PLANT EUOLOGY: A NEW APPROACH TO PESTS Eliot Coleman (1988)

It is a bit intimidating for a farmer, whose college degree is in literature, to go to a major agricultural research university and present a paper that questions the direction of their research. But that is what I have attempted occasionally. I have not done this by presenting my own contrasting layman's research, but rather by relating my successful experience in following a different way of thinking during my farming career. I have done it in hopes of inspiring academic researchers to investigate the potential of an alternative path to understanding the relationship between plants and pests.

No subject in modern agriculture is more controversial than pest control. On the one hand are those who claim that pesticides are indispensable for a continued high level of food production. On the other hand, are those who feel that the environmental pollution consequent to the use of pesticides is intolerable, and that other options for pest control must be explored. Many alternative programs, such as Integrated Pest Management, assume some pesticide use to be required. No programs yet go so far as to suggest that pesticides are unnecessary if proven cultural techniques are instituted to increase the resistance of the host plant. Many writers on pest control pay lip service to cultural practices as a factor, but they rarely go into detail. Little or no mention is made of the potential influence of plant nutrition and cultural conditions as major factors in determining the susceptibility of plants to pests. This discussion will deal with just that concept. I am aware that this is a 180-degree reversal from the idea that pesticides are indispensable, to the idea that pesticides could be superfluous, with a different approach to how plants are grown.

There are many examples of such 180-degree concept reversals in the history of human thought. We now praise Galileo for expressing the Copernican view that the earth revolves about the sun rather than the once prevalent Ptolemaic opposite that had the earth at the center of our solar system. Galileo was condemned by the authorities of his day for proposing such a radical idea. Back when wolves were considered bad, debates raged over whether it was better to shoot, trap, or poison them. Now a totally new understanding of their benefit as top predators in the ecosystem is commonly accepted. The attitude on forest fires has reversed from seeing them as something totally negative that only "YOU" could prevent, to understanding that they play an important role in maintaining ecosystems and ensuring the survival of certain plants and animals. Some brave thinkers in Yellowstone took a lot of abuse for pursuing that policy a few years ago.

The 180-degree radical idea in this paper suggests a new way of thinking about plants and pests. I contend that it makes much more sense to focus on enhancing the insusceptibility of the plants rather than killing the insects. This view sees insects and disease in agriculture as helpful indicators of plant distress rather than just as enemies to be destroyed. Insects and disease are bringing us a message that the plants are sub-standard. Since it is a message we haven't understood, and that we don't want to hear, we have tried to kill the messenger. If we pay attention to the message, we can hopefully learn to prevent pest damage from occurring. At that point pesticides become unnecessary.

I realized as soon as I started in this business 50 years ago that my choice of organic farming made me an instant oddball. Conventional farmers, fertilizer salesmen, extension agents, university professors and a majority of the general public all treated me with the type of scorn that our society reserves for the "reality challenged." My first act of self-protection was to stop using the word 'organic' and substitute the word 'biological' – as in 'biological' agriculture - the same as the word 'biologique' that the French use. At an international agricultural conference, a French friend asked me why I had made that change. "Well," I said, "Organic is an awkward word to use when talking with agricultural scientists. Whenever I mention organic, I can see their eyes begin to cloud over, and they start looking at their watch." "What a coincidence." He replied. "That is just what happens in France when I say biologique."

Despite my occasional discomfort at being considered an oddball, I was not unaware of the reasons why. First, I was espousing a theory in disagreement with popularly accepted thinking. And, second, I could produce very little hard scientific data to support my case. The only proof I had was my farm. People could come there and see that it worked, as my customers did when buying produce. But the naysayers hadn't seen it. And even if they had seen it, my successes were dismissed by science with a capital "S" as mere "anecdotal evidence". But similar anecdotal evidence, showing an understanding of the effect of cultural practices on the resistance of plants to insects and disease, has been around for quite a while.

For example, in a 1793 letter to his daughter, Thomas Jefferson wrote: "*I suspect that the insects which have harassed you have been encouraged by the feebleness of your plants and that has been produced by the lean state of the soil.*"

Erasmus Darwin, Charles Darwin's grandfather, speculated back in the year 1800 that the leaves of a fruit tree damaged by insects were "*previously out of health, which occasioned them to supply a proper situation for those insects which molest them.*"

Thomas Green Fessenden, author of a garden book, The American Kitchen Gardener, which was enormously popular in the 1830s, stated: "*The preventive operations are those of the best culture . . .choice of seed or plant, soil, situation,*

and climate. If these are carefully attended to . . . vegetables which are vigorous and thrifty are not apt to be injured by worms, flies, bugs, etc."

Vincent Gressent, a market gardener in Paris in 1870, was even more emphatic in his instruction book for Parisian growers, Le Potager Moderne: "*In principle, insect pests only attack weak, sickly plant specimens lacking proper nutrition . . . In proof of this I offer the market gardens of Paris where vegetable growing has reached perfection . . . One does not see pest problems in Parisian market gardens wherever copious compost use and rational crop rotations are practiced by the growers*".

In other words, growers had long realized that the best defense was to optimize the growing conditions. Or put in more scientific language: plants are inherently insusceptible when properly grown and they only become subject to insect and disease problems when they are stressed by unfavorable growing conditions (Coleman and Ridgeway, 1983). Many farmers have been able to grow healthy pest-free plants by focusing on soil organic matter, natural minerals, crop rotations, green manures, soil aeration, good drainage, irrigation and other cultural practices.

Since that was exactly my experience on my farm, I began to spend evenings many years ago in the periodical stacks of the nearby university library to see what scientific literature was available on the subject. The evidence was impressive. For example, an industry-financed survey of the literature on just one small segment of the subject, the influence of potassium on plant health by Perrenoud in 1977, cited 534 references, and it noted that since 1950 the number of new references available had doubled every decade.

A paper by TCR White in 1984 specifically exploring one theory about the relationship between plant stress and insect abundance cited more than 300 references and it has itself been cited hundreds of times in subsequent studies. That isn't to say that everyone agrees on this subject, but rather that a great deal of work had been and is being done.

Let me give some examples: Benepal and Hall in 1976 at Kansas State investigated the relationship between an imbalanced supply of the major plant nutrients on squash plants and their insect infestation by the squash bug. Plants grown in cultures deficient in phosphorus, potassium or sulphur showed an increase in the non-protein free amino acid level in the leaves compared with plants grown with full nutrition. The more imbalanced the nutrition, the higher the free amino acid level. They observed a direct correlation between the increased free amino acid levels in the leaves and the increased number of insects feeding on the plants. The more imbalanced the nutrition, the higher the number of insects. When plants were grown with balanced nutrition, insect feeding was negligible or non-existent.

TCR White in 1984 found similarly that plants under a wide variety of environmental stresses become a better source of food for invertebrate herbivores because the stresses cause an increase in the amount of free nitrogen available in their tissues. Further, the degree of the disruption of the metabolism of a plant that is necessary to induce these physiological changes may often not be sufficient to produce any visible signs of stress in the plant. The only indication is the presence of invertebrate herbivores feeding on the leaves.

In a study of rice crops from 970 sites in Brazil, Primavesi et al. (1977) stressed the importance of minor-element nutrition in protecting paddy rice from the disease - rice blast. They determined from field experiments that plant infection, even under conditions especially favorable to the development of the disease -- such as susceptible variety, unsuitable soil, infected seed, heavy nitrogen fertilization, and climatic conditions favorable to the fungus – rice blast could be prevented if sufficient levels of important minor nutrients, in this case principally manganese and copper, were available to the plants.

Van der Lann (1956) in Holland carried out trials on the specific influence of organic manuring on nematode infestations. The nematodes caused only minor damage on the organic-manure plots. He accounted for the difference as follows: (a) organic matter improved soil structure and moisture-holding capacity, and many parasites are known to cause less damage in improved soil; (b) organic matter increased soil micro-organisms, and the nematodes may have been killed by their natural enemies; (c) organic manuring is known to affect the morphological structure of the plants and their roots, and these changes may have made the plant more resistant to nematodes; and (d) physiological changes within the plant tissue also occurred which added to the resistance of the plant.

Von Thiem published a study in 1938 in Germany, in which he referred to both an absolute and a relative immunity to pests. The former he called genetic immunity and the latter pheno-immunity. He considered plants to be genetically immune when their resistance is such that a specific pest can never propagate and develop on them. Pheno-immune plants, on the other hand, are those whose degree of resistance is such that they will be susceptible or resistant depending upon outside influences. If the resistance of a pheno-immune plant is to be adequately maintained, then cultural conditions affecting soil structure, its physical and chemical make-up, and its biotic life must be carefully considered. Thiem further contended that even an agricultural practice such as large-scale monoculture, often considered a causative factor of insect multiplication, would present no problem if cultural practices succeeded in assuring pheno-resistance.

A few short quotes from the conclusions of other studies will complete the picture:

 Lees (1926) from the Annals of Biology: "*… perhaps in the future more reliance will be put on correct cultural conditions than on spraying, and the conditions of the host plant be more closely watched than the presence of the insect parasite*."
 Wittwer and Haseman (1945) from the Journal of Economic Entomology: "*possibly the continuing need for the creation of new insecticides to hold in check greater and more destructive ravages in insect pests is aggravated by the gradual but general decline in soil fertility from year to year*."
 Van Emden (1966) from Scientific Horticulture: "*There is ample evidence that the nutrient status of the host plant has major effects of economic importance on phytophagous insects*."
 Johnson (1968) from a Cornell University publication: "*the evidence supports the idea that plant condition as affected by water or nutrient stress can be a primary factor influencing the population dynamics of the insects feeding on the plant*."
 Leath and Ratcliffe (1974) from a publication by the American Society of Agronomy: "*One cannot help but be impressed by the extent and diversity of the research on the plant disease-fertility relationship. Evidence shows both direct and indirect effects of fertilizer applications on (1) pathogens in the soil and in the host, (2) the pathogenicity per se of an organism, as well as (3) the structural and physiological changes in the host that contribute to disease resistance, tolerance or escape*."
 Francis Chaboussou, a French researcher in 1976: "*To sum up, the results already obtained seem to show that the search for improvement in the plant's resistance through its physiology is not just Utopian but quite practical*."
 The USDA in its 1957 Yearbook of Agriculture has this to say: "*Well-fed plants usually are less susceptible to soil-borne organisms than are poorly-nourished plants. Good fertility may so enhance the resistance of the (host) plant that the parasite cannot successfully attack the roots*."
 And in one of the few studies specifically relating to organic farming, Culliney and Pimentel (1986) conclude: "*Whatever the cause(s) for the significantly fewer insects in the organic treatments, the results support the proposition that organic fertilizers can promote crop-plant resistance to attack by insect pests*."

Every one of these authors confirmed what I was seeing on my farm. I know from correspondence with other growers that this concept works not only on my farm, but also on organic farms all across this country and around the world. However, the idea meets enormous resistance. When I suggested to the organizers of a couple of conferences on alternative pest control that they include at least one paper introducing an outline of this theory, the suggestion was politely but firmly rejected. I suspect they thought this theory would jeopardize the legitimacy of the entire conference. They were right, but for the wrong reason. The idea is only weird when one is merely fiddling with the fine-tuning of the

status quo. What I am proposing is a revolutionary perspective. This theory deals in realities that seem to be outside the present framework of accepted entomological thought.

My suggestion to the conference organizers was rejected because I was asking what I call 'an unanswerable question.' Let me give an example. I have many times been involved in conversations with entomologists where I have requested that they pause for a moment in their discussion of alternative pest control. I have then asked them if they are aware of the fact that I and many other organic vegetable growers seem to have been able to establish systems where pest control, as they view it, is not the issue; that we have learned to view pests as indicators of plant stress rather than as enemies; that we deal with the situation by focusing on correcting the cause of the problem - inadequate growing conditions - rather than focusing on treating the symptom - pest damage. After I ask that question, they smile politely, thank me for my input, and return to their discussion of pest control. In this case I have asked an unanswerable question. They ignored me because the only way to deal with the issues that I had raised would have been to question the very assumptions at the basis of their thinking.

I can imagine a simple explanation for the failure of agricultural scientists to comprehend the existence of a different reality, for why they cannot imagine a world where optimizing the growing conditions creates high yields of vigorous plants that do not need the protection of pesticides and fungicides. There seems to be great difficulty in comprehending what I call a plant-positive approach (strengthening the plant through ideal growing conditions to prevent pests) as opposed to the conventional pest-negative approach (killing the pests that prey on weak plants). As Benjamin Walsh stated back in 1866 in The Practical Entomologist, "*Let a man profess to have discovered some new Patent Powder Pimperlimplimp, a single pinch of which being thrown into each corner of a field will kill every bug throughout its whole extent, and people will listen to him with attention and respect. But tell them of any simple common-sense plan, based upon correct scientific principles, to check and keep within reasonable bounds the insect foes of the farmer, and they will laugh you to scorn.*"

The first explanation is the lack of a word. There is no word in our popular scientific vocabulary to describe plant-positive thinking. We all know what the Department of Plant Pathology is concerned with (from the Greek word pathos which means suffering.). But does any university have the antonymic, the opposite, a Department of Plant _____? What would the scientific word be? I used Eu-ology for the title of this paper (from the Greek eu meaning good.) Sanology (from the Latin san – health) might also be suggested as a possible new word. Or we could call it the Department of Plant Phylactotrophy from phylact – protect and troph – nourish (protection through nourishment.) What if all the

Land Grant schools had a Department of Eucrasiotrophic Agriculture? Eu – good; crasio – constitution; trophic – nourishing: A good constitution through nourishment. What if we lived in a world where we had the expectation of healthy plants rather than pest-ridden plants? What if the Department of Phytostenics (phyto – plant, sten – strength), which would translate as the department of plant vigor, was publishing research explaining how plant health had to be subverted through mistaken cultural practices before pests could dominate? That would be a different world. But the fact remains that it is difficult for most people to comprehend a concept so novel that their language has never had a scientific word to define it.

The second explanation is that humans cannot imagine a world in which they are not in charge. As a biological farmer, I work in partnership with nature, and I'm a very junior partner. Given the limited amount of hard knowledge available, I often refer to my management style as "competent ignorance" and I find that a very apt description. But my level of trust in the design of the natural world and my willingness to be guided by it is discomforting to those who think we should exercise total power over Nature. Thomas Colwell, in his chapter in the book Human Values And Natural Science is most emphatic on this point: "*But though part of Nature, man's unique function . . . lies in controlling and transforming the natural world, not piously seeking its guidance. How profoundly we believe this today. How could we help but believe it; the entire edifice of our civilization is built upon it. The Baconian conception of science as control over nature is not only an intellectual presupposition of ours, it is a deeply implanted emotional attitude as well.*"

Another major source of resistance to the idea comes from human fear of powerlessness if we don't arm ourselves against our supposed enemies. This is obvious from the words we use in writing and speaking about agriculture. Pests "attack" the plant. They "ravage" the crop. We do "battle" with them in order to "defeat" or "conquer" the "enemy". We use bug "killer" in a spray "gun" to "blast" them. Robert Van den Bosch in his 1978 book, The Pesticide Conspiracy, painted a compelling verbal picture of the modern pesticide applicator portrayed as a swaggering, macho, Western gunslinger "pumping the lethal load of his Colt .44" into the bad guy. Our primary view of the biological world and of natural systems is one of fear and mistrust. Only rarely do we consider the improved relationship that could result from investigating, analyzing, understanding, and cooperating.

I have pondered a lot about the reasons for our attitude. I think we have difficulty in accepting the idea of a benevolent nature with elegant systems because we have made nature in our own warlike image. We see natural processes as if they are projections of our own actions and thought patterns. Thus, we see malevolence in the relationship of one organism to another and in nature's relationship to us. We don't notice the beneficial balances between

predator and prey that are maintained throughout the natural world. We miss the obvious logic of 'tipping that balance in our favor' by creating optimum growing conditions for the plants. All we can see are the temporary agents, the pests who inform us of the imbalance, as threatening forces to be battled and defeated. We need to look again.

It is a refreshing mental exercise to look at something familiar from a different perspective; to reappraise nature as a system that is not malevolent but benevolent; to see pests as helpful signals or indicators, not enemies; to see the relationship between predator and prey as natural management rather than violence; to understand that when we work against the system by doping up sick soil and killing pests we are contributing to the problem. The farmer's role is not to protect sick plants, but to enable healthy ones. You enable plants to attain their natural insusceptibility by removing plant stress. You remove plant stress by working to optimize all the agronomic factors involved in plant well-being.

In closing let me give a short summary of my argument. If we can modify our thinking to realize that pest problems in agriculture are symptoms of a deeper problem, we can learn from them to search for their causes. The extensive literature on the subject strongly suggests that the cause lies in the physiological dysfunction of the plant as a result of imbalanced nutrition or unsuitable growing conditions.

One effect on the plant of this physiological dysfunction is to increase its susceptibility to disease and enhance its suitability as a source of nourishment for insects. In consequence, to resolve the problem rather than only to mask the symptoms, the practices of the farmer must begin from a cause-correction thought pattern. For those farmers wishing to attempt such a shift, general experience has shown that practices which stimulate the biological activity of the soil such as organic matter, mineral balance, near-neutral pH, soil aeration, moisture level, and crop rotation to name a few, are the most widely effective and least expensive in enhancing the pest resistance, the yield, and the biological quality of the produce.

In all my years of commercial growing, I have never found any need for pesticides, whether chemical or organic, once I succeeded in creating growing conditions that optimized the physical well-being of the crop. Those conditions are not the same for all crops. I have had to experiment and observe. But in no case did the creation of those ideal conditions require more than the minimal resources of a small farm, or more than a reasonable understanding of soil science and agronomic principles. What it did require was a thought pattern that approached the problem from the point of view of cause correction rather than symptom treatment.

Many of today’s conservation and environmental organizations mention organic farming as an answer to the pesticide problem without any real

understanding of how it functions or how well it could function. It is held out as something akin to a fairy godmother. I'm reminded of the two customers walking up to my market stand one August. They were just abreast of our asparagus field. The asparagus fern was beautiful and green and about six feet tall. They had obviously been discussing the merits and demerits of organic agriculture because as they came in view of the asparagus field, one grabbed the other's arm and said: "There, I told you organic farming was sensational. Look at that dill!" It wasn't dill, but it was sensational.

Am I always successful? No. I occasionally don't get conditions right and the insects will appear to tell me so. But we are pretty consistently successful growing almost all crops pest free. My occasional glitch is not surprising given that these are basically seat of the pants techniques that I have arrived at through years of experimentation.

There are a lot of variables. Composts need to be mature and some are better than others. A year-old well-decomposed mixture of horse manure and straw is almost magical most of the time. We are near the ocean and can bring in a lot of seaweed. But that is not a panacea for all crops and can actually be detrimental for some the first year it is incorporated in the soil. Tilled under autumn leaves have a very beneficial effect on brassica crops, as do leguminous green manures. But for some vegetables I prefer a grass pasture as the preceding crop in the rotation because of the beneficial effect of the decomposed grass roots. The only pest I have not yet fully prevented through improved growing conditions is the Colorado Potato Beetle on potatoes. That is the last great puzzle on this farm. The beetles seem not to have read the same literature I have read. We control them reasonably well for the moment with the desiccating effects of inert rock powders like finely ground basalt dusted over the plants (Ebeling, 1971). I continue to experiment.

I don't consider any of the techniques that work for me to be universal panaceas. Our experience merely indicates that cultural practices can successfully enhance pest resistance (as that long list of researchers I quoted earlier also noted.) My hope is to see today's university researchers become curious about the successes of organic farmers and begin studies to determine how it all works and how to make it universal.

We need to begin studying the natural systems of agriculture from the point of view of aiding and enhancing the positive factors of plant growth, rather than only focusing on what we have determined is negative. The experience of organic farmers demonstrates clearly that when we accentuate the positive, we simultaneously eliminate the negative.

400 years ago, while struggling to change the prevailing view of cosmic patterns, Galileo realized that the popularly accepted idea of the earth at the center of the solar system was so established that he would have to "mold anew

the brains of men" in order to make any headway towards another reality. The change I am proposing -- from a preoccupation with pest destruction to a focus on plant construction -- requires a similar remolding. But it is a change that will allow us to seriously research and quantify the successes of real organic growers and make them understandable and accessible to all farmers.

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