Introduction

As a vegetable entomologist primarily interested in alternatives to insecticides for managing insects, I have found farmers to be a valuable source of information—particularly farmers who are highly motivated to avoid using insecticides, such as organic farmers and others striving toward sustainable agriculture. While these farmers have valuable lessons to teach scientists like me, they also have their own needs for information and techniques that are different from those of conventional farmers who rely more heavily on insecticides for management.

The idea for a farmer/scientist exchange was adapted from the "Farmer-to-Farmer" workshops that Margaret Christie, Ruth Hazzard, and others from the University of Massachusetts and the Northeast Organic Farming Association (NOFA) of Massachusetts organized a few years ago (see references to the proceedings from these conferences in "Resources for General Information" on page 72). I have also seen, through my participation in regional NOFA conferences and participatory research conferences organized by the Sustainable Agriculture Research and Education Program (SARE), that there are many farmers who are willing to share their own methods and observations and who are hungry for more information about how agricultural ecosystems work and how they can be managed.

Working with the Northeast Organic Farming Association of Connecticut (NOFA/CT), I wrote a proposal to the SARE program to study insect management on organic farms, then to have a farmer/scientist conference and document the results in a proceedings. The SARE program decided to fund the conference and the proceedings.

I identified farmers who had information to share about alternative insect management from lists of SARE farmer research projects, participants in the previous "Farmer-to-Farmer" conferences in Massachusetts, and contacts in organic farming organizations. In the invitation to the conference, farmers were asked what information they could share and what insect problems they wanted more information about. I designed the exchange around their answers to these questions, inviting scientists either with expertise that would supplement the information of the farmers on a particular topic or with expertise on an insect problem that the farmers wanted to solve.

On December 6 and 7, 1998, the Connecticut Agricultural Experiment Station and NOFA/CT held a farmer/scientist conference, "Alternatives to Insecticides for Managing Vegetable Insects." By design, this conference brought together a small group: farmers who had information to share from participation in research projects or from their own observations and experimentation, farm advisors (technical resource directors of organic farming organizations and extension personnel) with particular interests in alternatives to insecticides, and scientists whose work focuses on topics identified by farmers.

This book is the record of what happened at the conference. All of the speakers were asked to submit a summary of their talks before the conference. In general, these summaries have been printed as submitted, with very little editing, except for a few that were very different in form. When no summary was submitted, I summarized the talk from a transcript of an audiotape. Discussions were recorded by note-taking and audiotape, and I have summarized them as well as I could, depending on the quality of the notes and tape recordings available.

I have cut very little of what information was available from the conference. I know that it is unusual to see a discussion of weed management in corn, for example, in the proceedings from a conference on alternatives to insecticides. One theme running through this conference, though, was that tillage — how and when it takes place, the tools used, and the combination with cover crops and crop rotation — is an important factor in managing the whole farm system that contributes to insect management.

One comment I heard from several farmers was that they had never been to a conference where so many of the scientists spoke freely about what we don't know. I think most scientists know that the ecology of agricultural systems is very poorly understood. Even basic questions about the life cycles and movement patterns of some prominent insect pests, such as the potato leafhopper, have not been answered. As a result, I have summarized the conference with a list of questions raised to which we do not yet have answers, rather than with a set of recommendations (see appendix A, page 65). I hope that future conferences can gather together farmers, with their experience and knowledge about managing the entire system, with scientists, with their own more specialized experience and knowledge, to exchange information and questions and work together toward a more sustainable agricultural system.

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❧ SESSION 1 ❧

The Effects of Plant Health and Soil Health on Susceptibility to Pests

A History of the Idea That Healthy Plants Are Resistant to Pests

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(Summarized by Kim Stoner and Tracy LaProvidenza)

The purpose of this talk is to give an alternative theory of pest control. This theory holds that plants are inherently not susceptible to pests and that pest problems indicate some inadequacy of the growing conditions. This idea has a long history and was the dominant way of thinking about plants and their pests long before the invention of the idea of organic farming.

About 300 B.C., the botanist Theophrastus concluded that the visible signs of plant disease (such as fungal growth) were a result, rather than an inciting cause, of the disease. Disease was caused by growing plants in an unsuitable environment. This concept was dominant for some 2,000 years. There are numerous examples up to the mid-1850s where writers about agriculture and botany confidently attributed both insect pests of plants and plant diseases to poor growing conditions and asserted that plants grown in good soil under proper conditions were free of pests.

During much of that time, particularly before the invention of the microscope, people believed in autogenesis or spontaneous generation. New theories arose with the use of microscopes in describing the life cycles of bacteria and fungi. Eventually, the work of Heinrich Anton de Bary, Robert Koch, and Louis Pasteur overthrew the theory of spontaneous generation, and we entered a new age.

In the late 1800s there were two schools of thought in plant pathology: the Pathogenetists and the Predispositionists. The Pathogenetists emphasized that fungi (and later, bacteria and other organisms) caused plant disease. The Predispositionists continued to emphasize the importance of environmental conditions in causing susceptibility to disease. Two prominent Predispositionists of this period were Paul Sorauer of Germany and H. Marshall Ward of England.

According to C. E. Yarwood (1959): "'Predisposition' is the tendency of nongenetic conditions, acting before infection, to affect the susceptibility of plants to disease." Thus, the internal condition of the plant is important, and bacteria and fungi can infect only if the plant has somehow been weakened or predisposed.

To quote Paul Sorauer (1922): "Since. . . there is a possibility of altering the nutritional substratum produced by living plants, the production of such resistant individuals through cultivation is the first aim of our work . . .The healthy organism thus possesses a natural immunity, and any disturbance of this aids the possible parasitic attack."

Although there was no separate school of Predispositionists among entomologists, there have always been advocates of the idea that insect pests can be controlled through the soil, by altering the nutritional quality of the plants available. [In the talk, quotations from eighteen examples ranging in date from 1880 to 1997 were given, including a book, *Potassium in Plant Health* (Perrenoud 1977), which has a bibliography of over 500 studies of fertilization and pest resistance.]

T. C. R. White (1984) extended this idea to a variety of stresses that make the plant more susceptible to herbivores:

> "When plants are stressed by certain changes in patterns of weather, they become a better source of food for invertebrate herbivores because this stress causes an increase in the amount of nitrogen available in their tissues. Evidence is now presented in this paper that a similar physiological mechanism appears to operate when a wide variety of apparently unrelated stress factors impinge on plants or parts of plants in such a way as to perturb their metabolism."

T. C. R. White argued that stress on the plant resulted in the breakdown of protein to soluble amino acids. Nitrogen in the form of free amino acids is more easily available to many herbivores, so the populations of herbivores increase on the stressed plants.

What does this have to do with organic farming? Organic farming was born in 1940, when Sir Albert Howard (1940) wrote that he had "learned how to grow healthy plants free from diseases without the help of mycologists, entomologists, bacteriologists, agricultural chemists, statisticians, clearinghouses of information, artificial manures, spraying machines, insecticides, fungicides, germicides, and all other expensive paraphernalia of the modern experiment station." He believed that the birthright of every crop is health, when grown in the proper soil under the proper growing conditions. He also believed that "insects are the best professors of agriculture," and their presence in abundance indicates the need to make adjustments in soil and other growing conditions. Howard's wife has said that these ideas began when Howard was at Cambridge in 1898, studying with H. Marshall Ward, from the Predispositionist school of thought.

On his own farm, Eliot Coleman seeks to optimize every facet of the crop plant's physiological well-being, including drainage, moisture, balance of nutrients in fertilizers, and organic matter in the soil. He uses information from scientific studies and from his own experiments and observations to grow crops so that they do not meet the nutritional requirements of pest insects. For example, he did a study where he grew zucchini on one field fertilized with chicken manure and another with a compost made of one-half horse manure and one-half seaweed. The field with chicken manure had squash bugs and the other field did not. Thus, insects are present in the area, but are not abundant in fields with the right growing conditions. He expected this result because he had read a study showing that when nitrogen was out of balance with potassium and trace elements, squash plants would be more susceptible to squash bug (Benepal and Hall 1967).

He refers to his philosophy of agriculture as a "plant-positive" (as opposed to "pest-negative") approach. Although he has spoken and written about this plant-positive approach for many years, it has not been advanced by scientists or by anti-pesticide advocates to any substantial degree. Perhaps this reflects an aspect of our society that prefers to find an enemy (pest) to kill, rather than building up an environment optimal for the plants and unfavorable to pests.

The Relationship between Soil-Management History and Corn Susceptibility to Pests

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One of the core goals of sustainable agriculture is to understand farming from a whole-system, or holistic, perspective, in which changes in one part of the system can have unexpected impacts on other parts of the system. Proponents of organic agriculture have long held that their soil-management practices produce healthier crops, which are both less susceptible to insects and disease and of higher nutritional quality. Despite the fact that these claims date back more than 50 years, there have been few attempts by agricultural researchers to test them using scientific methods. After discussions with farmers, our lab decided to research the relationships among soil management, plant nutrition, and crop susceptibility to pests, using the complementary approaches of on-farm comparisons of organic and conventionally managed fields, and controlled greenhouse studies. In farm comparisons over three years, we found lower levels of serious corn pests (most notably European corn borer) on organic farms compared to neighboring conventional farms. Similarly in the greenhouse, we have found that European corn borers are less inclined to lay eggs on corn grown in soil collected from organically managed farms. This difference in insect pressure is observed despite similar corn yields from the two farming systems, dispelling the notion that organic farming's avoidance of synthetic fertilizers comes at the cost of lower yields. Although we are still conducting research on the connection between soil management and pest outbreaks, we believe that:

1. the maintenance of plant-mineral balance plays an important role in reducing corn susceptibility to pests, and

2. pest susceptibility is lower in organically managed soils in part because of the inherent capacity of these soils to buffer availability of minerals to plants.

This project demonstrates the successful integration of the experiential knowledge of farmers with the scientific or empirical approach of the research scientist. These sources of knowledge should be recognized as different but complementary, with each having value. Agricultural researchers should come to recognize the limitations of controlled experimentation conducted in small plots on university land and should be open to learning from the rich observations of farmers. For their part, farmers should play a less passive role in learning how to farm their land by reducing their dependence on fertilizer dealers and land-grant universities.

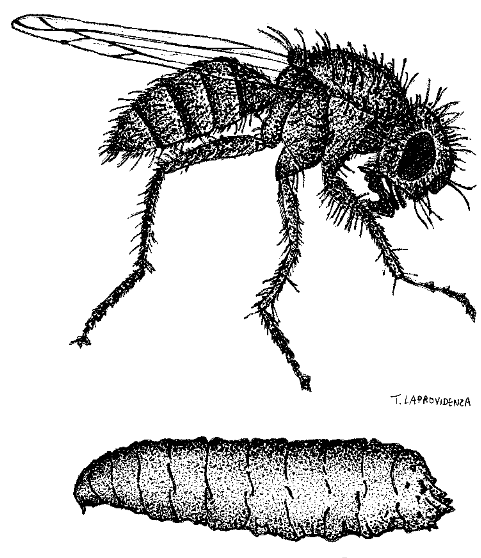
Discussion: Session 1

Audience: I have a question about the theory — What engenders plant health or plant resistance?

Eliot Coleman: T. C. R. White's paper proposed the theory that stressed plants are higher in free amino acids and that was the limiting factor in insect abundance, the availability of nitrogen. This is as close to an explanation as anything I have read. If you want me to comment as a nonscientist, I would say that I can look out my front window to the woods across the street, and the plants growing there are the ones whose needs are best met by the growing conditions of that site. That is why they aren't being deselected by the organisms that deselect other plant species.

My role as a farmer is to create soil conditions in my vegetable fields that are ideal for the needs of the crops I'm growing in order to optimize their physiological well-being. One reason organic agriculture makes sense to me is that compost contains a bit of everything, so it fulfills a broad spectrum of needs and is the simplest way to provide the right soil conditions. The forest floor in nature is doing the same thing — making compost. My approach is as simple as that.

When I started out years ago, I divided my field into strips. In one strip I put manure, in another seaweed, and in another autumn leaves. I planted every crop on the farm across these strips. We saw different diseases and insect infestations depending on the crop and the treatment. For example, in the seaweed-cabbage section, we saw root maggots, but in the autumn leaves–cabbage section, not one root maggot to be seen. I drew conclusions from this, whether or not this has to do with health. Health is a hard word to define. I'm trying to find optimal growing conditions for the plants.



Cabbage maggot adult fly and cabbage maggot larva

Audience: We need a word for the study of plant health. We have plant pathology now, we need the opposite.

Eliot Coleman: I invented a word, "euology," to mean health, but there is no "Department of Plant Euology" at any university. One reason we have trouble comprehending this idea is that we don't have a word for it.

Elizabeth Henderson: I appreciate the comparative studies done by Larry Phelan — it confirms what we as farmers have observed for years. What we need now are studies that move beyond these comparisons to identify the characteristics of plant health. My hope is that from this conference we can figure out the right questions to ask.

We had a three-year study on our farm looking at mycorrhizal connections between different crops and the soil. The mycorrhizae on our farm were different than the mycorrhizae on conventional farms, but what does that mean? We don't know.

Larry Phelan: The structure of the land-grant institution has perpetuated this problem — we have the agronomist making recommendations for soil amendments, then the plant pathologist and entomologist come in later and clean up the pest problems. We need to get rid of the departmental lines and the industrial paradigm which emphasizes specialization and size. We need to focus on the soil, and let the plants become an afterthought. We also need to take a holistic approach to farming — start with the whole system and identify the important correlates from the top down instead of starting from a particular organism, earthworms for example, studying them in depth and then making assumptions about their importance in the system.

Kim Stoner: Both of you have been talking about free amino acids as an important factor in insect susceptibility, but I didn't see data about free amino acids in your talks. A few years ago, inspired by Eliot Coleman, I attempted to measure free amino acids in potato plants grown in different ways, and I found it to be a pretty challenging thing to do. I am interested in your thoughts about free amino acids as an indicator of plant health — does that really hold water?

Larry Phelan: We just started our study of plant biochemistry, measuring the absolute levels of free amino acids, sugars, starch, and proteins. We are interested in this not only for insects, but also for herd health and human health. Using NIR (near infrared reflectance) spectroscopy has shown us that nitrogen is very important, and that goes along with T. C. R. White's work. Some people have generalized to say that if you have too much nitrogen it increases insect pests, but only two-thirds of the studies confirm this. The other third show no relationship or the opposite. This is where the idea of balance comes into play, where you can have too much or too little nitrogen. You also have to consider the form of the nitrogen. NIR spectroscopy shows that the form of the nitrogen is important. The level of elemental nitrogen may be the same, but it may be in different forms.

Eliot Coleman: Where we tilled in our autumn leaves and had no root maggots in the brassicas, we had a huge nitrogen flush in the spring. In the old literature, there were farmers saying that if they applied an extra kick of sodium nitrate in the spring, they would have no root maggots on their brassicas. This was a case where an excess of nitrogen worked beneficially to decrease the insect pest and favor the crop. When we do our rotations, we add in all these things we have learned.

Larry Phelan: The reason too little nitrogen can be as bad as too much is that when the plant is nitrogen-starved, it takes protein from the lower leaves, breaks it down into amino acids, and transports it to the meristem. So you can get elevated levels of amino acids with too low a level of nitrogen.

Cass Peterson: Is there a correlation between high Brix level and low damage? There seems to be contradictory evidence.

Larry Phelan: I've wondered about that, too. Maybe Brix is a measure of dilution of sap. If nitrogen is too high, the cell structure in the leaf is weaker and the water levels are higher. I wonder if Brix measures not so much sugar levels but overall levels of molecules being transported. We did buy a Brix meter and tried to find a correlation between insect damage and Brix reading, but did not see one.

Eliot Coleman: I have no way of testing these things, I read the literature and know what is going on in my field. In the 1980s, the only pest we hadn't controlled was the Colorado potato beetle. According to the literature, the stresses on potatoes that raise amino acid levels in the tissues were high soil temperature and fluctuating moisture. We started growing potatoes under mulch and found CPB damage down by about 90%. The literature said that cytokinin, a hormone produced in the roots, is a key to determining protein synthesis. When the roots are not "happy" due to high soil temperature or fluctuating moisture, they stop production of cytokinin. Maybe one reason liquid seaweed occasionally works is that it contains cytokinin. The plant may be able to use cytokinin from outside when it is not producing enough of its own.

Myra Bonhage-Hale: I liked Eliot Coleman's remark about scientists being like artists, chained by the ideological forces of their times. Maybe if we are moving from an industrial era to a new age, more matriarchal and nurturing, that may change our approach to agriculture.

Eliot Coleman: About five years ago, I sent a letter to 100 of the best organic farmers all over the country and asked them to tell of their experiences with plants and pests. All but one said they had fewer pests than their conventional neighbors and averaged a 75% success rate. I keep running into people who find it very difficult to attribute that to the farmers favoring the plants, rather than doing something that disfavored the insects.

I came to farming out of a pacifist background, and the idea of making war on nature doesn't appeal to me. I would rather be supporting my plants rather than attacking their "enemies."

Audience: How do you address issues of cost and availability of organic fertilizers?

Eliot Coleman: I don't believe in dependence on commercial organic fertilizers. I've written about the idea that the word "organic" is poorly served if it is understood merely as a substitution of one source of nutrients for another — i.e., using dried blood instead of sodium nitrate or rotenone instead of other insecticides. I would distinguish between this substitution philosophy, which I call "shallow organics," and a whole-system philosophy that maximizes the resources available within the farm, which I call "deep organics."

I mentioned my experiment with zucchini, and I happened to be near the ocean, so I used its resources in the form of seaweed. We are aiming now to have a noninput farm. Our only inputs are rock minerals (phosphate rock and lime), which we need to replace the minerals shipped out in our produce. We use locally available rock powder waste from the rock crushing industry and apply it to our hayfields. We cut our hayfields, compost the hay, and use the compost to amend the soil in our vegetable production land. We won't buy manure from other farms — they need their own manure because it's coming from the feed they fed their livestock. If organic farming only works because I have a neighbor who is a dairy farmer, if he gets out of the business or finds a better use for his manure, then I'm out of luck.

Larry Phelan: Most of the farms we work with are self-contained. They are dairy farmers or have some animals. You need a balance — enough animals to feed the soil and enough soil to feed the animals — so you can have a closed cycle. The Spray brothers I mentioned earlier haven't brought in any amendments to their soil in 40 years. They use legumes in their rotation and they have their own animal manure. Those are their only sources of nutrients.

(In response to comments about abundance of chicken manure and problems with its nutrient balance) — Chicken manure would work if you added carbon to it to get the proper ratio of nitrogen and carbon.

Audience: You can use the chicken manure to grow the carbon. Use it to grow green manure instead of applying it to your food crops.

Audience: Is there any way to measure biological buffering or soil health and how they affect plant health?

Larry Phelan: People have been struggling with how you measure soil quality. The organic matter measurement you get in a conventional soil test is useless. It shows recalcitrant organic matter that is thousands of years old and doesn't feed microbes. The organic matter that is important is the organic matter you put down each year. There are measurements of quality of organic matter for scientific purposes, but they are not generally available for farmers. Farmers don't need a measurement if they are putting organic matter down each year.

Eliot Coleman: Since I don't have a Ph.D., I am glad to answer that question. This is the way I tell (holds up a beautiful carrot from his farm). If I can turn out produce like this consistently for 25 years on my farm, that is my definition of soil health and plant health.

Audience: Can you look at the soil microflora as a predictive test? Is a soil with a balanced microflora guaranteed to be productive?

Larry Phelan: People are beginning to look at the ratio of soil fungi to bacteria, but it is not far enough along as a predictor yet. Some organic farmers use herd health as an indicator. It is "after the fact," but in the long term they have found that with organic methods, their vet bills went down and efficiency and production went up.

Aaron Gabriel: I agree with the concept of plant health, but will that solve every pest situation? Can we have healthy plants that are still attacked by some pests?

Eliot Coleman: The trouble with the words "plant health" is that the words confuse people. Why would an insect choose to eat a spindly, sickly plant as opposed to a beautiful, lush one? It makes more sense to think of a sick plant as a stressed plant, and the stress predisposes the plant to insect attack. When I wrote a paper with a USDA entomologist (Coleman and Ridgway 1983), the USDA wouldn't let us publish it with the words "plant health" in the title. They insisted that we use, " The Role of Stress Tolerance in Integrated Pest Management," because it was easier to understand.

Larry Phelan: Insect pests of fruits may be more difficult to control with this methodology because a fruit by definition is a part of the plant meant to be eaten.

The realization I have come to is that even when we find natural alternatives which are much more ecologically acceptable methods of controlling pests, they represent an input and a cost to the grower nevertheless. We need to start by investigating how we can grow the crop to be less susceptible, and if that doesn't work, then we find alternative pest control methods. It is a two-pronged approach, but we need to change the emphasis.