are more similar to those in soils of natural ecosystems,
- they enhance water infiltration and reduce soil compaction, thus extending rooting depth,
- they serve as important habitat for beneficial insects, providing both food and shelter, and
- they help preserve soil and water quality by maintaining living plant cover above ground and active roots in the soil.

Increase Diversity

Diversity, both in the crops you grow and how you manage them, can reduce pest problems, decrease the risks of market and weather fluctuations, and eliminate labor bottlenecks. Enrich diversity:

- across the landscape (within fields, on the farm as a whole and throughout a local watershed),
- throughout the season (different crops on the same farm at different stages of growth and managed in different ways), and
- from year to year (rotations of three or more crops).

Ideally, agricultural landscapes will look like patchwork quilts: dissimilar types of crops growing at various stages and under diverse management practices. Within this confusing patchwork, pests will encounter a broader range of stresses and will have trouble locating their hosts in both space and time. Their resistance to control measures also will be hampered.

As plant diversity intensifies above ground, diversity builds in the soil. Through a system of checks and balances, a medley of soil organisms helps maintain low populations of many pests. Good soil tilth and generous quantities of organic matter also can stimulate this very useful diversity in pest-fighting soil organisms.

Researcher Matt Liebman reviewed cropping system studies to get at how plant diversity deters weeds. His summary of various studies that grew 27 test crops in rotation compared to monoculture systems found that:

- weed plant density in rotation was less than in monoculture in 19 out of 25 cases,
- weed seed density in crop rotation was lower in 9 out of 12 cases, and
- yields of test crops were higher in rotation than monoculture in 9 out of 12 cases.

“These results suggest that crop rotation can be an important component of strategies to reduce weed density and maintain or increase crop yield,” Liebman says.

In Oregon’s Willamette Valley, Larry Thompson’s 100-acre fruit and vegetable farm blossoms with natural insectaries. “To keep an equilibrium of beneficials and pests and to survive without using insecticides, we have as much blooming around the farm as we can,” he says.

Thompson uses cover crops to recruit ladybugs, lacewings and praying mantises in his battle against aphids. Overseeded cereal rye is already growing under his lettuce leaves before he harvests in late summer and fall. “It creates a nice habitat for overwintering beneficials and you don’t have to start over from ground zero in the spring,” he says.

Between his raspberry rows, Thompson lets his dandelions flower into a food source for nectar- and pollen-seeking insects before mowing them down. Forced out of the dandelions that nurtured them in early spring, the beneficials pursue a succession of bloom. They move first into his raspberries, then his Marion berries and boysenberries.

Later in the year, Thompson doesn’t mow his broccoli stubble. Instead, he lets the side shoots bloom, creating a long-term nectar source into early winter. “The bees really go for that,” he says.

Robert Boettcher, Big Sandy, Montana

Robert Boettcher has never been averse to change. Two decades ago, he looked around and saw cracks forming in Chouteau County's wall-to-wall grain production that to him spelled opportunity.

They don't call that part of north-central Montana the Golden Triangle for nothing: One acre of dryland grain meets the next—and so on as far as the Big Sky reaches.

"So much of this area is farmed in a monoculture," says Boettcher, who has 1,000 acres near Big Sandy. "Farmers have created their own problems."

Boettcher and his son, Earl, now rotate their grains with sunflowers, lentils and such green-manure crops as alfalfa, lentils and peas. Organic since 1992, he uses no chemical pesticides or fertilizers—and estimates he loses less than 1 percent of his crops to pests.

Count insect pests? He doesn't have enough troublesome critters to bother tallying them up. Weed problems? "It's almost frustrating: We have very few weeds and the neighbors still won't admit we're doing something right."

Crop rotation "sort of sets everything off balance," says Boettcher of the pests he rarely sees. His problems with wheat stem sawfly—a "nasty" pest that began flaring in the Big Sandy area about a

half-dozen years ago—have been "insignificant."

During the first year of a three-year study of Boettcher's farm, Montana State University scientists found just half the number of damaging insects in his diverse rotation with sunflowers and lentils than in a more typical wheat-barley-summer fallow rotation.

"The Boettchers use more complex rotations, with more crops that aren't hosts," says Andy Lenssen, associate research professor in MSU-Bozeman's Department of Entomology.

Dryland grain crops growing under Montana's big skies are less prone to insect pests and foliar diseases than those produced in more humid environments, Lenssen says. "In a lot of ways, it's an ideal place to

be an organic producer of grains."

But the dryness that bakes out foliar disease organisms also protects insect pests from the fungi, bacteria and viruses that might otherwise curtail their numbers. So the effects of Montana's climate are mixed.

The Boettchers try to crop three-quarters of their ground. On the other fourth—green manure grown on what used to be summer fallow—they kill the legume with a chisel plow and leave as much residue as possible to blanket the soil. In the winter, they leave their grain stubble as high as they can to catch snow.

Dense plantings during the growing season not only protect soils but also thwart weeds. Boettcher plants his lentils and his grains—

barley, buckwheat, durums, soft whites and hard reds—with 6- to 7-inch spacings. "You get a ground cover really quick, and if there are some weeds there, the ground cover shades them out," he says.

Generally, though, weeds do not flourish there. Boettcher works the ground once before he plants, cultivates the resulting weed flushes, then drills.

That is one of the most striking differences between the Boettchers' farm and most other Golden Triangle operations, says Lenssen. "In conventional systems, it's very unusual to go without herbicides—and they are one of the more expensive inputs in this region."

With significantly lower production costs, Boettcher says his operation is consistently more profitable than

conventional farms. His yields are often within 80 to 90 percent of theirs, but the prices he gets for his organic crops can be up to three times higher.

Ecologically based pest management has not brought dramatic surprises, just steady, satisfying improvement. "Some significant changes have happened in the soil," he says. "Its texture has changed completely."

Where the farm used to experience water erosion, his new soil-building practices have virtually eliminated storm-caused ditches.

"Maybe we're doing some things right," Boettcher says. "We're on track for trying to build up the soil and get it to a more healthy condition. We don't have many worries about pests and our plants are healthier, too."



Strategies and Practices for Reducing Pest Pressures

Reducing pest problems relies on many “little hammers,” each contributing to one or more of the following general strategies:

- producing healthy crops
- increasing stress on pests
- enhancing beneficials

You can redesign the farm to become a more complex agricultural ecosystem. Maximize the farm’s favorable ecological processes, such as nitrogen fixation, nutrient mineralization from organic matter and beneficial insect populations. Minimize undesirable processes, such as nutrient loss, disease development and feeding damage by crop pests.

“We’re not trying to turn farms into completely natural systems,” says Teasdale. “In a natural system, no one species becomes dominant. In an agroecosystem, the crop is going to dominate. But within that much simpler, very managed system, we can apply many principles from natural ecosystems to make it easier to control pests.”

Produce Healthy Crops

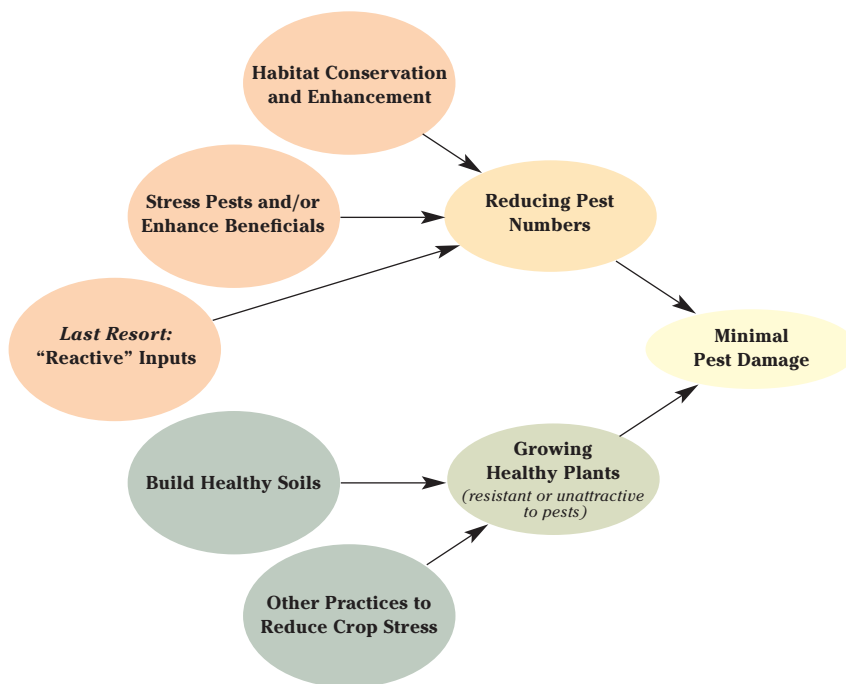
Vigorous crops compete better with weeds and tolerate more insect damage and disease. Growing crop varieties that are resistant to particular pests, such as a fungal disease, usually results in more vigorous crops that are better able to resist other pests. Reducing environmental stresses through better soil and crop management helps plants better compete with or resist pests.

Build and maintain soil health. The link between healthy soils and healthy plants remains fundamental to ecologically based pest management. The ability of a plant to resist or tolerate pests is grounded in favorable physical, chemical and biological properties of soil. Adequate moisture, good soil tilth, appropriate pH, the right amounts and balance of nutrients, and a diverse and active community of soil organisms all contribute to plant health. (See Resources, p. 20, for information about the new SAN book, *Building Soils for Better Crops*.)

Conserving and building soil organic matter encourages soil fertility and promotes more complex food webs among soil organisms. Healthy plants depend on healthy root systems. “Creating aerobic soil conditions increases the health of plant roots,” says John Luna, extension specialist in integrated farming systems at Oregon State University. “By maintaining good drainage, good tilth and good aerobic condition, you’re able to promote a whole array of beneficial microorganisms and to discourage the pestiferous ones.”

Beneficial bacteria and fungi that colonize root surfaces can prevent infection by such disease-causing organisms as *Pythium* and *Rhizoctonia*, especially in biologically diverse systems with more complex food webs. Beneficial soil fungi, nematodes and insects also can be more effective in complex than in simple soil systems.

Scientists are finding that contact with pest invaders can actually mobilize resistance mechanisms in plants. For example, a leaf infection by a plant pathogen or a bite by an insect can prompt resistance to future attacks by these or very different pests. This “systemic acquired resistance” occurs throughout the plant, even in tissue far away from the initial site. Farming practices can enhance it. Amending soil with compost, for example, has produced systemic resistance within cucumber to anthracnose. Similarly, inoculating transplants with



beneficial mycorrhizal fungi has protected roots from root rot fungi such as *Cylindrocarpon* and *Pythium*.

Composting imported organic-waste residues before applying them to soils may help fight crop diseases. Good composts are costly to buy and slow to produce, but they can pay their own way—especially on farms that produce high-value vegetables and small-berry fruits. At Ohio State University, plant pathologist Harry Hoitink and his co-workers have found that compost may suppress root and foliar diseases. Among the possible reasons:

- compost-treated plants are usually healthier and better able to resist infection,
- compost feeds microorganisms, which produce plant growth hormones and chelates that make micronutrients more available to plants, and
- compost hosts beneficial organisms that feed directly on disease organisms, compete with them for nutrients or produce antibiotics.

Some soils or potting mixes blended with medium-maturity compost—which still contains enough food for microorganisms—have sparked systemic resistance in plants, Hoitink says. “These plants have elevated levels of biochemical activity relative to disease control and are better prepared to defend themselves against diseases.”

Not all composts provide this beneficial effect. In fact, composts and other biological materials that are rich in available nitrogen may actually stimulate some plant diseases. Among these diseases are *Phytophthora* root rot in soybeans, *Fusarium* wilts in vegetable crops and fire blight in fruit crops. To reduce the risk of initiating disease, spread these materials many months before cropping, allow the salts to leach away, or blend in low-nitrogen materials before application.

In Ohio, vegetable grower John Hirzel recorded 25-percent yield increases in tomatoes that were started in the greenhouse in mixtures of one-third compost, then transplanted to the field into soils amended with 10 to 12 tons of compost per acre. Hirzel, who died in 2000, found that tomatoes grown with more compost have better resistance to bacterial canker, bacterial spot and bacterial speck. “As soon as they germinate, they are living in a soil that has natural bacteria and fungi,” he said in a 1999 interview.

On the other hand, farming practices that cause imbalances in nutrition or other factors can lower natural resistance. High nitrogen fertilizer levels can fuel the germination and growth of many weed species, boost the incidence of diseases such as *Phytophthora*, *Fusarium* and corky spot, and stimulate outbreaks of aphids, mites and other insects.

Creating refuge strips of flowering plants amid field crops, such as this row of anise growing in Ingham County, Mich., attracts beneficial insects that prey on insect pests. Photo by Doug Landis.



Pennsylvania vegetable farmer Steve Groff lays down an experimental biodegradable clear plastic mulch on cover crop residue to warm soil for no-till sweet corn. Photo by Ray Weil.

Some herbicides lower the resistance of crops to invading disease-causing organisms. Even more serious, as it decays, glyphosate-treated vegetation can create flushes of *Fusarium*, *Rhizoctonia* and other pathogenic fungi.

Rotation, in the absence of known pests, has improved growth and yields in many crops by about 10 percent. Longer rotations tend to increase crop yields more than shorter rotations; yields of corn and wheat

grown as part of three-year rotations exceed those in two-year cycles or in continuous monocultures. Adding organic matter—through cover cropping, animal manures and crop residues—boosts crop performance and may improve pest tolerance.

For three decades, Dick Thompson has planted cover crops, managed weeds like covers instead of like pests, and lengthened and expanded his crop rotation. “I’m not saying we don’t have any insect problems, but they



A WORD OF CAUTION REGARDING NO-TILL. If not managed properly, eliminating tillage can provoke problems. Annual weed populations can build more rapidly if seeds stay on the soil surface, soils may warm up more slowly in the spring and, under some conditions, no-till may increase plant disease because some pathogens survive better in undisturbed soils.

You may need to till to control perennial weeds that crop up in undisturbed fields. Soils—especially wet, poorly drained ones—may need tillage to alleviate compaction by heavy machinery. In such cases, devise a rotation that involves tillage only during selected years or seasons, or use strip-till or ridge-till instead of no-till. In regions with cool, wet springs, no-till may not work well for early planted crops. You may want to talk to professionals from the Extension Service or the Natural Resources Conservation Service before changing your tillage regime.

Richard DeWilde, Viroqua, Wisconsin

Let this be a warning to all Colorado potato beetles in the vicinity of Viroqua, Wis.: Richard DeWilde has a flamer and he's not afraid to use it.

Intended to control weeds, a flamer has instead become DeWilde's preferred instrument for dealing death to the beetles that have plagued his eggplant crops for years.

"It's kind of tricky, and you can end up singeing some leaves if you're not careful," says DeWilde, who grows about 50 vegetable,

fruit and herb crops on 60 acres for direct sale to consumers in Madison and Chicago. "But it toasts beetles and larvae to the point that they just curl up and fall off. It's very satisfying."

He and his crew of employees were forced to be especially creative and diligent about controlling both insect pests and weeds in 1999, when southwest Wisconsin got too much rain. That caused weeds and pests to bedevil DeWilde more than usual. It did not sound, though, as if they're

going to get the upper hand any time soon.

With 25 years of organic farming under his belt, DeWilde could be considered a pioneer. He says his experience led him early to a conclusion others have followed: improving soil fertility should be the focus of his weed and pest control strategies. Flamer aside, cover crops and compost are his most effective tools.

"I grow a lot of rye as both a cover crop and for mulching," he says. "If I had 20 more acres, I'd grow rye

on all of it and use it all for mulching—at \$2 or \$3 dollars a bale, it's too expensive to buy. But if I could grow and use more I would. It's that good."

That problem—not enough acreage—is also a reason DeWilde relies more on compost to build the soil and control weeds than crop rotation, which usually plays a larger role on larger farms. He spreads about 300 tons of composted manure, which he gets from an organic dairy farm next door, on his fields each year.

do not constitute a crisis," Thompson says. "We don't have to treat for them. We haven't done that for years."

On his Boone, Iowa, farm, Thompson uses a corn-soybean-corn-oats-hay rotation, with at least four different kinds of hay. He shreds weeds in his ridge-till system, then cultivates and lays them between the rows, turning a pest into a mulch.

At 6 percent, his soil organic matter is now double that of neighboring conventional operations. "You can tell it by working it," Thompson says. "I can do things with a cultivator that others can't do. I'm not moving big clods but fine soil. The dirt flows and allows you to cover up the weeds."

Because his soil no longer blows or washes away as easily as it once did, Thompson's high ground is becoming more productive. "Our yields are just as good — if not better — on the hills as they are on the low ground."

Reduce tillage for healthy soils. Many people consider tillage necessary for crop production. However, this seasonal practice can destroy some vital processes by depleting organic matter, intensifying the loss of topsoil to erosion and destroying soil tilth. Damaged soils are less able to provide nutrients, hold water and support biological activity. The net result: less diversity in crucial soil organisms.

"In my opinion, there's no single greater catastrophic event in the life of the soil than to have some big piece

of tillage equipment run across it," says Luna. "Worms and bugs are killed, fungi are broken up and destroyed, and you end up with a much more simplified biological system."

To plant and establish vigorous crops, you need to clear vegetation and residues from at least a portion of your field. Some equipment, however, minimizes soil disturbance. No-till planters, which cut a slot just wide enough to insert seed, disturb soil the least. Strip-tillage disrupts only a band of soil along the crop row, leaving untilled areas between rows. Ridge-till systems produce only shallow soil disturbances. Chisel plows do disturb soil structure, but, unlike moldboard plows, they do not invert or pulverize soils. No-till, zone-till and ridge-till also leave accumulations of plant residues covering the soil.

In a 1997 vegetable trial, Oregon State University researchers found a Willamette Valley farmer improved corn yields after strip-tilling into a winter cover of oats, vetch and Austrian winter peas. The farmer planted in eight-inch strips cut into the cover crop residue. The new system returned \$100 per acre more than the standard tillage system.

Surface plant-residue mulches supply organic matter that reverses many of the detrimental effects of tillage. They take the edge off soil temperature extremes and keep soil moisture more consistent, thereby favoring a wide group of organisms. These factors combine to

In Ohio, John Hirzel recorded 25-percent yield increases in tomatoes started in the greenhouse in mixtures of one-third compost, then transplanted into soils amended with 10 to 12 tons of compost per acre.

His neighbor includes corn-stalks, partially broken down by hooves, from the cows' bedding.

"He doesn't test or measure any of the ingredients, but he's hit a perfect 20 to 1 carbon/nitrogen balance every time in the past two years," he says.

While composting is believed to boost the immune systems of plants, DeWilde and a researcher from the University of Wisconsin found it raised instances of diseases like *Rhizoctonia solani*. But even with a mild

spike in some diseases, DeWilde says the attention he's paid to soil fertility has been worth it.

"Most of the time, weeds are indicators of the nutrients that are missing in your soil," he says. "When you get weeds with long tap-roots, that's a sign that the nutrients you want near the surface are down deep. The weeds tell you what's missing."

In a season of heavy rains, weeds will grow on any soil, weak or strong. So he and his crew have been

standing ready. He has three tractors outfitted with belly-mounted cultivators, offset cultivators and an implement made in Michigan that employs a series of rubber, finger-like attachments to pluck weeds.

"We don't hesitate," he says. "As soon as the ground is dry enough, we're out there trying to stay ahead of the germination the rain brings." He's just as diligent against insect pests. In addition to the double duty borne by his flamer, he uses Bt against corn borers

when traps tell him he's getting a significant number of moths in the field at night. He applies Rotenone, a pesticide made from the bark of an African shrub, against flea beetles in his greens and herbs. The powder is known to be toxic to fish and bees, so he doesn't apply it when rain is imminent, or on flowering plants like squash and melons.

That decision leaves his squash vulnerable to beetles, but DeWilde says he's reached at least a temporary understanding with

them. Knowing their attraction to the color yellow, he lines an early stand of squash with yellow plastic mulch and stands back while they attack. They decimate that particular patch, he says, but tend to leave his other stands of more commercially desirable squash unmolested.

This arrangement is fine for now, he says, but once he develops his flaming technique a bit more, even squash beetles may find it a little too hot to hang out at Harmony Valley.

Interspersing non-host plants can hinder the movement of insect pests and crop disease organisms by altering light and humidity and jumbling the critical visual and chemical signals insect pests use to recognize their hosts.

Klaas and Mary-Howell Martens, Penn Yan, New York

Soon after Klaas Martens and his wife, Mary-Howell, decided to stop using synthetic pesticides on their legume and grain farm in upstate New York, they started digging. It wasn't just the soil on their 900 acres they hoped to turn over; they also sought old research and forgotten information about organic farming methods.

They found it. Unearthing a series of research papers on weed control and soil science from the late 1930s and writings on soil chemistry from the 1940s and 1950s was just the beginning. The couple also discovered a wealth of information in the memories and experiences of older people in their small Finger Lakes community of Penn Yan who had farmed before the use of synthetics became widespread.

Mary-Howell Martens says the collective wisdom they've tapped in their efforts to grow the best crops without chemicals points them in one direction: soil health.

The more they've studied, the more they've come to believe soil composition matters more than any other weed and pest control regimen, no matter how strict. In fact, she claims that, "anyone who thinks they can get into organic farming and just depend on mechanical weed control is in trouble."

That's not to say the Martens don't own and use their share of cultivators and rotary hoes on their soybeans, wheat, triticale, corn and red beans. They've just come to believe their strongest ally in the fight against weeds and pests isn't something you can hook to a tractor, release from a sprayer, or even see with the naked eye. Instead, it's vigorous microbial activity in the soil, in combination with a proper balance of nutrients and minerals.

In his efforts to promote the maximum amount of biological activity in his soils, and to maintain the kind of mineral presence that both feeds plants and heightens tilth and absorption abilities, Klaas Martens has discovered the secret isn't necessarily in inputs. He uses ground fish and an organic bio-stimulant, but has concluded that "a lot of it has to do with cover crops and a good rotation schedule."

He refers to an early paper by German scientist Bernard Rademacher: "If each crop is grown after its most suitable predecessor, the competition of weeds is checked through its vigor alone."

Pests appear to like the Martens' soil improvement efforts about as much as weeds do. A recent extension service test of their 100-acre sweet corn crop

yielded absolutely zero cutworms. Klaas later discovered some worm larvae on a few ears while harvesting, but the plants were the cleanest he'd ever seen or grown.

"They didn't get sprayed once," he says. "To my mind, those results are due to a good rotation schedule and strong plants in good, supportive soil that are healthy enough to discourage infestation without a lot of help from me."

In recent years, Mary-Howell has published several articles in *Acres USA* magazine about the education she and her husband have undergone in their quest to make organic growing profitable. Her articles detail the weed and pest management practices they've adopted, provide rotation strategies, list their tillage and cultivation practices — as well as the equipment they use — and discuss the economics of growing organically as opposed to using chemical inputs.

In her writing, she makes clear that she and her husband believe both in doing their homework and in making farming a community affair. In the years since they switched to organic growing, about six neighboring farmers have followed suit. When others expressed interest, the Martens instituted regular monthly meetings where they and their

fellow organic growers trade tips and get to know each other better.

"Klaas and I are so grounded now in studying soil chemistry and plant pathology, and rediscovering the expertise that was out there and generally available before chemicals made it all seem unnecessary," she says. "We like to see what we can do to support one another, how someone who has been organic for a while can help someone who is just getting interested."



improve biological activity, soil tilth and nutrient- and water-holding capacity.

In Lancaster County, Pa., Groff says his cover crops—along with his “full time, 100-percent commitment to no-till” —have increased his soil organic matter from 2.7 to 4 percent in the last decade. Although he farms on slopes as steep as 17 percent, his annual erosion losses are only a fraction of the county’s average.

When putting in underground irrigation lines, Groff found “roots of my rye cover crop 40 inches deep and earthworm holes 36 inches deep. By not tilling the soil, by leaving all of that structure intact, over several years I have a soil that begins to open up.”

Maintain surface residues. More diverse biological and physical environments at the soil surface spark more bountiful opportunities for regulating pests. The living and dead plant materials linked with no-till management readily establish biological activity, which can contribute to natural suppression of pests. The soil

organic matter and fertility generated by cover cropping and reduced tillage also lessen pest damage simply by improving the growth and vigor of crops.

Cover crops supply generous amounts of surface vegetation and residue that can be customized for specific needs. Live, they furnish excellent habitat and food for beneficial insects. Strip-tilling a cash crop into a winter annual cover crop or overseeding the cash crop with a cover crop after the last cultivation allows bands of live covers to flourish between rows without over-competing.

In some systems, cover crops eliminate the need for pre-plant herbicides and reduce the need for post-emergence herbicides. (See Resources, p. 20, for information about the comprehensive book, *Managing Cover Crops Profitably*.) Winter annual cover crops continue to yield crop benefits even after they have withered. Along with residue from previous crops, they can interfere with pest populations by:

- ✦ hindering weeds or other soil pests by physically obstructing their growth, tampering with soil temperature or moisture, or unleashing plant-inhibiting allelopathic chemicals,
- ✦ preventing fungal spores from being dispersed by water or wind, thereby curbing foliar diseases, and
- ✦ enhancing populations of predatory insects such as ground beetles and spiders.

“We see it over and over in our research,” says weed specialist Teasdale. “The tomatoes in the vetch cover crop system stay green and healthier longer than tomatoes grown on a black plastic mulch.” Indeed, the tomatoes maintain healthy green foliage about 50 percent longer.

**PERCENTAGE REDUCTION OF VARIOUS PEST POPULATIONS/
INCREASE OF BENEFICIAL INSECTS**

(averaged over the 1997–1998 growing season at
USDA-ARS, Beltsville, Md.)

Pest species	% reduction/increase by a hairy vetch cover crop
Annual grass weed number	- 83
Early blight disease severity	- 52
Colorado potato beetle number	- 82
Beneficial lady beetle number	+ 250

Comparisons made from experiments with tomatoes grown in hairy vetch versus black polyethylene mulch for disease and insect data and from experiments with corn grown in hairy vetch versus unmulched soil for weed data.

Hana Newcomb stands by the vegetables produced by her 30-acre organic farm in northern Virginia. She and her mother, Hiu, rely on mulches to control weeds — from onion plants blanketed by composted leaves, to blueberry bushes rising through mounds of sawdust, to cucumber plants pushing protective sheets of white polyester. Photo by Valerie Berton.



Beneficial predatory and parasitic organisms generally do not flourish in fields with only one plant species.

Other practices for building healthy soils. Good management of soil organic matter—reducing tillage, applying animal manures and composts, and rotating with such soil-building crops as sod-forming grass and legume forages—forms the basis for healthy soils. Develop strategies to encourage on-farm nutrient cycling and help organic matter accumulate. Take care to avoid compacting soils. You may need to keep heavy equipment off wet soils, maintain controlled traffic zones on soils susceptible to compaction, or use some tillage to break up compacted layers. Many of the soil-building practices discussed above help reduce soil erosion. On soils that are prone to erosion damage, consider strip cropping, grassed waterways to conduct runoff off fields, and soil terracing to help keep topsoil in place.

Create Multiple Stresses on Pests

Maximizing the impacts of many “little hammers” takes an understanding of the life cycles of pests and of beneficial organisms. In ecologically based systems, farmers scrutinize the life cycles of pests and beneficial organisms, looking for times and places where small control measures can add up to big results. A good opportunity might arise during a pest’s overwintering stage, for example, and another while it is first colonizing the crop. A beneficial organism may offer protection at one stage and need protection at another. Even in small increments, pest mortality can eventually pare a big problem to a low level.

In Sentinel Butte, N.D., cattle producer Dennis Dietz is battling a 75-80 percent leafy spurge infestation with several species of imported flea beetles after herbicides had little effect on a pest that plagues farmers in the western Plains. The flea beetles, however, are leaving their mark.

“I’ve seen dramatic changes in stem count and flowering,” says Dietz. “My feeling is that the control is excellent, and it’s long term.” Established in his own on-site insectary plantings, the flea beetles “will be there forever,” he says. “Chemical control, in my opinion, is way too expensive and it doesn’t last as long.”

Not only do the adult beetles feed on the tops of leafy spurge, but flea beetle larvae burrow into the weed’s roots, exposing them to a second stress: opportunistic disease organisms.

Cooperating in a “Team Leafy Spurge” project through the USDA Agricultural Research Service in Sidney, Mont., Dietz has begun to add a third stress—sheep—to his biocontrol strategies. Their mission:

graze off the tops of the plant while the beetles work on the roots.

Discourage the pests’ dispersal or connection with crops. Interspersing non-host plants can hinder the movement of insect pests and crop disease organisms by altering light and humidity and jumbling the critical visual and chemical signals insect pests use to recognize their hosts. Non-host plants put distance between susceptible plants and, like fly paper, intercept spores to limit the spread of diseases.

Flea beetles that attack cabbage and other crucifers are less abundant when clover—a non-host species—is sown between cabbage rows. Crop losses to mildew are higher in pure stands of barley than in mixtures of barleys that differ in their susceptibility to disease races.

Disrupt pest populations by destabilizing habitat. When pests are adapted to some crops but not to others, rotations that include non-host crops can help with control. Placing a non-host crop in a rotation sequence often destroys the habitat a pest needs, limiting population growth. Infestations of Colorado potato beetles, for example, are more severe in continuous potatoes than in potatoes that follow winter wheat or rye. Similarly, rotating soybeans with such non-hosts as corn reduces charcoal rot.

To be suppressed by rotation, a target pest must have specialized feeding habits that restrict it to a narrow host range. Its ability to move to other locations also must be low. Finally, its dormant and resting stages must be shorter than the time gap between susceptible crops.

Rotations that include diverse crops and management practices tend to have fewer weed problems than simple rotations and crop monocultures. By continually changing the “rules of the game,” complex rotations discourage the selection and adaptation of weeds.

Giant foxtail, for example, is less of a problem in a three-year corn-soybean-winter wheat rotation than in corn-soybean or continuous corn. Differences in the timing of germination, growth and competitiveness among the three crops, plus the suppressive effects of wheat straw, are likely reasons.

Reduce weeds’ access to resources. Many crops lack canopy cover and substantial root growth when they are young, limiting the plants’ ability to fully capture sunlight, water and nutrients. Instead, these crops give invading weeds a foothold. Later in the season, weeds



will compete with the crop and reduce its yield. Narrower row spacings, higher crop population densities and intercropping may all rob weeds of the resources they need to grow.

On the other hand, these same weed-choking practices can increase disease levels in some crops. Denser stands of wheat, for example, are more susceptible to mildew. Use disease-resistant varieties with such practices.

Enhance Beneficial Organisms

“Farmscaping” — a term coined by Robert Bugg of the University of California — describes a comprehensive approach to nurturing populations of beneficials. It examines and redesigns the whole farm landscape, rearranging fields, hedgerows, conservation buffers and other farm features to favor the beneficial organisms that protect crops.

Beneficial predatory and parasitic organisms generally do not flourish in fields with only one plant species. They need overwintering sites and different types of microenvironments — such as shady, moist places — where they can find protection from their own natural enemies. Besides the pests on which they prey, beneficials often need additional sources of food. Parasitic wasps and predacious hoverflies, for example, depend on a daily supply of honeydew, nectar and pollen for energy and reproduction. Alternative food sources are critical to the development of slow-reproducing predators.

To improve habitat for beneficials, consider:

- ✦ sowing cover crops between rows of cash crops,
- ✦ maintaining “beneficial insectary plantings” at field edges,
- ✦ providing permanent refuge strips — “or beetle banks” — for ground beetles, an important group of soil-dwelling generalist predators,
- ✦ harboring natural predators, parasitoids and wildlife in perennial grasses, forbs, shrubs and trees on field edges or in strips,
- ✦ through conservation tillage, preserving soil structure and complex food webs for ground beetles and other beneficials, and
- ✦ supplying root disease-suppressing microbes with life-sustaining organic matter by means of cover crops, animal manures and composts.

“An intelligent addition to the diversity of habitat on the farm allows a lot of different kinds of predators and parasites to work on the side of the farmer,” says Kim Stoner, assistant entomologist at the Connecticut Agricultural Experiment Station in New Haven. “It makes sense to go for a spectrum of flowering plants over the course of the year.”

In western Texas, pecan grower Kyle Brookshier uses one key strategy to limit dispersal of stink bugs. He plants black-eyed peas between or around all 1,300 acres of his nut trees. Drawn to the peas, the stink bugs now leave his pecans virtually alone. Rather than the 12–13 percent damage they used to cause in his nut crop, Brookshier now sees less than 1 percent.

“We have almost ceased to get damage from stink bug,” he says. “I think it should be a standard cultural practice in pecan orchards.”

Brookshier plants the peas two to four rows wide at two-week intervals between late June and late July. That way, his trap crop is always lush when the stink bugs are active. An added bonus of this inexpensive pest control strategy: The black-eyed peas are a hit at family meals.

Crimson clover is often grown in California nut groves and orchards to provide nitrogen to tree crops. Its eye-catching flowers produce abundant nectar for bees and contain pirate bugs that prey on small pests like thrips. Photo by Ray Weil.

Bill Chambers, Willamette Valley, Oregon

When Bill Chambers began working to make his Stahlbush Island Farms more sustainable back in 1990, doubtful observers in Oregon's lush Willamette Valley expected a wreck. Their only question: Which of his varied fruit and vegetable crops would fail first?

"The pleasant surprise was that we haven't had any disasters," says Chambers, a cattle rancher's son who chose to raise crops rather than cows in the valley's classic Mediterranean climate. "There have been no crop failures — and a lot of folks thought we wouldn't have any crops to harvest."

Stahlbush Island Farms, an 1,800-acre integrated farm-food processing plant in Corvallis, Ore., markets its frozen products to industrial food firms. It no longer uses herbicides, fungicides and insecticides in its sweet corn, squash, pumpkins and green beans. Compared to its conventional competitors, Stahlbush applies only 15 percent as much pesticide on its broccoli, strawberries and spinach.

Educated as an agricultural economist at Oregon State University, Chambers knows that staying profitable is key to sustaining the farm. "But," he says, "profit maximization is not our sole objective. All economic decisions are not dollars and cents. We include non-cash factors in our decisions. We

value how we do things as much as what we do: If our farm is healthier and if we're healthier, then we live longer and more fulfilled lives."

The costs of using a pesticide should not be underestimated, Chambers says. They include potential damage to beneficial organisms, to the environment, to crops, to consumer trust and to worker health.

"Who likes to deal with a poison or a toxic product?" asks Chambers. "I won't ask



people to do things that I'm not willing to do myself."

A main Stahlbush value is innovation — and innovate they do, by:

- Growing no crop on the same ground two years in a row, and by completing their rotations in a minimum of seven years, they break disease and insect cycles, control weeds and improve overall soil health.

- Planting cover crops each year after harvest and working them back into the soil before planting, they

build organic matter, generate soil nitrogen, control weeds and prevent nitrogen leaching.

- Substituting mechanization, computer technology and intensive management for pesticides, they deliver a higher-value product to their customers, usually at the same price.

Stahlbush's cost structure is not equal. "We tend to have much higher labor costs than a conventional system, but I believe the sum of our

costs is lower," Chambers says. "They're different kinds of costs: our system is management- and capital-intensive and most conventional systems are much more chemical-intensive."

Not only do ecologically based operations have different costs, they also bring unusual payoffs. When Chambers first stopped treating garden symphylans with pesticides, he calculated that he could tolerate any resulting crop losses. The value of the small patches he was losing was

less than the cost of the pesticide that would keep the root-chewers in check.

Instead, Chambers hit paydirt: "I found that over time, the symphylan damage just disappeared." The pests, he believes, "have come into balance with an insect or disease or something else that preys on them."

"What we've found is that the whole soil-insect-fungi-bacteria relationship is an interwoven web of predators and prey," Chambers says. "When you go in with a harsh pesticide, you disturb all of that."

To keep soil microbes in balance and prevent some from reaching bullying levels, Chambers takes his fields out of irrigation every three or four years.

Chambers reflects on what he was once taught: that the soil is a "mineral sponge" to be managed with an input-output model. For best results, yesterday's farmers were told to simply replace pound-for-pound the fertilizers their crops had used.

"In reality, the soil is an ecosystem and I'm just putting the dominant species into that ecosystem," says Chambers. "By managing it as an ecosystem, we're much more successful than looking at it as a mineral sponge."

Only as a Last Resort, Use Targeted Attacks

Even in ecologically based pest management systems, farmers may need to use pest control tactics, including pesticides. Managing weeds without tillage or herbicides, for example, is not consistently reliable. Because unwanted populations of annual and perennial vegetation can build very rapidly, herbicides remain an important tool, especially in no-till systems.

Judicious selection and limited use of herbicides that are low in toxicity and short in environmental persistence—combined with minimum-till and cover crop management—will help create habitat for beneficial organisms and develop healthy soils.

Sometimes key insect and disease pests—often introduced from another part of the world—can damage crops significantly. Ecologically based controls may not be available for these recently imported species. In this situation, reacting with the least disruptive, most specific chemical may be the farmer's best option.

Use reactive interventions only after clear decision-making. As you assess, consider the following:

- properly identifying the pest and possible beneficial species present,
- assessing the pest population and its threat to the crop, and
- selecting the appropriate tactic—a chemical, bio-control organism or other intervention—based on full knowledge of the range of measures available and their effectiveness, cost and side effects.

Options for pesticides and biorationals. To kill pests, disrupt their life cycles or deny their access to crops, farmers have an assortment of conventional and biorational materials at their disposal. Conventional chemicals include synthetic, broad-spectrum pesticides that often leave in their wake unwanted side effects—harming other species or polluting the environment.

Biorationals are more specifically toxic to or disruptive of target pests. Naturally derived or synthesized, they include growth regulators, microbial toxins, anti-feeding agents, pest-smothering oils, and disruption pheromones that confuse insects and reduce their reproductive success.

“They’re an improvement and—if used properly—there should be an economic gain to the grower,” says Ed Rajotte, integrated pest management coordinator at Penn State University. For now, he says, many biorationals are more expensive and more difficult to use.



Rajotte’s emphasis today: helping farmers substitute the many “little hammers” of management information for the “big hammer” of broad-spectrum pesticides.



If the agricultural research and extension community applies “a concerted effort” over the next decade, Magdoff believes ecologically based pest management systems could be widely adopted.

“A lot of people have parts of this ecologically based pest management system working very well for them right now,” says Magdoff.

Beware the temptations of the “big hammer,” says Fred Kirschenmann, an organic grain farmer in North Dakota. Like everyone, he points out, farmers want to see immediate results. Quick satisfaction from a big hammer strategy often gives way to disappointment over the long term.

“Develop the attitude that every time a ‘big hammer’ strategy is used, it represents a failure in the system,” Kirschenmann says. “You should always assess what went wrong and what strategies to follow up with to put the ‘many little hammers’ back in place.”

Hanging a sticky sphere coated with a fruit-like odor to attract apple maggot flies helps apple growers determine when pests are present in significant numbers, allowing them to target insect controls rather than spraying the typical three times a season.
Photo by Ron Prokapy.

Resources

GENERAL INFORMATION

Appropriate Technology Transfer for Rural Areas (ATTRA), Fayetteville, AR. Offers a series of publications on agronomy and pest management covering various aspects of ecological pest management. (800) 346-9140; <http://attra.ncat.org/>

Sustainable Agriculture Research and Education (SARE) program, USDA-CSREES, Washington, D.C. Studies and spreads information about sustainable agriculture via a nationwide grants program. See research findings at www.sare.org/projects/

Sustainable Agriculture Network, Beltsville, Md. The national outreach arm of SARE, SAN disseminates information through electronic and print publications, including:

- Building Soils for Better Crops, 2nd Edition. \$19.95 + \$3.95 s/h.
- Managing Cover Crops Profitably, 2nd Edition. \$19 + \$3.95 s/h.
- Steel in the Field: A farmer's guide to weed management tools. \$18 + \$3.95 s/h.
- COMING IN 2003: Ecological insect control handbook.

To order: www.sare.org/htdocs/pubs/; Lee.Hendrickson@uvm.edu; (802) 656-0484

Alternative Farming Systems Information Center (AFSIC), National Agricultural Library, Beltsville, MD. Offers bibliographic reference publications on ecological pest management on line. (301) 504-6559; afsic@nal.usda.gov; www.nal.usda.gov/afsic.

PUBLICATIONS

Agroecology: The Science of Sustainable Agriculture (2nd ed.) by Miguel Altieri. Key principles in case studies of sustainable rural development in developing countries. \$36 to Perseus Books Group, (800) 386-5656; westview.orders@perseusbooks.com; www.westviewpress.com/

Alternatives in Insect Pest Management—Biological and Biorational Approaches by University of Illinois Extension. Rates the effectiveness of microbial insecticides, botanical insecticides soaps, attractants, traps, beneficial insects, etc. Web only. www.ag.uiuc.edu/~vista/pdf_pubs/altinsec.pdf

Alternatives to Insecticides for Managing Vegetable Insects (NRAES-138) by Kimberly A. Stoner. Proceedings from a conference on alternatives to insecticides for vegetable growers in the Northeastern U.S. \$8 to NRAES Cooperative Extension, (607) 255-7654; NRAES@cornell.edu; www.nraes.org

Best Management Practices for Crop Pests by Colorado State University Extension. Integrated pest management oriented to western U.S. crops and pests. Bulletin XCM-176. Free (\$3 shipping) to The Other Bookstore, (877) 692-9358; cerc1@ur.colostate.edu; www.cerc.colostate.edu

Biodiversity and Pest Management in Agroecosystems by Miguel Altieri & Clara Nicholls. Entomological aspects and the ecological basis for the maintenance of biodiversity in agriculture. \$74.95 (hard cover) from The Haworth Press, Inc., 1-800-HAWORTH;

getinfo@haworthpress.com; www.haworthpress.com

IPM in the Western United States, (various crops) University of California Press; (800) 994-8849; www.ipm.ucdavis.edu.

The Control of Internal Parasites in Cattle and Sheep by Jean Duval, Macdonald College, Quebec, Canada (514) 398-7771; info@eap.mcgill.ca; www.eap.mcgill.ca/Publications/EAP70.htm

Insect Pest Management in Field Corn by J. Van Duyn. Discusses cultural practices useful in controlling various insect pests. <http://plymouth.ces.state.nc.us/pubs/ent/index1.html>

Integrated Parasite Management for Livestock by Ann Wells, Appropriate Technology Transfer for Rural Areas. (800) 346-9140; <http://attra.ncat.org/attra-pub/livestockipm.html>

Michigan Field Crop Pest Ecology and Management (E-2704), *Michigan Field Crop Ecology* (E-2646) and *Fruit Ecology and Management* (E-2759) by Dale Mutch et al. \$12 each to Michigan State University Extension. (517) 355-0240; bulletin@msue.msu.edu; <http://ceenet.msu.msu.edu/bulletin/>

Natural Enemies Handbook: The Illustrated Guide to Biological Pest Control (#3386) by Mary Louise Flint and Steve H. Dreistadt and *Pests of the Garden and Small Farm* (2nd ed.) (#3332) by Flint. \$35 each to University of California Press; (800) 994-8849; anrcatalog@ucdavis.edu; www.ipm.ucdavis.edu.

Pest Management at the Crossroads by Charles M. Ben-

brook. Pest management strategies that rely on interventions keyed to the biology of the pest. \$29.95 + \$6 s/h. www.pmac.net/bymail.htm or (208) 263-5236

The Soil Biology Primer by USDA-NRCS. Describes the importance of soil organisms and the soil food web to soil productivity and water/air quality. http://soils.usda.gov/sqi/SoilBiology/soil_biology_primer.htm. Or \$11 to SWCS, (800) THE-SOIL x10

Suppliers of Beneficial Organisms in North America. California Department of Pesticide Regulation. A resource for purchasing biological controls. Free & online in full-text, (916) 324-4100; chunter@cdpr.ca.gov; www.cdpr.ca.gov/docs/ipminov/bensuppl.htm

Weeds as Teachers: 'Many Little Hammers' Weed Management by Sally Hilander. Proceedings of a 1995 weed management conference on least-toxic and non-toxic techniques for controlling weeds in the Northern Plains (Canada and U.S.). \$14 to Alternative Energy Resources Organization (406) 443-7272, aero@desktop.org; <http://sunsite.tus.ac.jp/pub/academic/agriculture/farming-connection/weeds/home.htm>

WEB SITES

Biological Control: A Guide to Natural Enemies in North America, www.nysaes.cornell.edu/ent/biocontrol/

Biological Control as a Component of Sustainable Agriculture, USDA-ARS, Tifton, Ga., <http://sacs.cpes.peachnet.edu/lewis>

Center for Integrated Pest Management. Technology development, training, and public awareness for IPM nationwide. <http://cipm.ncsu.edu/>

Database of IPM Resources. A compendium of customized directories of worldwide IPM information resources accessible on line. www.ippc.orst.edu/cicp/

Iowa State University www.ipm.iastate.edu/ipm/

IPM World Textbook, University of Minnesota's list of integrated pest management resources. www.ipmworld.umn.edu

Michigan State University Insect Ecology and Biological Control www.cips.msu.edu/landislab/www.cips.msu.edu/biocontrol/

North Carolina State University www.ces.ncsu.edu/depts/ent/pestlinks.shtml <http://ipm.ncsu.edu/ncpmip/>

Pennsylvania State University IPM, <http://paipm.cas.psu.edu>

University of California Integrated Pest Management Project, www.ipm.ucdavis.edu

Pest Management at the Crossroads. Comprehensive set of links to ecologically based pest management. www.pmac.net

SARE works in partnership with Cooperative Extension and Experiment Stations at land grant universities to deliver practical information to the agricultural community. Contact your local Extension office for more information.