FRONTIERS of Plant Science

FALL 1996
Volume 49 No. 1

Pierre Bennerup speaks at Lockwood Farm

Redefining horticulture in the 21st Century
Integrated approach helps manage weeds
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ISSN 0016-2167

Redefining horticulture in the 21st Century

By Pierre Bennerup, President
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Alexis de Tocqueville, the great French writer on political affairs, toured Connecticut in the 1830s. He was astounded and dismayed that the landscape had been totally denuded. An occasional tree stood by a house here and there. Elsewhere they were gone. The great virgin forests of the pre-colonial days had been decimated. Less than 5% of Connecticut was forested and even that was secondary growth. Over 90% of the population depended on farming. Every available acre was farmed if it could be.

Today, less than 5% of our land is farmed in one way or another. We have over 20,000 miles of roadways. Add to that all our buildings, driveways, parking lots, etc., and you will discover that more of our land is covered by human construction than by cropland. In dollar volume, horticulture has become the largest component of Connecticut agriculture, producing over 40% of our dollar volume by best "guesstimate". My "Best Guesstimator" in this case is Larry Carville, Executive Secretary of the Connecticut Nurseryman's Association. He has also contributed some additional information from Bob Heffernan, Executive Secretary of the Connecticut Greenhouse Growers. In rough figures, the state's horticulture industry contributes $600 million of wholesale product to our coffers. About $400 million of that comes from outdoor tree and plant growers, $100 million from bedding plant growers and $100 million from cut flower and other miscellaneous growers. Revenues generated by landscapers and retail garden centers would bring that to over $1 billion. That is about 5% of the $20 billion national total.

So, here we are sitting on this thin, "boney" plot of land, the third smallest state in the country, just over 1% of our nation's population, and we're doing over $1 billion worth of horticulture business on about 1% of our land. How do we do this? Federal subsidies? No. Smoke and mirrors? No. Just dumb luck? No. Statistical aberration? Maybe, but not likely.

We do it because our meager, minimalist situation has forced us to deal, not with our hands, not with our lands, but with our minds. For example, Sunny Border Nurseries has a small tissue culture lab. This lab accounts for less than 10% of our total production. We clone plants in test tubes. Our so-called growing chamber is about 200 square feet. In that space, two women produce about 200,000 plants a year. At an assumed value of $1.00 each, that translates to $1000 per square foot, a lot more than an average acre of wheat produces in Kansas. (43,560 square feet in an acre times $1000 works out to be $4,356,000 gross revenue per acre.).

No, all Connecticut nurseries are not that productive, mine included. But we are very, very productive. What has happened in Connecticut, with great help from this experiment station, is no less than a revolution in growing techniques during the last 50 years. Our soils are less than perfect so we've learned to grow in containers in which we recycle a whole range of waste products which otherwise might be clogging our landfills. This experiment station has been instrumental in that research. Fifty years ago plants and trees had to be fresh dug in the field before they could be sold. Because we learned to containerize, our plants and trees go to market ready to sell. Connecticut has led in the marketing of such plants, two out of three of which go out of state, thus bringing valuable revenue into the state. I think it is safe to say that we produce more varieties of plants of better quality in less space than any other state in the United States. We have done this without federal help but, fortunately, with the help of the experiment station.

When the Midwest and the Plains states opened up in the 19th Century, Connecticut farmers found they couldn't compete with Kansas on wheat or Iowa on corn, etc. We did have the advantage of being in the East, near the centers of population. We could still compete with perishable crops such as dairy products, fruits and vegetables which could be sold locally. But when methods of preserving and shipping foods became more sophisticated during the first half of this century, thousands of Connecticut farms were abandoned and allowed to go back to forest. At the turn of the century we had about 50,000 farms. By 1950 there were fewer than 10,000 left. Today there are only about 3000 farms, many of which are part-time.

Why has the nursery business come to be such a large part of agriculture in Connecticut? It all boils down to money. We can produce more dollar value of product per man hour on less space than anyone else and we do it better. Our nurseries have adopted beneficial technology as soon as it has become available and in many cases we have initiated it. Our Connecticut Yankee ingenuity has never led us to assume that good can't be made better and we're usually the first ones to figure out how to do so. Often these improvements have come with the help of this experiment station.

Now, I'm supposed to be redefining horticulture for the

Samuel W. Johnson Memorial Lecture delivered Plant Science Day, August 2, 1996 at Lockwood Farm in Hamden.

21st Century. Instead I've told you everything that's already happened, which most of you already know anyway. But I have to tell you one more thing before I get out my crystal ball. Gardening is by far and away the most popular American avocation. According to the National Garden Bureau, more time and money are being spent on gardening than on any other hobby. Furthermore, gardening is steadily growing in popularity. I don't know why gardening has become so popular. Maybe all those farmers who abandoned their farms earlier in the century are getting homesick. Then again, maybe millions of people are looking for any sane relief from the computerized madness of today's work world. Whichever, we nursery men and women stand ready to rescue you all from your travails and hopefully to rescue a bit of your money in the process.

So what is horticulture anyway? *Horticulture is the art of cultivating gardens.* Simple, isn't it? Horticulture is the art of cultivating gardens. The key word here is "art". Look at it this way. The plants are the paint; the soil is the canvas. Your job is to paint the picture. Thereby, you will redefine gardening in the 21st Century, not me. You will do it with our "paints", the new and better plants that we will introduce. Some of you will take up perennial gardening, some will go into herbs, some will do water gardening, others will create moss and fern gardens, still others will build alpine rock gardens, some will garden with native plants, some only with trees and shrubs, while others will specialize in exotics. Gardening, just like all art forms, is constantly redefining itself. It is your job to redefine it for us and for yourselves.

Let me just spot the main trends: native American plants will play an enormous role in the future of garden design and consequently in nursery production. Our own native "forbs", (you will begin hearing a lot of this word), or local plant populations, will be featured in "ecologically sound" gardens. A whole new concept of design has already sprung up over a fairly simple concept. Over the millennia native plants have adapted themselves to the idiosyncrasies of our very unforgiving climate. Plants from other parts of the world have not. Additionally there is a sense that these are our plants and we should not allow foreign interlopers to claim their place.

The second trend to note revolves around the word "natural". We are in process of rejecting highly stylized European design concepts, many of which are very labor intensive. There will be a notable trend to natural meadow planting and woodland enhancement. Such plantings require nothing more than supplementing "forbs" to an existing situation, all of which is relatively labor free.

Finally, flowers and flowering plants will continue to gain serious ground in popularity as opposed to trees and woody ornamentals which will show steady but minimum growth. The "woody" growers have always thought that the trend to color is a passing fad. It is not. By the year 2000, flowering plants will outsell woody plants at every level.

My prediction? Horticulture will become a much bigger deal in the 21st Century. In Connecticut it will begin to rival tourism and gambling as our biggest money earners. The whole world will flock here to tour, to gamble and to garden. We intend to be in the middle of it.

An integrated approach helps manage weeds in nurseries

By Todd L. Mervosh

Weeds compete with other plants for water, nutrients, and light. In dry summers such as in 1995, weeds become even more serious pests because they are adapted to extreme conditions and compete vigorously for soil moisture. In addition, they can harbor insects and pathogens that may spread to nursery stock. Another important consideration for nurserymen is that weeds detract from the appearance and marketability of ornamental plants.

Successful weed management requires proper identification of weeds and an understanding of their growth habits and life cycles. For example, an annual weed may germinate from seed in the spring (summer annual) or in the fall (winter annual). Perennial weeds may propagate by seed or spread via underground rhizomes. Knowledge of these characteristics will help in planning a strategy to manage weeds. If chemical controls are being considered, the biology of the problem weeds will dictate herbicide selection and the appropriate application rate and timing.

Manual weeding is the oldest and simplest weed control practice. However, it is slow, tedious work that is labor intensive. In addition, plants can be damaged as weeds are pulled from containers or hoed in the field. Weeding between rows of plants with tractor-drawn equipment is more efficient in terms of time and labor, although equipment and fuel costs add up. Cultivation helps loosen the soil between rows, but it may accelerate moisture loss and soil erosion.

Figure 1. Todd Mervosh checking weed plots at Lockwood Farm.

Also, weeds within the plant rows are those that compete most with the plants being grown, but these weeds cannot be controlled by cultivation. Cultivating too closely can damage the crop.

Although the weed problems and control options for ornamentals grown in the field and in containers are different, prevention and sanitation are important components of weed management programs. Controlling weeds surrounding production areas will keep perennial weeds from encroaching and reduce the number of weed seeds that blow in. For example, each horseweed (*Conyza canadensis*) produces thousands of tiny wind-dispersed seeds. Thus, removing horseweed or other weeds before they produce seeds can greatly reduce future weed populations.

Mulches and cover crops offer many benefits to nurserymen. Organic mulches (bark, pine needles, composted leaves) suppress weed growth, conserve soil moisture, and protect the soil from erosion. Black plastic, or perforated matting (which facilitates drainage), is commonly used to prevent weeds in container production areas although weeds can emerge through tears and holes. In the field, small grain or vetch cover crops can be used as a "living mulch" to protect soil and suppress weeds. However, cover crops need to be managed or they may compete too vigorously with the nursery stock.

Herbicides can provide a high level of weed control and reduce the need for cultivation and/or hand weeding, thereby minimizing labor costs. The larger the nursery, the more cost effective herbicides become as an option. For some troublesome weeds, especially spreading perennials, herbicides may provide the only practical control measure. However, herbicides must be used properly to avoid plant injury or environmental damage.

Integrated weed management implements multiple strategies to manage vegetation. Mulches may suppress weeds enough that the few that emerge can be hand pulled, hoed, or spot treated with a herbicide such as Roundup (glyphosate). A cover crop, such as oats planted in early fall between rows of nursery stock, helps control soil erosion and suppresses growth of winter annual weeds. The oats will die during the winter and provide a mulch effect into the spring. Another example of integrated weed management is the practice of applying herbicides in a band within the plant row instead of over the entire field. Periodic cultivations are used to control weeds between the rows. Such an approach greatly reduces the need for hand weeding and requires less chemical input than does a broadcast herbicide application.

Because few herbicides are labeled for use on most ornamental crops, growers are limited in their weed control options. I am currently evaluating new herbicides for potential use in nursery production. A new herbicide may safely control a troublesome weed, such as yellow nutsedge (*Cyperus esculentus*) or mugwort (*Artemisia vulgaris*), and therefore be valuable to nurserymen. Most herbicides registered in recent years are active at lower rates than older herbicides, such as simazine. Thus, less chemical is needed to control weeds. Also, newer herbicides tend to have very low toxicity to animals and low water solubility, which minimizes chemical leaching through soil or potting media.

Along with Dr. John Ahrens, weed scientist emeritus, I am evaluating the efficacy of two new herbicides, sulfentrazone and halosulfuron, for preemergence weed control and safety to yew (*Taxus cuspidata*), arborvitae (*Thuja occidentalis*), hemlock (*Tsuga canadensis*), juniper (*Juniperus horizontalis*), and rhododendron (*Rhododendron catawbiense*). Halosulfuron is already registered in corn, soybeans, and turf, and sulfentrazone will soon be approved for use in soybeans, tobacco, and some ornamental crops. Both herbicides control sedges and various broadleaf weeds at rates lower than most current herbicides. Gallery (isoxaben), a preemergence broadleaf herbicide registered for many ornamentals, was included as a standard treatment. Sulfentrazone (0.125 to 0.5 lb/acre), halosulfuron (0.03 to 0.125 lb/A), and isoxaben (0.75 lb/A) treatments were sprayed over field plots at the Valley Laboratory containing all five species in early June of 1995 and 1996. The plants were actively growing, thus the potential for injury was greater than if treatments were applied when the plants were dormant.

Gallery did not injure any of the ornamentals, nor did sulfentrazone except for temporary injury of hemlock foliage. In contrast, halosulfuron caused severe yellowing and growth reduction in yew and, to a lesser extent in arborvitae and rhododendron. Initially, all treatments prevented emergence of annual sedge (*Cyperus* sp.), which was extremely dense and competitive in untreated plots. Sulfentrazone controlled annual sedge for the entire growing season; residual control from halosulfuron lasted about 2 months, and from isoxaben 1 month. No treatment adequately controlled large crabgrass (*Digitaria sanguinalis*) or prostrate spurge (*Euphorbia supina*). Two months after treatment with isoxaben, broadleaf weed densities were 50 to 80% lower than in untreated plots. Halosulfuron provided the best control (>85%) of horseweed (*Conyza canadensis*), but it had poor activity on other broadleaf weeds. Sulfentrazone prevented the emergence of purslane (*Portulaca oleracea*), carpetweed (*Mollugo verticillata*), and lambsquarters (*Chenopodium album*). In general, sulfentrazone provided the best weed control with negligible injury to the ornamentals. Although more research is necessary, sulfentrazone may become a useful weed management tool for nurserymen.

Successful weed management in nurseries is accomplished by the integration of multiple approaches to minimize undesirable vegetation. The focus of my research is to provide nurseries with economically and environmentally sound weed management options.

Quantifying the probability of apple scab fungus infection to improve disease management

By Donald E. Aylor

Apple scab is the most serious disease of apples in Connecticut and must be controlled in order to produce marketable fruit. Scab is caused by a fungus (*Venturia inaequalis*) that attacks the fruit and leaves of apple trees. On fruit, the lesions appear as scabs, which can cause the fruit to deform and crack. Often, secondary rotting pathogens enter these wounds and completely destroy the apple.

Venturia inaequalis survives the winter as small black fruiting bodies the size of finely ground pepper in apple leaves on the orchard floor. The fungus subsequently spreads by two types of spores. The first type are ascospores which begin to emerge in the spring at a time corresponding roughly with the emergence of the first green apple tissue. These ascospores are carried by the wind to the developing leaf and fruit buds, on which they cause primary infections. Once lesions are established on new leaves, the fungus produces a second type of spores, called conidia. These can cause numerous new infections, and increase the severity of the disease. This disease buildup establishes colonies that eventually return to the ground on fallen, infected apple leaves and survive the winter to begin the cycle anew the following spring.

The best way to control apple scab is to minimize the number of infections caused by ascospores released from infected leaves on the ground. My research focuses on quantifying the probability of scab infection in terms of the amount of inoculum carried over winter from the previous season. Quantifying the probability of infection allows more flexibility in making decisions about controlling apple scab.

Several methods are currently used to try to determine the beginning and end of the ascospore release season. In one method, the fungus fruiting bodies (pseudothecia) are removed from a leaf using a scalpel and examined using a microscope. These examinations give a kind of snapshot of the number of mature ascospores present at the time. Another method involves collecting leaves from the orchard. These sample leaves are wetted in the laboratory to simulate rain, and to initiate ascospore release. The spores are trapped on a sticky surface, and counted using a microscope. The third, and most direct method, is to monitor actual airborne ascospore concentrations in the orchard. This method, however, requires specialized equipment and considerable effort.

My approach is to develop a mathematical model that incorporates information on aerial dispersal of *V. inaequalis* ascospores and their infection efficiency on apple tissue at various stages of development. The model, when completed, can be used to calculate the probability of primary infection as the ascospore-release season progresses, which corresponds roughly to the time when the first green tissue emerges from the buds (green tip) through the time when the flower petals fall (petal fall) and early fruit development.

The risk of scab infection depends on several factors: 1) the total number of ascospores available for dispersal throughout the season (which directly reflects the amount of disease that was present at the end of the previous season); 2) the fraction of the available ascospores that get into the air; 3) the amount of dilution by the wind, and losses of spores from the air due to washout by rain and by deposition on non-target areas during aerial transport; 4) the efficiency of deposition of ascospores on susceptible apple tissue; and 5) the amount of susceptible apple tissue per unit ground area and the infection efficiency of ascospores. These factors are addressed by my mathematical model of spore transport.

All of these factors change as the growing season pro-

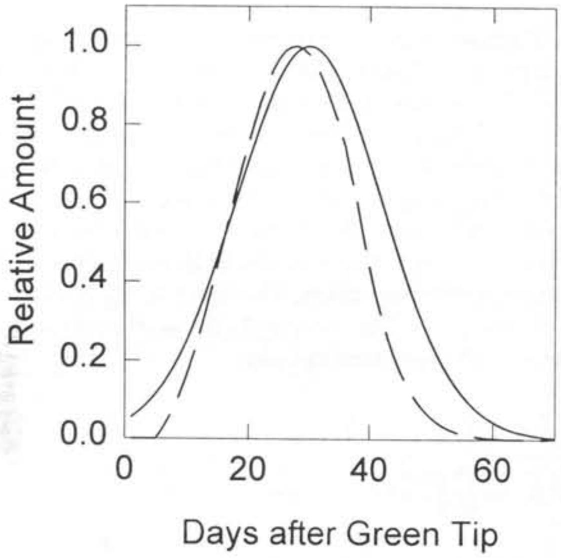

Figure 1. Relative amount (of the total in the source leaves) of ascospores ready to be released (solid line) and the relative amount of risk of infection (dashed line) over the course of the ascospore release season.

gresses. For example, all of the ascospores are not available at once, but become gradually available as they mature over several weeks. The maturation rate of ascospores first increases, reaches a peak, and then decreases over the season. The maturation process extends roughly between green tip to the time when developing fruit are about 1 inch in diameter for McIntosh apple trees. During this same time, the area and susceptibility of the apple tissue both change dramatically as the developing apple buds and shoots unfold and expand. The amount of susceptible apple tissue area also increases at first, reaches a peak, and then declines as leaves age. In addition, the inoculum-harboring leaf litter on the ground breaks down due to mechanical and biological forces, and thus the effective inoculum supply decreases during the season. I combined the time course of these changes in ascospore maturation, susceptible leaf area, and leaf litter in a simple model to estimate risk, and compared this "risk" curve to the time course of the maturation of ascospores. The comparison suggests that chemical control measures might be reduced both in the early and the late part of the ascospore release season. The success of such a strategy depends on the amount of overwintering inoculum, and its relationship to the concentration of ascospores in the air in the orchard. I am developing a mathematical model of spore transport to help quantify these factors and allow prudent management decisions for control during the early and late part of the ascospore release season.

Figure 2. The author inspects a spore sampler used to collect ascospores in the orchard.

For our modeling effort to be successful, we must be able to predict the number of infections that can potentially develop (under the most favorable weather) on plants exposed to known concentrations of spores in the air.

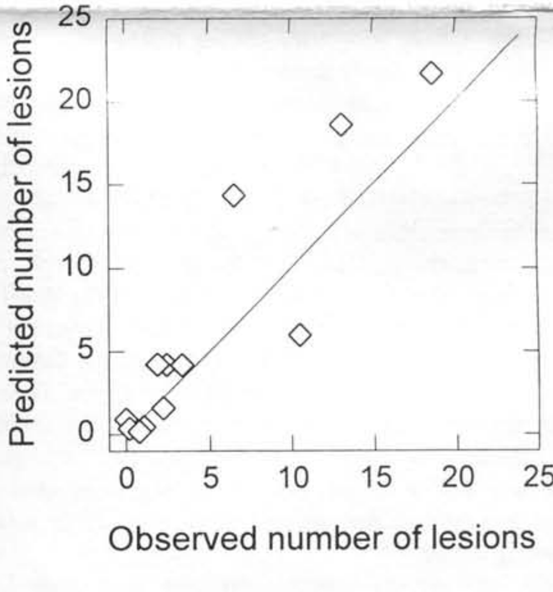

Figure 3. The relationship between the observed number of lesions per shoot and the number predicted by the model.

My colleague Dr. Richard Kiyomoto and I performed field and laboratory experiments designed to estimate the number of scab infections likely to be initiated by exposures to known concentrations of *V. inaequalis* ascospores in the air. To do this, we compared the number of scab lesions that

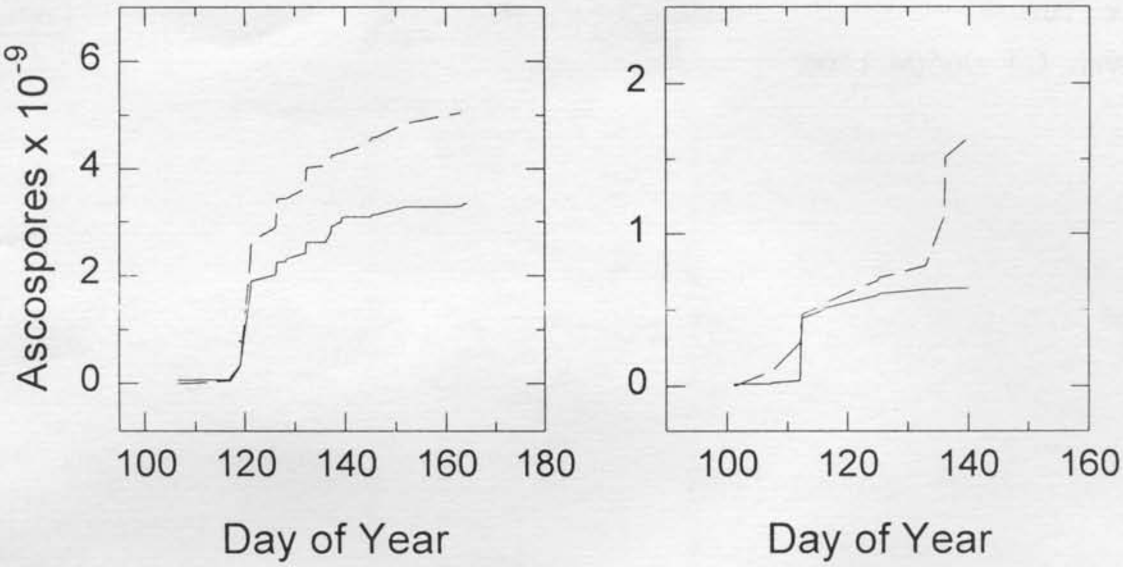

Figure 4. Comparison of the cumulative number of ascospores obtained by field measurements (solid line) and that obtained from the results of the laboratory experiments (dashed lines). The left panel shows results for a source in a grass field and the right panel for a source in an orchard.

developed on leaves of potted McIntosh "trap" trees exposed outdoors with the airborne concentration of ascospores sampled close to the trees. Ascospore concentrations in the air, C (number of spores per cubic meter of air), were monitored using spore samplers.

Following the exposure to ascospores in the orchard, the trees were incubated under controlled conditions until scab lesions developed and the number of lesions per shoot was recorded for each tree. We found a strong positive relationship between the number of lesions and the exposure to ascospore concentration (C x exposure time). To further quantify this relationship we needed to know the lesion-causing efficiency of ascospores, E; that is, how many ascospores (on average) it takes to cause one scab lesion.

The lesion-causing efficiency of ascospores was determined in the laboratory by inoculating individual leaves on potted McIntosh trees with known numbers of ascospores. E was found to depend strongly on leaf age. The most susceptible leaves were those aged approximately 3 to 5 days after unfurling from the shoot. For these young leaves, it took, on average, about five ascospores to cause one lesion (making E equal to 0.2 lesions/spore). The susceptibility of leaves to infection decreased dramatically as they aged. For example, it took nearly 70 ascospores to cause a lesion on leaves that had been unfurled from the bud for 15 days or more.

We used the mathematical spore transport model to estimate the deposition (number of spores per unit area of tissue) of ascospores onto susceptible leaves for a given exposure to ascospores in the air. These calculated values of spore deposition were combined with values of E and with the measured areas of susceptible leaves to estimate the number of lesions likely to develop. The number of lesions estimated using the model were well correlated (r=0.83, $P <$ 0.01) with the number actually found on trees exposed in the field. This good agreement with field observations encouraged us to take the next step in developing the model.

If we had a way to predict the concentrations of ascospores in the air, we might be able to predict infection probabilities. My colleague Jie Qiu and I studied the relationship between the amount of fungal inoculum overwintering in the apple leaves on the ground and the concentrations of ascospores in the air using two independent methods. In the first, we measured the number of airborne *V. inaequalis* ascospores released from a ground level source. We determined the number of ascospores carried by the wind at several heights above the ground by measuring ascospore concentrations and values of the horizontal wind speeds. We used spore samplers to measure ascospore concentrations and anemometers to measure wind speeds at several heights above the ground near the center of the source. The highest concentrations of airborne ascospores occurred close to the ground and early in the season, with the majority of the spores being released before flower petal fall on our McIntosh apple trees. The concentration profiles and wind speed profiles were combined to yield the number of ascospores per second carried past our samplers by the wind, that is, these gave vertical profiles of the horizontal flux of ascospores. The vertical integration of these flux profiles yielded a direct measure of the number of ascospores released from the source upwind of the sampler locations.

For our second measurement method we used a laboratory test to see how many ascospores could be released from

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samples of leaves. Twice a week, throughout the season, we collected leaves from the ground where we were making our field measurements. When the leaves were wetted, they released the ascospores that were mature at the time, and these were counted. These laboratory tests yielded rates of spore release per leaf throughout the field season. At the same time, we counted the number of source leaves per unit of ground area in the source. This allowed us to estimate the potential release of ascospores from the sources. Finally, we used the fundamental law of nature that airborne ascospores are neither created nor destroyed to obtain a relationship between the number of spores released by the source and the number of spores airborne above the source.

We then compared our estimates of airborne ascospores using the first method with potential spore release obtained using the second method.

The two independent methods yielded values for the cumulative total seasonal release of ascospores which agreed well for sources in a grass field and an orchard of dwarf apple trees (to within a factor of two for a source in a grass field and to within a factor of three for a source in an orchard of dwarf apple trees). These results show that the laboratory method can give a reasonable estimate of the number of ascospores released over time, and will aid in modeling disease spread, and in making management decisions about when fungicides may be needed to control the disease. The good agreement between the micrometeorological field method and the biological method is also encouraging for further development of my aerial spore dispersal model.

My model is still under development and requires more testing and calibration to be quantitative. In the meantime this approach yields some useful qualitative interpretations, as for example those depicted in Figure 1. These results point to the possibility of shortening the primary scab control season. Caution is warranted, however, because these findings indicate relative (not actual) risk of infection. Thus, relaxation of control measures may not be warranted if inoculum levels are high in the orchard or in neighboring trees. I am pursuing my modeling efforts to add quantitation to these suggestions and to help answer the question "How high an inoculum level is too high for delaying initial sprays and/or foregoing a late season spray."

Understanding these interactions between the host, the pathogen, and the weather allows us to design better and more effective disease control strategies. Integrated crop management aims to use the best available biological and physical information to produce a high quality and profitable crop with the minimum possible impact on the environment. By quantifying the probabilities of apple scab infection in terms of the amount of overwintering inoculum, my model should help growers evaluate the extent to which scouting, sanitation measures, and ground cover management might reduce the need for fungicides in disease management and afford them with more and better options for control.