SESSION 2

Putting Biological Control to Work

Biological Control: Past, Present & Future

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With the availability of synthetic insecticides in the 1950s, easy control of insect pests appeared at hand. However, in a relatively short time it became obvious that there were problems associated with insecticide use. Insect pests became resistant and more difficult to control, environmental and health hazards were identified, nontarget organisms were adversely affected, and pest resurgence occurred.

Today, the protection of food and fiber crops from insect, disease, and weed pests in conventional agricultural systems still relies to a large extent on the use and continued availability of synthetic pesticides. However, continued reliance on conventional pesticides is questionable, and alternatives need to be developed.

In vegetable crops, the need to develop alternatives to conventional pesticides may be more acute than in other commodities. In many areas, vegetables are considered minor crops, thus it is less likely that new products will be registered or existing ones reregistered. Full implementation of the Food Quality Protection Act may have major impacts on the availability of insecticides for vegetables. Populations of many major vegetable insect pests, including diamondback moth and Colorado potato beetle, possess resistance to insecticides. Also, vegetable growers, especially fresh market producers with small and diverse operations and roadside stands, are highly visible to the public. The application of pesticides is frequently obvious and may result in conflicts with urban neighbors. Whether the perception is real or not, the application of a pesticide is most often perceived as dangerous by nonagriculturists. Alternatives that would reduce the need for pesticide use could help alleviate some of these conflicts.

Many alternatives are available, and they are all part of the integrated pest management (IPM) strategy. Integrated pest management is ecologically based and promotes nonchemical pest control tactics such as pest-resistant plants, cultural control methods, and biological control. Pesticides are part of the IPM strategy but are to be used only when needed. The remainder of this discussion will focus on biological control of insect pests, a critically important tactic to IPM in vegetables.

Biological Control Agents

All insect pests of vegetables have natural enemies. These enemies may be predators, parasitoids, or disease-causing pathogens. Using these organisms to manage pests is known as biological control. The emphasis here is on the biological control of insects, though biological control can also be important for the control of weeds and plant diseases.

Predators, such as lady beetles and lacewings, are mainly free-living species that consume many prey during their lifetimes. They include many beetle, bug, fly, mite, and spider species. Both adults and immatures are relatively mobile and actively search for prey. In some species, such as lady beetles, both the larvae and the adults feed upon prey. In others, such as syrphid flies, only the larvae consume insect prey. The adults may obtain nourishment by feeding on nectar or pollen.

Parasitoids are species that have an immature stage that develops on or within a single insect host, ultimately killing the host. The adult parasitoid lays her eggs on, within, or near the host. The immature parasitoids, which hatch from the eggs, are entirely dependent on their host for nourishment. They feed (internally or externally) on the host, developing to maturity and eventually leaving the host as adults or to complete development. Adult parasitoids may be predatory, killing or incapacitating prey, or may seek other food sources. Many species of wasps and some flies are beneficial parasitoids.

Pathogens are disease-causing organisms including bacteria, fungi, and viruses. They kill or debilitate their hosts and are relatively specific to certain insect groups. Their effectiveness can be dependent on environmental conditions such as humidity, and frequently they are most effective when the susceptible insect species occurs at high densities (crowded conditions). Under the correct environmental conditions, certain diseases can decimate insect populations.

Types of Biological Control

Conservation

The conservation of natural enemies is probably the most important and readily available biological control practice available to vegetable growers. Natural enemies occur in all vegetable production systems, from the backyard garden to the commercial field. They are adapted to the local environment and to the target pest, and their conservation is generally simple and cost-effective. With relatively little effort, the activity of these naturally occurring beneficials can be observed. Lacewings, lady beetles, syrphid fly larvae, and parasitized aphid mummies are almost always present in aphid colonies. Fungus-infected adult flies are often common following periods of high humidity. These natural controls are important and need to be conserved and considered when making pest management decisions. In many instances, the importance of these naturally occurring beneficials has not been adequately studied or does not become apparent until insecticide use is stopped or reduced. Often, the best we can do is recognize that these factors are present and minimize negative impacts on them. If an insecticide is needed, every effort should be made to use a material that will have the least impact on natural enemies. Table 1 (page 11) depicts a selection of natural enemies found in sweet corn.

Classical Biological Control

In many instances the complex of natural enemies associated with an insect pest may be inadequate. This is especially evident when an insect pest is accidentally introduced into a new geographic area without its associated natural enemies. These introduced pests comprise about 40% of the insect pests in the United States. Examples include the European corn borer, cereal leaf beetle, and Japanese beetle. To obtain the needed natural enemies, we turn to classical biological control.

Classical biological control is the practice of importing and releasing natural enemies to help control introduced pests, although it is also practiced against native insect pests. The first step in the process is to determine the origin of the introduced pest and then collect appropriate natural enemies (from that location or similar locations) associated with the pest or closely related species. The natural enemy is then passed through a rigorous quarantine process to ensure that no unwanted organisms are introduced. The natural enemy is then reared, ideally in large numbers, and released. Follow-up studies are conducted to determine if the natural enemy successfully establishes at the site of release and the long-term impact (benefit) of its presence.

There are many examples of successful classical biological control programs:

- Damage from the alfalfa weevil, a serious introduced pest of forage, was substantially reduced by the introduction of several natural enemies. About 20 years after their introduction, the alfalfa acreage treated for alfalfa weevil in the northeastern United States was reduced by 75%.
- A small wasp, *Trichogramma ostriniae,* introduced from China to help control the European corn borer, is a recent example of a long history of classical biological control efforts for this major pest.
- Another recent example is the establishment of a small wasp that parasitizes the tarnished plant bug. There are many classical biological control programs underway across the United States and Canada.

Table 1. Natural enemies associated with (+) insect pests of sweet corn (partial list)

Natural enemy	Corn leaf aphid	European corn borer	Corn earworm	Fall armyworm
Predators (lady beetles)				
Pink-spotted lady beetle	+	+	+	
Seven-spotted lady beetle	+	+	+	+
Cycloneda munda	+	+		
Glacial lady beetle	+			
Convergent lady beetle	+	+		
Variegated lady beetle	+			
Other predators				
Minute pirate bug	+	+	+	+
Damsel bugs	+	+	+	
Lacewing	+	+	+	
Hover flies		+	+	
Bigeyed bug		+	+	+
Spined soldier bug		+	+	+
Parasitoids (wasps)				
Macrocentrus grandii		+		
Eriborus terebrans		+		
Trichogramma		+	+	
Microplitis croceipes			+	
Lysephlebus testaceipes	+			
Cotesia marginiventrus			+	+
Parasitoids (flies)				
Lydella thompsoni		+		
Archytas marmoratus			+	+
Pathogens (viruses)				
Nuclear polyhedrosis virus		+	+	+
Cytoplasmic virus			+	
Pathogens (fungi)				
Beauveria	+	+		
Nomuraea rileyi			+	
Pathogens (bacteria)				
Bacillus thuringiensis		+		
Pathogens (protozoa)				
Nosema pyrausta		+		
Vairimorpha necatrix		+	+	

Classical biological control has the advantage of being long lasting and inexpensive. Other than the initial costs of collection, importation, and rearing, little expense is incurred. When a natural enemy is successfully established, it rarely requires additional input, and it continues to cause mortality to the pest with no direct help from man and at no cost.

Augmentation

The third type of biological control is augmentation, which involves the supplemental release of natural enemies. Relatively few natural enemies may be released at a critical time of the season (inoculative release), or literally millions may be released (inundative release). Additionally, the cropping system may be modified (habitat manipulation) to favor or augment the natural enemies.

An example of inoculative release occurs in greenhouse production of tomatoes and cucumbers. Periodic releases of the parasitic wasp *Encarsia formosa* are used to control greenhouse whitefly, and the predacious mite, *Phytoseiulus persimilis,* is used for control of the two-spotted spider mite.

In 1997, inoculative releases of *Trichogramma ostriniae* were made on several farms to “seed” sweet corn fields with this wasp, since it does not occur naturally (i.e., does not overwinter). Despite exceptionally low densities of corn borer, the wasps successfully parasitized egg masses, reproduced, and were recovered late in the season. These results suggest that simple and inexpensive early season inoculative releases may provide some level of control of corn borer. Although not necessarily sufficient to replace insecticide treatments, inoculative releases against corn borer may reduce the number of sprays required.

Lady beetles, lacewings, or parasitic wasps such as *Trichogramma* are frequently released in large numbers. Recommended release rates for *Trichogramma* in vegetable or field crops range from 5,000 to 200,000 per acre per week depending on the level of pest infestation. Recent research with repeated releases of *Trichogramma ostriniae* (120,000/acre) against European corn borer in sweet corn has shown that up to 90% of borer egg masses can be parasitized. Unfortunately, levels of damage to the harvested crop are, in some cases, still too high. Entomopathogenic nematodes are released at rates of millions or even billions per acre for control of certain soil-dwelling insect pests.

Although many species of natural enemy are available for purchase and release, the benefits of such releases have not always been adequately studied. Notable exceptions are the use of some microbial insecticides (Bt’s) and the use of certain natural enemies in greenhouse systems.

Habitat manipulation is another form of augmentation. This tactic involves manipulating the cropping system to augment the effectiveness of a natural enemy. Most parasitic wasps and flies and also many of the predatory insects benefit from the sources of nectar and the protection provided by refuges such as hedgerows, cover crops, and weedy borders. Mixed plantings and the provision of flowering borders can increase the diversity of habitats and provide shelter and alternative food sources. They are easily incorporated into home gardens and even small-scale commercial plantings, but are more difficult to accommodate in large-scale vegetable crop production.

Examples of habitat manipulation include the planting of flowering plants (pollen and nectar sources) near crops to attract and maintain populations of natural enemies. For example, syrphid fly adults can be attracted to umbelliferous plants in bloom. Caution should be used with this tactic, because some plants attractive to natural enemies may also be hosts for certain plant diseases, especially plant viruses that could be vectored by insect pests to the crop. Although the tactic appears to hold much promise there are only a few examples that have been adequately researched and developed. Interest in this tactic has recently increased, however, and numerous studies are now underway across the country in a variety of cropping systems.

The future for biological control in vegetables is promising, but much more applied research is needed to develop it to its full potential. Biological control will constitute just one tactic that will need to be used in concert with other integrated pest management options.

Crop Diversification and Encouraging Biological Control

What Growers Can Do to Enhance Biological Control of Insects

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Effects of Cover Crops and Conservation Tillage on Insect Management

Pest insects cause substantial crop losses annually. In nature, pest insects are maintained under an economic threshold by their natural enemies. These natural controls take the forms of predators, parasites, and diseases. However, in conventional systems, killing insect pests with toxic chemicals also kills their natural enemies, which are known as beneficials. Conservation of these natural enemies of pest insects is a key to achieving sustainable pest management.

The aim is to make each farm field more hospitable to beneficials. Effective use of conservation methods requires limits to pesticide use, and, when essential, selection of materials which are the least harmful to beneficials. Avoid cultural practices such as tilling and burning, which are detrimental to the beneficials. In addition to removing factors that destroy beneficials, it is essential to provide what they need to survive. Properly managed cover crops supply moisture, protect habitat, and provide food in the form of insect prey, pollen, honeydew, and nectar.

In an agroecological farm system that maximizes beneficials, cover crops are raised primarily for their benefit to soil or other economic crops and are not sprayed with insecticides. This allows beneficials to be in place when spring or summer crops are planted. However, if cover crops are incorporated with tillage, most of the beneficials present in the field at crop planting time are destroyed. Conservation tillage leaves cover crops on the surface. No-till mechanically disturbs only a 2- to 4-inch area, while strip-tilling disturbs an area up to 24 or more inches wide.

Cover crops left on the surface may be living, temporarily suppressed, dying, or already dead. Their presence protects beneficials and their habitat. The farmer-helpful organisms are hungry, ready to eat the pest organisms of cash crops planted into them. The ultimate goal is to provide year-round food and habitat for beneficials to ensure their presence within, near, or around economic crops.

There is growing but still scanty information on the effects of cropping sequences and cover crops on beneficial and pest insect populations. Researchers have found that generalist predators (which feed on many species) may be important in the biological control of insects that attack crops. They showed that during periods when pests are scarce or absent, several important predators can subsist on nectar, pollen, and alternative prey afforded by cover crops. They postulated that this could lead to enhanced biological control on the beneficiary crops. Others have shown that in southern Georgia, the insidious flower bug *(Orius insidiosus)*, bigeyed bugs (*Geocoris* spp.), and various lady beetles (Coleoptera: Coccinellidae) can attain high densities in various vetches, clovers, and certain cruciferous crops. These predators subsisted and reproduced on nectar, pollen, thrips, and aphids, and thus were established before the arrival of key pests.

In Georgia, researchers found that when summer vegetables and other crops were planted amid “dying mulches” of cool-season cover crops, some insect predators moved to feed on the crop pests. Recent research has looked carefully at how beneficials and crops interact. In undisturbed, biodiverse settings, the interactions are complex and intricate. Crop plants send signals to beneficials when they are attacked by pest insects. Appropriate beneficials respond, moving in to find their prey.

Maximizing these interactions with pests is the goal of biologically based integrated pest management.

Some examples:

- Colorado potato beetles were observed attacking eggplant planted in strip-tilled crimson clover at 9:00 A.M. By noon, assassin bugs were found clustered around the potato beetles. All the potato beetles were destroyed by evening.

- Cucumber beetles attacking cucumbers were similarly destroyed by beneficials within a day.

- Aphids attacking many crops in cover crop systems are kept under control by lady beetles.

Cover crops, if properly selected and managed, can enhance the soil and field environment to favor beneficials. Success depends on properly matching cover crop species with the harvested crops and anticipated pest threats.

- Fall-sown and spring-sown 'Insectary Mixes' with 10 to 20 different cover crops work well as underorchard systems. This approach has been successfully used by California almond and walnut growers participating in the Biologically Intensive Orchard Systems (BIOS) project.

- In Georgia, growers are participating in a number of systems combining different agronomic and vegetable crops with cover crops in minimum-till or no-till systems. Examples of systems used by growers are: Rye or other small grain followed by peanut, and crimson clover or Cahaba vetch or rye followed by cotton. The level of sustainability depends on individual growers. Some have completely eliminated insecticide applications while others have substantially reduced insecticide applications on peanut, cotton, and vegetable crops.

- In Georgia, Mississippi, and South Carolina, minimum-till cotton with crimson clover/cahaba vetch has been successful in reducing fertilizer and insecticide inputs.

- In Maryland, tomato planted in cover crop mulches has been successful in suppression of weeds.

Cover Crop and Conservation Tillage Research in Georgia

In 1985, we started our research on evaluating cover crops to improve soil and reduce pest pressures. The first year of trials we evaluated 20 cover crops. Cover crops were planted in November. These overwintering cover crops were strip-killed with glyphosate and then tilled. In the spring, various vegetable crops were planted in these strip-tilled plots. These strips were 12 inches wide and placed 3 feet apart on beds with 6-foot centers. Cover crops in the middle and side of the bed were alive at the time of vegetable planting. As the season progressed, most of these cover crops died. Herbicides and fertilizers were used as needed. No insecticides, fungicides, or nematicides were used.

To our surprise, we observed less than 1% damage from insect pests, and essentially there were no foliar disease problems. We continued this work for another year with the same results. Based on the success of our trials, we applied for a Southern Region IPM grant to study "Effect of Cover Crops on Weeds, Insect Pests, Diseases, and Nematodes on Vegetables." This research was funded for two years and renewed for another two years. Four years of research involved five cover crops and fallow, followed by two double-crop vegetable rotations. During these six years, land was plowed in the fall before planting cover crops, and cover crops were planted every year. After six years of research with cover crops, we learned that insect pests and foliar diseases were substantially reduced in a relay cropped system as outlined above. However, seedling diseases and nematodes became major problems in legume cover crops. We also observed similar problems on growers' fields.

This ultimately convinced us to evaluate a conservation tillage system. Since 1991, a number of cover crops followed by vegetable crops and agronomic crops have been evaluated. Since 1993, many of these rotations have been used by growers to reduce pest pressures and reduce pesticide use. Thus, these systems are environmentally friendly and economically feasible. Conservation tillage will improve soil quality and make it more productive and healthy.

Healthy soil grows healthy crops. Healthy crop plants resist pest pressures more effectively. Excessive use of fertilizers and pesticides destroys natural ecosystems and the plant's natural defenses. To reduce pest pressures, we need to work with nature and not try to control or destroy nature.

How to Improve Soil Quality, Make Soil More Productive and Healthy

Land that has been under trees and pastures for over ten years, when brought in cultivation, remains productive for two to three years. Bumper crops are raised in this newly opened soil with very little off-farm inputs in the beginning. As the time goes by, with more plowing and harrowing, organic matter is destroyed and higher off-farm inputs are needed to produce the same yields of crops. This increases production costs. This increase in off-farm inputs includes substantial increases in pesticide use due to increased pest pressures.

Soil that has been under cover of trees and pastures is not mechanically tilled. This helps build organic matter, which in turn improves soil structure and supports a high level of biological activity. This improves soil quality and productivity. The same results may be achieved by a shift in paradigm, that is by changing the way we till the soil. Adapt crop production to conservation tillage. By making this change, growers will eliminate tillage operations that are detrimental to soil structure, soil organic matter, soil biological activity, and, indirectly, soil productivity. These detrimental operations include plowing, disc harrowing, and rototilling.

Conservation Tillage How-To

Collect soil samples, preferably in the fall, and get them tested. Apply all nutrients needed to bring levels to medium-high or high. Adjust pH as needed. Lay out beds. Plant selected overwintering cover crops (small grains, legumes, etc.) during fall. In the spring, broadcast or strip kill the cover crop mechanically or with herbicide. Leave cover crop residues and crop residues on the surface. Plant agronomic or vegetable crops. Crops raised under this system are not subjected to severe moisture and nutrient stresses and thus are healthy. These crops resist pest pressures better than conventionally grown crops.

Benefits of the total system of crop production outlined above are summarized below:

Insect Pests

1. Living, dead, and dying mulches provide habitat and food for beneficials.

2. Beneficials are in place on winter cover crops at the time of spring planting.

Weeds

1. Reduced tillage and plowing leaves a large number of weed seeds buried.

2. Cover crop and crop residues form a thick mulch to suppress weed germination.

3. Some cover crops like rye are allelopathic. Mulches of these crops are more effective in controlling weeds.

Diseases

1. Foliar diseases are substantially reduced in this system. No sandblasting, no injury to plants from cultivation and other effects on surface microflora.

2. Seedling diseases may be higher during the first year. However, incidence of soilborne diseases is drastically reduced during succeeding years.

3. Viruses are reduced (e.g., tomato spotted wilt virus, squash mosaic, cucumber mosaic, etc.).

Nematodes

1. Reduction is seen in nematodes and/or nematode damage to crops, probably due to increase in organic matter.

Providing habitat for beneficial insects and the use of trap crops will play a major role in sustainable crop production of the future. Research teams around the country studying these and other field environments include specialists in insects, weeds, soil life, nematodes, crop diseases, cover crops, horticultural and agronomic crop production, farm machinery, and cropping economics. These interdisciplinary teams try to look at the whole range of interrelated activities in the field in order to manage more complete and more dynamic agroecosystems.

Insect Habitat on a Diversified Farm

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One of the goals of our farm design is providing ample year-round habitat for insects. Achieving this goal requires breaking many of the rules of modern agriculture.

We allow native wildflower stands (read: weeds) to grow adjacent to our fields, against the advice of the experts who warn that we are providing cover and breeding sites for many destructive pests. Our rationale is that we are also providing cover and breeding sites for the natural enemies of those pests.

Our farm system is designed to be as hospitable to as many insects as possible. This task is made simpler by the fact that we produce a diversity of crops, including flowers, over a long season. Specifically, we:

- Intersperse cut flower crops throughout the vegetable crops.

- Intersperse herb and vegetable crops in the Apiaceae family (dill, cilantro, fennel, etc.) throughout the vegetable crops. Further, we allow these crops to remain in the field after they have bolted, unless native Apiaceae members (such as Queen Anne's lace) are blooming at the same time. Since many of these crops are seeded repeatedly through the year to provide salable crops in succession, we can count on having Apiaceae in bloom over a long period.

- Maintain "nursery" crops for the raising of certain beneficials. Example: Alfalfa is grown in a field adjacent to the vegetable fields. The alfalfa is harvested by a neighboring dairy farmer. At the time of the first cutting, the alfalfa (unsprayed, of course) is almost always infested with aphids and teeming with lady beetles. When the alfalfa is cut, the lady beetles migrate to our vegetable fields and clear out any aphid infestations there.

Our greenhouses are also managed entirely with beneficial insects for pest control. We use *Aphidoletes aphidimyza*, *Aphidius colemani*, and lady beetles for aphids; *Neoseiulus cucumeris* for thrips; *Encarsia formosa* for whitefly; and *Hypoaspis miles* for fungus gnat and shorefly.

The native strain of *Aphidius* is active in our fields, and we have seen evidence that some beneficials migrate from the greenhouse to the fields over the course of the season.

Because of our interest in encouraging a diversity of insects, we rarely use the botanical pesticides permitted under an organic regimen. Pyrethrum and rotenone are broad-spectrum pesticides that will kill beneficials much more efficiently than they will kill pests. Even insecticidal soap can be harmful to many insect species other than the whiteflies and aphids they are most commonly used against.

In general, we are pleased with the balance achieved in most years. Under difficult growing seasons (excessive heat and drought), we do lose some crops to an imbalance of insect populations. Many of our fall brassica plantings were lost to aphid infestations that could not be controlled by native predators.

There are also pests for which we have not identified an appropriate control, the vast family of stink bugs being among them. We tested a new predator against tarnished plant bug in spring strawberry and lettuce crops this year, with encouraging results. [Editor's note: This might be the egg parasitoid *Anaphes iole*, discussed in the session on tarnished plant bug. Also, technically, the tarnished plant bug is not a stink bug because it belongs to a different family (Miridae, which are called plant bugs).] Release of the predator must be carefully timed to the egg-laying cycle, however, and further research on that needs to be done.

We do not pretend to know or understand the complex interplay of insects on our farm. Some activity we can see—the carcasses of tomato hornworms that have been parasitized by braconid wasps, the mummified bodies of aphids attacked by *Aphidius matricariae*. We can see the great number of solitary bees and the diversity of spiders in our fields, but we cannot quantify their activities. We can only assume it is, on the balance, beneficial.

Pests and Peacework

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I spent this growing season getting set up at a new farm to grow vegetables in 1999, so the only pests I struggled with were rats who had undermined part of the barn floor. Starting over at Peacework Organic Farm, I hope to learn from what I have done before.

Just about everything I do on the farm is connected with everything else. I cannot talk about pest management without also talking about soil and crop management. I grow a wide variety of vegetables, flowers, and small fruits in a relatively small area — 70 or so crops on 15 acres. The largest amount of ground in a single crop might be an acre. I practice careful rotations, never repeating crops of the same family on the same field two years in a row. We put down 14–20 tons of compost an acre, as well as turning under cover crops. I underseed many crops to avoid bare earth — corn with clover, late brassicas with oats or rye, winter squash with clover, spring peas with millet. Any opening of 30 to 40 days between crops, I seed buckwheat as a green manure.

At Rose Valley, we deliberately planted more flowering shrubs in the treelines to increase biodiversity and improve habitat for wildlife. All farm laneways were seeded with clover/grass sod. I transplanted parsnips that survived the winter into the apple orchard. We made birdhouses out of gourds and hung them on trees around each field. By abstaining from using poisons, except for a very occasional dose of rotenone to save baby brassicas from flea beetles, we created a space where natural diversity could flourish. There is an amazingly dense population of insects, birds, toads, frogs, snakes, and soil microorganisms. Looking at the ground, you see something like Grand Central Station at rush hour. Our crops had every pest I have ever heard of, but the pests had predators. A sort of dynamic equilibrium held sway with critters eating one another and not doing much damage to crops.

On the new farm, we decided to make permanent beds, leaving the clover-grass sod that was already on the fields between the beds. I was inspired by the examples of Steve Gilman, and Robin Ostfeld and Lou Johns. Besides, the soil at Crowfield Farm, where I am renting 20 acres, is extremely light silty loam. Exposed to the wind, there would be a lot of soil erosion, even though the fields are quite level. Only the sweet corn will have a regular field, but we will underseed the corn and follow it with potatoes grown in beds. Since the farm has been free of chemicals for many years, I hope we will find the same sort of balance we enjoyed at Rose Valley.

In the latest *Growing for Market* (November 1998), there is a very nice piece by Pamela and Frank Arnosky, "Got bugs? Let them work it out among themselves." They describe their philosophy of pest management in much the same terms I have often used: "Our whole approach to pest control is balance, where we understand that we can live with a certain amount of pest damage, and we can encourage predators and beneficials to live here, too, and the system can take care of itself with very little input."

Bio-Strip Intercropping at Ruckytucks Farm

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This system is based on a total biological approach to pest control that integrates room and board for beneficials — protective habitat and nectar/pollen food sources — right into the field alongside the crops in a form of practical permanent agriculture.

Although scouts have found just about every pest common to Northeast vegetables at Ruckytucks Farm, none have been in significant enough numbers to threaten the crops. The scouts have also found an abundance of beneficials. The result is that we have not had to use any pest controls at all, including Bt's, for the past five years now.

Ruckytucks Farm in Saratoga, New York has been certified organic since 1990, growing some 140 varieties of vegetables for area restaurants and a CSA. There are 10 acres under cultivation with 7 in intensive production. A marginal Zone 5, frosts are likely until the end of May and can come as early as mid-September. The soils are clay-based and prone to cracking during dry periods and waterlogging when too wet — although both extremes are being ameliorated by the wide-scale use of cover crops and compost, particularly aquatic weeds delivered from a nearby operation harvesting lake weeds.

A holistic farming system has been evolving over the past 15 years or so. The entire farm is laid out in permanent raised beds, which effectively provide a compaction-free zone, quick to warm up in the spring. The highly organic tilth promotes both drainage and moisture-holding capacity and enhances increased root growth.

Primary tillage and bed formation are provided by a 52-inch Kuhn® rotovator rear-mounted on an International® 340 tractor with wheels set up to straddle the beds. Additional cultivation of the beds is done with an Allis Chalmers® 'G', also set to wide wheel spacing.

Some time ago, I began questioning the validity of keeping the strips between the beds clean cultivated. What has evolved over time are permanent sod strips, sown partially to Dutch white clover but also containing a hugely diverse number of perennial grasses, wild herbs, and wildflowers that grew in naturally. Perennial weed species such as quackgrass and thistle were mostly eliminated by repeated cultivations before the beds were formed.

These "bio-strips" serve a multitude of functions:

- They provide solid, muck-free footing for the tractor and the farmers, particularly when the fields are wet in the spring or after heavy rains.
- Over one-third of the entire farm is now in permanent cover all of the time, preventing and providing barriers to soil and wind erosion. The beds themselves are sown to specific cover crops when not in crop production, particularly over the winter, providing nearly 100% soil coverage most of the time.
- When allowed to grow (not mowed), the 'wildflowers of the week/month' that grow in become important pollen and nectar food sources for beneficial insects and wild pollinators. The strips are bright yellow with dandelions in the spring, white with Queen Anne's Lace in late summer, and so on. Each wave of wildflowers is mowed before going to seed, except for the white clover to help promote increased stands.
- The bio-strips also offer protective habitat — right in the field, side by side with the crops — for the beneficials. For pest species, it's literally a hostile jungle out there with enemies lurking everywhere. The permanent strips also provide an overwintering habitat for large populations of beneficials.
- All the beds are numbered, and spreadsheets are used to manage rotations so that no bed is planted back to the same crop family for at least three years. Also, crop families are kept spaced apart in the field to maximize plant community diversity and prevent monocropping situations that can help breed up pest populations.
- The sod strips seem to maintain a deep-rooted connection to the falling water table in the heat of the summer, providing a positive upwards hydraulic action that also benefits the more shallow rooted crops in the beds in between.
- Mycorrhizae, prevalent in the sod, also seem to colonize the beds and act as water pipelines for the crop's roots. The beds themselves are usually planted to more intensive spacings, and the denser plant canopies help shade the soil in the beds, conserving moisture during droughty periods.
- A "mow-and-blow" system utilizes a heavy duty rotary mower to periodically cut the

bio-strips and blow the biomass material directly onto the adjoining beds as a mulch or a food source for soil microorganisms when rotovated under. For tender crops, such as lettuce, the mulch is blown onto the prepared beds first, and the lettuce plugs are transplanted through it. The lettuce matures before the strips need cutting again. Many crops from squash to tomatoes benefit from several mow-and-blow mulchings before fruit set. The bio-strips become less vigorous/more dormant later in the heat of mid-summer and do not need mowing — allowing for the maturation of a biodiverse habitat for beneficials.

- Attention is paid to potential incompatibilities. Queen Anne's Lace may be a reservoir of aster yellows (carried to lettuce by a leafhopper vector), for example, and is mowed before it develops anywhere near lettuce beds.

Once in balance, this system creates a deep reservoir of plant protection and transforms nature from being viewed as a hostile force out to destroy and devour a farmer's crops into a powerful and awesome ally. Conventional intervention thresholds no longer hold true or become necessary. The farmer, too, becomes an integral part of the whole system, privy to working with nature in a positive, creative, and meaningful way.

Biodiversity in Farm Vegetable Production: Sustainable Agriculture Practices

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(Summarized by Kim Stoner from outline and tape)

Summary statement: Biodiversity in farming eliminates all need for chemical fertilizers and biocides.

We purchased a dairy farm of about 35 acres in 1974 and began conversion to biodiverse farming. We raise livestock, vegetables, Christmas trees, and medicinal herbs. At any given time, the livestock on the farm might consist of: 8–12 head of beef cattle, 40–50 breeding Chevoit and Borderleister ewes raised for meat and wool, 30 chickens, and 20 turkeys. The various vegetables are grown using two different methods, as row crops in a five- to seven-year rotation with forage crops, or in French intensive beds, as discussed below. Christmas trees are grown in raised beds using an intensive 4-foot-by-5-foot spacing, with rotational grazing by sheep to keep weeds under control. I began studying medicinal herbs in 1995, including medicinal weeds, which were already growing naturally on the farm, as well as species we introduced and began growing as a crop. As a result of these studies, I am teaching a course at the University of Connecticut on growing and using Asian medicinal plants.

The rotation of the forage crops with production of vegetable row crops is as follows: There is a 13-acre field used as the forage-hay-vegetable garden. This field is divided into 1- to 2-acre sections. Each section is planted to row crop vegetables (winter squash, pumpkins, fall potatoes) every five to seven years. The fall and winter before using a section for vegetable crops, the beef cattle graze and are fed with round hay bales in that section. That builds up organic matter and spreads the manure naturally over the section. The following June, the forage crop is harvested as hay and stored for winter feeding, and the section is plowed, disked, and planted with a two-row planter. It is cultivated early in the season, and then left alone until about 150 bushels/acre of winter squash, pumpkins, and potatoes are harvested in September for wholesale or retail sale. Winter rye is sown that fall to hold the soil over the winter, provide green manure, and also provide late fall and early spring grazing. The following spring, the section is disked, stones are removed, and a forage mixture of legumes and grasses is sown. In late summer, the forage crops will be cut twice for winter livestock feed. The forage crops continue growing for the rest of the rotation and are grazed and harvested for feeding the livestock on the farm.

No added fertilizer is used, and no biocides or herbicides. The long rotation eliminates overwintering of insects and weed seeds.

Greens, most root crops, brassicas, solanaceous crops, and leguminous vegetables are grown using the French intensive bed method. Many of the beds are raised, using a two-bottom plow and rototiller. The soil warms up earlier in the spring in these raised beds. Red plastic mulch is also used to warm the soil and retain moisture in the beds used for solanaceous crops. The beds are 4 feet wide and from 100 to 300 feet long. Within a bed, the crops are planted inches apart. This allows intensive production: 400–700% higher per square foot than with row cropping. Crops are rotated among the beds so that there is an interval of three to four years between crops in the same family in the same bed.

Poultry are used to control insects and weeds in the raised beds. Laying hens are let out two to three hours daily before dusk to graze and forage on insects. By limiting the amount of time they spend in the beds, the direct damage to the plants is limited. A rotational grazing system is used.

Manure from the sheep, chickens, and turkeys is composted. Ten to twelve percent of this manure is used in the vegetable beds, and the remaining compost is spread on sod pasture and forage crop land. The sheep are grazed rotationally for two to three years on land destined for vegetable beds and are also grazed in the Christmas tree plantation area. One hundred percent of the feed for the beef and sheep is produced on the farm, and the manure is used on the farm.

Combining livestock and poultry on the same farm with crop plants balances the ecosystem and reduces or eliminates the need for off-farm inputs.

Discussion: Session 2

Audience: How do you mow your sod strips, and how wide are the beds? What about using a flail mower?

Steve Gilman: I'm working on about 8 acres of land over the course of the season. I use a heavy-duty Troy® mower with a 5½ horsepower engine, which works fine for my purposes. For a larger scale system, a tractor with a power take-off mower would be appropriate. The beds are 52 inches wide, and the pathways are 28 inches wide.

I like the ability to blow the cuttings onto the beds as a mulch—particularly, transplanting tomatoes into the mulch. You might be able to get two or three cuttings of mulch and build up a nice layer by the time the tomato plants fall over, so that there's no ground contact. I don't mow any more than I have to. I'd rather see it long and mow as little as possible, because mowing is labor-intensive.

Michael Keilty: I use a push mower.

Cass Peterson: When we planted in strip beds, we used 30-inch riding mowers to blow cuttings onto the beds, but we killed about three riding mowers doing that. Our terrain is not real even, and riding mowers are not built for that.

Audience: What about keeping crabgrass and other grasses from going to seed?

Steve Gilman: I clean cultivate first to get rid of the quackgrass because that will invade, and then I watch and mow before the flowers go to seed.

Audience: Michael, do you feed your livestock grain?

Michael Keilty: They are outside grazing three to four hours every day, even in the winter, and I store hay from my fields. I don't put artificial lighting in the chicken house, so they keep their natural body clock. I may use cracked corn to supplement the chicken feed.

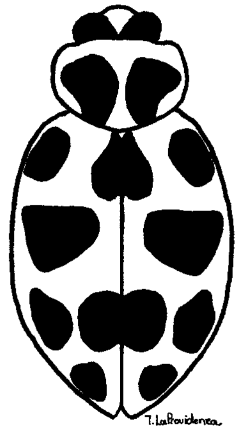
Audience: What do you recommend planting in the sod strips?

Steve Gilman: Dutch white clover stands treading well.

Elizabeth Henderson: Chamomile and Dutch white clover do well with compaction. I'm also interested in using legumes and native grasses.

Michael Keilty: Plantains and fescue.

Cass Peterson: Orchard grass, overseeded with clover, with basically whatever is there. We gave up using sod strips with strip beds and went to a system of patches because grass was intruding into the crop area. Cleaning it out was very labor-intensive. We also needed to use overhead irrigation on the lettuce, which proved to be ineffective on a 48-inch bed.



***Coleomegilla maculata*, sometimes called the pink-spotted or twelve-spotted lady beetle**

There was a discussion of cover crops and the possibility of growing cover crops that could be marketed (e.g. fenugreek and tendrils of Austrian field peas). The advantages and disadvantages of cover crops that winter kill and of using cover crops as a living mulch, a "dying mulch," a dead mulch, or killed and incorporated into the soil were also discussed. There was agreement that there is no single best answer for everyone, and cover crops must be chosen based on the needs of the land and the farmer, and the time and equipment available for management. Two books were recommended for further information: *Managing Cover Crops Profitably* and *The Real Dirt* (see "Resources for General Information," page 72).

Ruth Hazzard: I have an observation relating to what Steve said about the succession of flowering plants, with the first being a big flush of dandelions. We have observed that the twelve-spotted lady beetle overwinters in large congregations on the south side of trees on the north sides of fields in the leaf litter, then later we found them on crops — corn and potatoes. In between, we found them feeding heavily on dandelion pollen. Do you see a lot of twelve-spotted lady beetle, Steve?

Steve Gilman: I see quite a number of lady beetles, though I'm not sure which is which. My neighbor is a beekeeper, and he has made me more aware of the importance of having flowers to attract and feed wild bees and other pollinators, particularly with the decline in honey bees due to mites. A good book on the subject is *The Forgotten Pollinators* (see "Technical and Specific References by Session," page 73).

Audience: There is information that plants produce volatiles that attract beneficial insects. Is there evidence that when the plants are under nutrient and water stress, their production of these volatiles is affected?

Sharad Phatak: If they are under stress, they don't produce enough. A balance of nutrients and water is the key.

Jake Guest: Michael, I have found that the complexity of maintaining livestock is such that I don't think I could do that and produce an adequate income. I wonder, do those of you who farm rely solely on farm production to make a living? What are the economics of it?

I have had livestock in the past but found that to make a realistic income, the livestock had to go. I grow vegetables and bedding plants.

Michael Keilty: Since 1974, my primary source of income has been farming. Using livestock in vegetable production eliminates the cost of inputs, i.e., fertilizers and biocides. It adds to farm health and completeness. If you take them out of the equation, then agriculture becomes specialized, and you need special techniques, like row covers and "natural" biocides to accomplish the same thing.

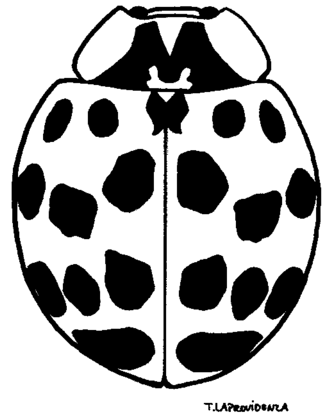
Steve Gilman: I don't have manure sources anymore, so I use a local resource and take my organic materials from local lakes (aquatic weeds). Trying to grow vegetables is like juggling, and adding livestock production is like throwing another ball in the air. You need more land to be able to support them, and you have to learn all about livestock care and maintenance. I think Michael's system is very healthy, no doubt, but every farm is unique, and it may work for some, but not for all.

Elizabeth Henderson: The history of biodynamic farming is that biodynamic farms don't bring in anything from outside, but the farms Rudolph Steiner described were 20,000 acres and encompassed several whole villages. A farm that is 10, 20, even 100 acres is different. We may need to think of our borders as wider than just our own farm.

There is organic material out there that you can recycle. We get manure from neighbors and aquatic weeds harvested from Lake Ontario.

Cass Peterson: I work with a dairy farmer who maintains my pastures. I also bring in chicken manure from outside.

Sharad Phatak: We need to develop sustainable communities, as opposed to separate, smaller farming systems. Also, low off-farm input goes together with a high input of management time and expertise.



***Harmonia axyridis*, the multicolored Asian lady beetle: a pest in homes but also a natural enemy of aphids**