FRONTIERS of Plant Science

FALL 1993
Volume 46 No. 1

Bruce P. Bickner speaks at Lockwood Farm

Hybrid corn, past, present, and future

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ISSN 0016-2167

1993 Samuel W. Johnson Lecture

Hybrid corn, past, present, and future

By Bruce P. Bickner
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My topic today is hybrid corn, which *Time* magazine has called one of the most important achievements of the past 1,000 years. Since the advent of hybrid corn in the 1930s, corn yields have quadrupled, allowing a smaller number of farmers to produce bigger and bigger crops. With fewer farmers needed, Americans have migrated to cities in droves, changing forever the fabric of our society.

Here in Connecticut, we're a long way from the Corn Belt, but it was Connecticut researchers who were responsible for developing hybrid corn. In 1908, Edward Murray East produced the first single-cross hybrids at The Connecticut Agricultural Experiment Station in New Haven. His best hybrids yielded an astounding 202 bushels per acre more than the open pollinated corn in his plot. Ten years later, the world's first double-cross hybrid corn was grown right here at Lockwood Farm by Donald Jones, one of Dr. East's students.

For those of you who may be unfamiliar with the terms, hybrid corn is a cross of two or more unrelated lines of corn. The offspring of this cross exhibits traits from both parents. But more important, the hybrid benefits from a unique phenomenon called "heterosis," or hybrid vigor. This vigor is the key to hybrid corn productivity.

Before hybrid corn was developed, corn was open pollinated. In other words, farmers saved part of their harvested corn seed to plant the following spring. Today, they buy hybrid seed from companies such as DEKALB. In less developed parts of the world, however, farmers still use open pollinated corn.

All modern hybrids are produced by crossing two inbred lines. This is called a single cross. Early corn hybrids were made by crossing *four* parental lines, but single crosses were found to be more productive. DEKALB was the first company to market large quantities of single-cross hybrids in the 1960s.

Today, when 100 percent of the corn grown in this country is hybrid, it's hard to imagine that hybrid corn was once considered a radical, even foolish idea. Yet, when DEKALB began research into hybrid corn in 1924, our research was kept a complete secret for four years.

Tom Roberts Sr., the founder of the DEKALB Agricultural Association, and Charlie Gunn, the company's first corn breeder, decided to look into hybrid corn after a visit from Henry C. Wallace, then Secretary of Agriculture. Wallace told them about the work of Edward Murray East and others, mentioning that his son was also experimenting with hybrid corn. That son, Henry A. Wallace, went on to found Pioneer Hi-Bred, our chief competitor.

While Roberts and Gunn were excited about the potential of hybrid seed, they decided to keep their work under wraps until they had gained some confidence. When they finally showed their first experimental hybrids to the DEKALB Board of Directors in 1928, one promptly called the project "hogwash." He resigned from the board, convinced that hybrids would never replace good open-pollinated corn.

Time has certainly proved him wrong, but it wasn't easy in those early years to produce, market and promote hybrid corn. The challenge was made even tougher by the Depression, when farmers, along with everybody else, were struggling. Yet Tom Roberts Sr. persisted because he believed in the potential of hybrid corn.

DEKALB advertised its hybrid corn seed as "The Mortgage Lifter," and that's the origination of our logo, which pictures an ear of corn with wings. Nearly 60 years later, we're proud to use the same logo, and we're still working to improve our farmer-customer's profitability.

In 1934, DEKALB produced its first crop of commercial hybrid seed—only about 500 bushels. Roberts and Gunn felt lucky to produce even that small amount because drought had scorched the Midwest that summer. The next year, Roberts planted 310 acres—the largest hybrid corn field to date—and built a plant capable of processing 50,000 bushels of hybrid seed. During the late 1930s, Roberts engineered the construction of five more processing plants throughout the Midwest. His faith in hybrid corn was well-placed. As farmers became familiar with the benefits of hybrid seed corn, they wanted all they could get.

As demand grew, Tom Roberts developed an innovative way of marketing hybrid seed. The company selected prominent farmers who were using DEKALB seed on their

Figure 1. Retired Experiment Station Director James G. Horsfall, left; former Vice President of U.S. Henry A. Wallace, center; and Donald F. Jones, former Chief Geneticist at the Station and originator of the practical double-cross corn hybrid at Lockwood Farm in 1955.

own farms and asked them to become dealers. These farmer/dealers called on their neighbors for orders, took delivery of the seed, secured payment, and then paid DEKALB. In an updated form, this system is still widely used by seed companies.

DEKALB also developed a partnership with farmers to produce hybrid seed corn. We contracted with farmers to grow certain hybrids, paying them for half of their fall harvest in December and for the other half the following spring. Because they invested their land and their labor in producing seed for DEKALB, these farmers, in essence, helped carry the company's inventory costs. This partnership—which still exists today—has been critical to the economics of the seed industry.

By 1942, Iowa became the first state to plant its entire corn acreage to hybrid corn. That same year, our nation's farmers produced the first 3 billion bushel corn crop.

Other milestones quickly followed. By 1959, the nation's corn crop reached 4 billion bushels, and by 1970, 5 billion bushels. Last fall, American farmers produced a record 9 billion bushels of corn; approximately one-half of the total world production. Most of the corn will be consumed by livestock, either here in the United States or abroad. These yield gains over the years are remarkable, and most of them are due to improved genetics. Improved cultural practices (fertilizer, weed control and plant density) have also played an important role.

However, higher corn yields haven't come without a significant cost. At DEKALB, for example, our research budget was a mere $50,000 in 1936. This year, DEKALB will spend over $27 million on corn seed research, roughly equal to 13 cents out of every sales dollar.

We have greatly increased the scope of our breeding programs over the years. In 1970, we had nine corn breeding programs. Today, we have 36, located across the United States Corn Belt, South America, Europe, Mexico, and Asia. We've also added support programs in pathology, entomology, statistics, physiology, germplasm, and biotechnology.

Our corn breeders use genetic selection to improve the plant traits that are most important to farmers. These traits include yield, moisture content at harvest, standability, drought tolerance, and resistance to disease and insects.

Traditional corn breeding is a time-consuming process. It takes between seven and 10 years before a commercial hybrid can reach the marketplace. Nonetheless, traditional corn breeding continues to be very effective. In each year, our research program develops new hybrids that offer meaningful performance advantages to farmers. This spring, for example, we introduced 13 new corn hybrids to the market.

Can the industry continue to increase corn yields even more? If so, where will the gains come from? The consensus among agricultural experts is that most future yield gains are likely to come from genetics. This is partly because many cultivation techniques have reached their practical limits.

Agricultural experts also agree that biotechnology is almost certain to drive the next leap in productivity. Already, scientists are using biotechnology tools to develop the corn hybrids of the future. Most of this research is being conducted by the private sector. Unfortunately, resources are limited at colleges of agriculture, which have been dealing with flat to declining budgets for years.

At DEKALB, biotechnology research is conducted just 45 miles from here in Mystic. There we opened our new Discovery Research Center last fall to accommodate our growing biotechnology program.

It was important to us to keep the research center here in Connecticut. When our former facility in Groton could no longer meet our needs, we discussed relocating our biotech program to the Corn Belt. However, our Connecticut staff was second to none, they wanted to stay here, and we wanted to keep them with DEKALB.

In 1990, our biotechnology research team made headlines when it succeeded in transforming corn. This accomplishment was the culmination of more than a decade of research. Corn transformation demonstrated to agricultural scientists worldwide that biotechnology could be used to improve field crops of major economic interest.

Corn transformation is one of the two main biotechnology tools used by DEKALB scientists. Simply put, transformation is the process of transferring foreign genetic material into corn cells. The desired trait is then expressed in the corn plant and passed on to the next generation. Corn transformation allows researchers to isolate useful genes from any living thing and place them in corn. By contrast, traditional corn breeders can cross only closely related species.

The other biotechnology tool that we're using at DEKALB is DNA marker technology, also known as gene mapping. DEKALB was the first company to apply DNA marker technology to the development of superior corn hybrids. With this technology, we are seeking to identify and mark the location of genes for insect and disease resistance. Because corn has more than 40,000 genes, this is no easy task.

With an improved ability to both identify and manipulate genes of special value, we are well-prepared to custom design new corn hybrids. We are focused on improving corn hybrids in four primary ways:

- Developing resistance to herbicides
- Developing resistance to insects
- Increasing drought tolerance, and
- Enhancing the nutritional value of corn

The first DEKALB genetically-engineered hybrids on the market probably will be those with herbicide resistance. At present, farmers use herbicides on more than 95 percent of United States corn acreage. Farmers use these herbicides because weed competition is a major factor in limiting corn yields.

Unfortunately, however, prolonged use of some of these chemicals builds residue in the soil and pollutes groundwater. The good news is that several broad-spectrum herbicides have recently been developed that control weeds with little impact on the environment. The bad news is that these compounds not only rid fields of unwanted weeds, they also kill corn!

We are working to overcome this dilemma by developing corn hybrids that are resistant to environmentally friendly herbicides. This summer, we are field testing several herbicide-resistant seed corn hybrids. We will test the yield performance of these hybrids both with and without herbicide applications. We would expect to market the first of our herbicide-resistant products in the next three to four years. Such products will give farmers the opportunity to use highly efficient, less environmentally damaging herbicides.

Our second product target is development of corn hybrids with specific insect resistance. Two insect pests—the European corn borer and the corn rootworm—cost United States corn growers more than $1 billion a year in chemical treatment and yield losses. We are using the tools of biotechnology to develop corn that has a built-in resistance to these pests.

One of the avenues we're pursuing is incorporating a natural insecticide into the corn plant. This insecticide is a protein produced by the bacterium commonly known as *Bt*. *Bt* is really nothing more than a common soil microorganism, but it is toxic to certain insects, including the corn borer. Many home gardeners are probably using *Bt* to fight caterpillars. What our researchers are doing is inserting a *Bt* gene into corn so that the corn plant itself produces a *Bt* protein. When the corn borer takes a bite from the corn plant, the insect also ingests this *Bt* protein and is rapidly killed.

This built-in resistance to the corn borer will not only increase corn yields, it will also greatly reduce the need for chemical insecticides. We expect to market these insect resistant hybrids in the late 1990s.

Weeds and insects can be devastating, but the major threat to the corn crop is drought. One of our ongoing goals is developing corn plants that perform well under drought conditions. DEKALB corn breeders working in the field select for genes and traits associated with drought tolerance. Meanwhile, our researchers working in the laboratory isolate drought tolerance genes from microbes and drought tolerant plant species. They then introduce these genes into corn. We would expect to produce hybrids by the late 1990s that are less sensitive to the timing and amount of rainfall or irrigation.

Figure 2. The DEKALB "Mortgage Lifter" logo.

Finally, the DEKALB biotech research team is working to improve the nutritional value of corn. More than half the corn harvested in this country is fed to cattle, hogs and poultry. Because corn lacks nutritionally complete protein, livestock producers must supplement the feed with other protein sources. Using transformation technology, we are increasing the levels of these essential proteins within the grain itself. The result will be corn with added feed grain value.

I hope this description of our biotechnology research demonstrates that hybrid corn has a very bright future. Through biotechnology, scientists can look to almost any living thing as a source of genes to improve corn performance. As corn hybrids incorporate a resistance to herbicides, insects and drought, yields will improve dramatically. At the same time, these new hybrids will protect—and even improve—the environment by reducing the need for agricultural chemicals.

The challenges facing agriculture are great. Today's world population of 5.8 billion is forecast to grow to 8 billion by the year 2020. To keep up with this growth, the world food supply must double. At the same time, less arable land is available, and crop pests continue unabated. Fortunately, however, biotechnology has the potential to meet these challenges and to help hybrid corn productivity take the next leap forward.

Ehrlichiosis, a rickettsial disease, occurs in Connecticut

By Louis A. Magnarelli and John F. Anderson

The first convincing case of canine ehrlichiosis in Connecticut was recognized in 1990. A veterinarian from Milford called us to report the infection in a Brittany spaniel from that town. This dog had anemia and low blood counts for platelets and lymphocytes and a relatively high concentration of antibodies (titer = 1:2,560) to *E. canis*. The dog's health returned to normal after antibiotic treatment. Discussions with the dog's owner revealed that the dog had not traveled out of Connecticut. Based on this and growing evidence in the scientific literature that ehrlichiosis was being reported in several states, we analyzed blood specimens to determine if other dogs and equids in Connecticut had been exposed to ehrlichiae.

Serum specimens from hundreds of dogs and equids were available for analyses. Submitted by veterinarians over the past decade, these samples had been tested as a part of other studies, such as Lyme disease, and had been kept at -60C in a serum bank at the Experiment Station. There were representative specimens from all counties of the state.

We used an indirect fluorescent antibody staining method to determine if antibodies to ehrlichiae were present in sera. Antibodies are proteins produced by an animal's immune system to fight infectious disease organisms. In short, this staining procedure requires the combining of the animal's serum with dead ehrlichial organisms on a glass microscope slide. Special staining reagents are added to complete the reactions, and slides are examined under a fluorescence microscope. If antibodies to ehrlichiae are present in the animal's serum, a fluorescent reaction is observed. Antibody concentrations can then be determined for positive sera by retesting a series of serum dilutions.

Our serologic tests revealed antibodies to *E. canis* and *E. risticii* in dogs and horses, respectively. Of the 60 dog sera screened, 7 (11.7%) were positive. All dogs had fever,

Ehrlichiosis

Ehrlichiosis is a disease caused by rickettsial organisms in the genus *Ehrlichia*. Hard-bodied ticks are known or suspected transmitters of these bacteria to mammals. Of the various ehrlichial diseases, canine ehrlichiosis was the first to be reported in the United States in 1962. Dogs with *E. canis* infection usually present with fever, loss of appetite, and swollen lymph nodes. In more severe cases, a dramatic decline in red blood cells, blood platelets, and leukocytes can occur because the disease organisms tend to infect these and other cells.

Horses also can be infected by ehrlichial agents. In 1985, *E. risticii*, the causative agent of equine monocytic ehrlichiosis (Potomac horse fever), was isolated, identified, and linked to a sometimes fatal illness of equids in Virginia and Maryland. Although numerous *Ehrlichia* agents have been described worldwide (Table 1), *E. canis* and *E. risticii* have the most extensive distribution in the United States and are most likely to occur in Connecticut. The brown dog tick, *Rhipicephalus sanquineus*, has been shown to transmit *E. canis* to dogs in the laboratory, but other tick species, such as American dog ticks *(Dermacentor variabilis)*, may also carry this agent. The tick that transmits *E. risticii* to horses is unknown.

lethargy, weight loss, and/or swollen lymph nodes. Three dogs with these signs and antibodies also had low red blood cell counts. In analyses of equid sera, 17 (9.1%) of 187 samples had antibodies to *E. risticii* at concentrations similar to those noted for dogs (1:80 to 1:320). Clinical records for the horses were unavailable. All positive reactions for dogs and equids indicated that these animals had been exposed to ehrlichiae. However, positive antibody tests do not necessarily mean that the animals had active infections when the blood samples were obtained. Times of initial infection and duration of infection for these animals are unknown.

Dogs and equids that had antibodies to *E. canis* or *E. risticii* lived in inland as well as coastal towns (Fig. 1). There was at least one positive animal in each of the eight counties. Dogs living in the following towns had been exposed to *E. canis*: Darien, Deep River, East Hampton, Madison, Middletown, and Milford. We detected antibodies to *E. risticii* in horses from Berlin, Cheshire, Colchester, Easton, Fairfield, Guilford, Litchfield, Mansfield, Morris, Ridgefield, Scotland, Wallingford, Westbrook, and Westport. Although travel histories were unknown in many cases, we feel that many of these animals probably acquired these infections in the state.

In separate studies, ticks were collected in Connecticut during 1989 through 1991 and were examined for ehrlichiae. We focused on American dog ticks and *Ixodes scapularis* (formerly known as *I. dammini*). The former transmits rickettsial agents that cause Rocky Mountain spotted fever, while the latter species transmits *Borrelia burgdorferi*, the etiologic agent of Lyme disease. These ticks were selected because they are abundant, widely distributed, and are known to feed on a variety of mammals, including humans, dogs, and horses.

Live ticks were used for laboratory analyses. Hemolymph (blood) was collected from an amputated tick leg and placed on a glass microscope slide. Preparations were tested with a special antibody reagent for *Ehrlichia* species and examined under a fluorescence microscope. We observed rickettsialike microorganisms in blood cells from 59 (9.7%) of 609 *I. scapularis* nymphs and adults and from 5 (6.9%) of 73 *D. variabilis*. The infected ticks were collected from numerous scattered sites throughout Connecticut. Although the rickettsialike organisms reacted with reagents for ehrlichiae, we are unable at this time to conclusively identify them as members of the genus *Ehrlichia*. Isolation of organisms from ticks or mammalian hosts and subsequent characterization by serological and molecular procedures are ultimately required to properly identify infectious

Table 1. Ehrlichial organisms that may infect mammalian hosts in Connecticut.

Ehrlichia species	Hosts	Geographic distribution	Likelihood of Occurrence in Connecticut
E. canis	domestic & wild dogs	worldwide	probably present
E. chaffeensis	humans	southern & eastern U.S.	possibly present
E. equi	horses	Europe and U.S.	possibly present
E. ewingii	dogs	southern U.S.	possibly present
E. phagocytophila	sheep and cattle	Europe	possibly present
E. ondiri	sheep and cattle	Kenya	probably absent
E. platys	dogs	eastern & midwestern U.S.	possibly present
E. risticii	horses	North America, Europe	probably present
E. sennetsu	humans	Japan, Malaysia	probably absent

Note: *E. equi* and *E. phagocytophila* are thought by some scientists to be the same organism.

agents. Such studies have begun.

Although ehrlichiosis is primarily a veterinary problem, human ehrlichiosis, a relatively mild and chronic disease, is reported in the United States. Cases have been documented in southeastern and eastern states extending as far north as New Jersey. The causative agent is *E. chaffeensis*. Similar to veterinary ehrlichiosis, persons with *E. chaffeensis* infection usually develop fever and have low blood counts for red blood cells, platelets, and lymphocytes. With abundant tick populations in the Northeast and an apparent widespread distribution of human ehrlichiosis in the United States, studies have been initiated to determine if *E. chaffeensis* infects ticks and humans in Connecticut.

We conclude that canine and equine ehrlichiosis occur in Connecticut, albeit at low prevalence rates. We have found that conducting serological tests for antibodies can help diagnose these diseases and identify sites where ehrlichial infections may have been acquired. Moreover, our finding of rickettsialike organisms in the blood cells of ticks has provided a clue as to possible transmitters of ehrlichial agents.

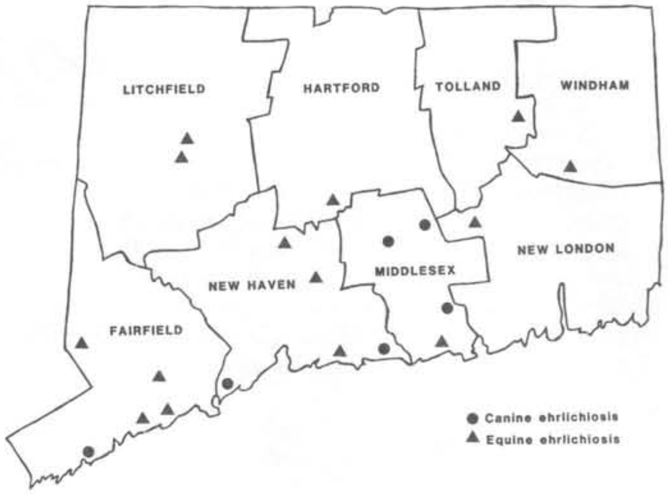

Figure 1. Locations in Connecticut where dogs and horses lived and may have been exposed to *Ehrlichia canis* or *Ehrlichia risticii*.

The challenge of controlling diseases in the greenhouse

By Sharon M. Douglas

As the days get shorter and the last of the season's field crops are harvested, significant agricultural activity in Connecticut turns towards the indoors and to greenhouses, where crops can be produced out-of-season and the growing season can be extended for many tender crops.

A wide variety of crops are produced in Connecticut greenhouses including tomatoes, bedding plants (flowering annuals and vegetable transplants), perennials, cut flowers, seasonal crops such as poinsettias, Easter lilies and spring bulbs, and woody ornamentals. One of the key challenges to producing healthy, vigorous plants is disease control.

Growers routinely bring a variety of plant diseases from the greenhouse to the attention of the Plant Disease Information Office at The Experiment Station. These include diseases caused by fungi such as damping off of seedlings, root rots, and vascular wilts; those caused by bacteria such as cankers and blights; and those caused by viruses and mycoplasmalike organisms which result in mosaics and yellows.

The solutions to these problems lie in understanding how the diseases start and what measures can be taken to eliminate or to minimize their effects on the crop.

How Diseases Start in the Greenhouse

The development of plant diseases in the greenhouse is influenced by many factors. In fact, disease *cannot* occur unless there is a susceptible plant host, a disease-causing agent, and a favorable environment. In the case of some diseases (e.g. those caused by some viruses and mycoplasmalike organisms), disease cannot spread without the presence of an insect vector or carrier.

Plants are continually challenged by disease agents which gain entrance into the greenhouse in many ways. Some are brought in on infected plants from suppliers or through exchange between growers, others with infested soil, equipment, and clothing, and yet others from windblown fungal spores, aerosols containing bacteria, and insects capable of transmitting viruses and mycoplasmalike organisms. The warm, humid, and usually wind-free conditions common to most greenhouses are not only favorable for plant growth but are also ideal for the development and spread of many plant diseases.

Strategies for Disease Control

Because of the opportunities for intensive management of greenhouse crops, growers have great flexibility in their ability to effectively integrate a program of sanitation, cultural manipulations, genetic resistance, and appropriate pesticide usage for disease control into their crop production plans.

Sanitation. Sanitation in the greenhouse is the first line of defense against disease, both *before* each crop is started and *during* the entire period of crop production. By far, the easiest way to reduce or eliminate many disease problems is to eliminate their opportunity to occur. Although good sanitation is not a guarantee against disease problems, poor sanitation almost always fosters disease development. Here, disease control starts with a clean area. By removing all weeds, plant debris, unsold stock, and cull piles from the greenhouse and the surrounding area, important sources of inoculum as well as hosts for insect vectors are eliminated. Since diseases develop at any stage in the life of a crop, it is also important to follow these practices throughout all stages of production.

Growers can also remove possible contaminants by disinfesting benches and floors, irrigation equipment, tools, supplies, and pots. A number of disinfestants are available, but a 10% solution of sodium hypochlorite (household bleach) is a good, general disinfestant.

The importance of starting a crop in a clean greenhouse is well documented by the case of one Connecticut grower who brought in samples of geraniums which were yellowing, dropping leaves, and had black lesions at the soil line. I identified the disease as black root rot caused by *Thielaviopsis basicola,* a fungus that infects both geraniums and poinsettias. The source of infection for this new crop of geraniums was carry-over inoculum from unsold, infected poinsettias that had been inadvertently left in the house.

Similarly, serious outbreaks of *Botrytis cinerea,* one of the most important and troublesome pathogens encountered on many greenhouse-grown crops have been traced to senescing plant debris thrown under benches or left in cull piles during crop production.

Use of disease-free, pasteurized, or sterile media also helps to ensure a healthy start to greenhouse crops. The types of media and techniques that are available include soilless mixes, steam sterilization, and chemical fumigation. A good example of the effectiveness of this tool is illustrated by a Bridgeport bedding plant grower who came to the Experiment Station with recurring problems with two important seedling diseases, pre- and post-emergence damping off caused by the fungi *Pythium* and *Rhizoctonia.*

Figure 1. Sharon M. Douglas with a plant in the greenhouse.

Our diagnosis pointed to the use of a non-pasteurized, soil-based mix as the source of his problems. When the grower switched to a soilless medium, he significantly reduced and effectively controlled both problems.

Good sanitation also starts with healthy, disease-free and/or virus or culture indexed seeds, bulbs, cuttings, or plants. Since the introduction of culture- and virus-indexing, many of the key viral, bacterial, and vascular wilt diseases of geranium have virtually been eliminated from commercial production in Connecticut since most growers routinely start with these types of cuttings.

The logistics of a greenhouse allows growers to closely follow plant health during all stages of production and careful monitoring of each crop relies on early recognition and detection of disease problems before significant losses are involved. When disease is present, roguing, or destroying infected plants is often necessary for effective disease control. For example, geranium growers throughout the state are constantly watching for symptoms of bacterial blight caused by *Xanthomonas campestris* pv. *pelargonii.* Since there are no effective chemical controls for this highly contagious disease, early detection and roguing are the best strategies for control.

Cultural manipulations. A second key opportunity for disease management focuses attention to cultural manipulations which help to minimize the conditions favorable for disease development. Although growers usually strive to produce and maintain vigorous, healthy plants that are generally less susceptible to disease, in some cases the grower must compromise and choose between the conditions for optimum disease control and plant vigor and the conditions for optimum economic productivity. Since stress resulting from this choice can produce a potentially injurious strain on a plant, it has a critical role in predisposing plants to infection and in rendering them more vulnerable to secondary or opportunistic pests.

Some of the common stress-producing factors in Connecticut greenhouses result from the necessity for growers to utilize high density production methods and multiple cropping systems which promote plant stress in order to maximize economic returns. We commonly find tomato and pepper seedlings on benches beside vinca and marigold seedlings where growers have chosen conditions for growth that represent a compromise between the conditions which are optimum for each plant. The plants are also frequently placed pot-to-pot to maximize efficient use of space—this practice of close spacing often creates problems with air drainage.

Additionally, trying to meet target dates, such as providing poinsettias at Christmas and Easter lilies at Easter, create further stress on many greenhouse crops as growers manipulate the growing conditions to meet these deadlines. Oftimes these manipulations inadvertently create conditions that favor disease. This year a Connecticut grower found his crop of pansies ready for sale 6 weeks before the anticipated market date. In an attempt to hold the crop, the grower set the greenhouse temperature to 40F. The stress placed on the seedlings for this period of time predisposed them to infection by *Alternaria* blight and a significant portion of the crop died.

It is also possible to manipulate various environmental factors such as temperature, water potential, crop nutrition, and light to minimize stress on the plants and to help avoid conditions that allow infection, particularly those which promote the formation of dew on plant and greenhouse surfaces.

Many Connecticut growers successfully limit the spread of common foliar diseases on bedding plants by increasing the spacing between plants on a bench which promotes good air drainage. Similarly, a change in cultural practices now used by most growers has resulted in the decline of black root rot, historically a serious disease of poinsettias. Using soilless as opposed to soil-based media and maintaining pH levels between 4.5 and 5.0 have effectively minimized occurrence of this disease in the state.

High relative humidity is frequently associated with serious disease outbreaks and has become increasingly important as efforts to conserve energy through tightly sealed greenhouses are addressed. Changes in day and night temperatures in conjunction with still or wind-free air provide the conditions which are optimum for the formation of condensation on plant and greenhouse surfaces. This is of particular importance for many fungal pathogens since most require a film or drop of water on a plant surface for infection.

For disease control, growers manipulate relative humidity levels by appropriate use of heat, ventilation, and circulating fans. The "horizontal air flow" method is one popular technique for these types of manipulations. In this system, large masses of air are moved horizontally in the greenhouse by fans located just above the crop. Humidity can also be reduced by watering early in the day so that plant surfaces dry more quickly with the warmer, daytime temperatures. Many Connecticut growers have successfully minimized the occurrence and spread of *Botrytis* blight on many crops by reducing and maintaining relative humidity levels below the optimum of 93% required for germination and infection by this pathogen.

Another important means for reducing disease is careful attention to processes like tying, deleafing, staking, irrigating, trimming, and harvesting since these processes can predispose plants to infection and can also spread disease if not done properly. This year a Litchfield County grower submitted tomato samples showing black stem cankers and sudden plant collapse; sometimes entire rows or portions of rows were affected. I identified the problem as bacterial canker, a serious and contagious disease of tomato that is commonly spread by tying and deleafing processess. The grower was able to manage this problem by deleafing in the early morning on bright, sunny days in order to promote wound healing and by paying more attention to sanitation to minimize spread of the disease-causing bacterium between plants.

Genetic resistance. Use of genetic resistance, when available, is probably the most desirable and effective method of disease control since it circumvents the need for additional controls. Unfortunately, resistance is not available for many greenhouse crops, especially for many ornamentals, seasonal crops, and bedding plants. Growers can select tomato lines with resistance to races of *Verticillium* wilt, *Fusarium* wilt, and tobacco mosaic virus and rose cultivars with resistance to powdery mildew and black spot, but there are no snapdragon varieties with resistance to *Pythium* root rot or *Botrytis* blight nor are there cyclamen varieties with resistance to *Fusarium* wilt.

Pesticides. Although it is possible to successfully manage many disease problems without the use of pesticides, there are situations where pesticide usage is important and highly successful. In the greenhouse, fungicides provide excellent control for many fungal diseases. In most cases, however, the degree of control depends upon the proper selection, timing, and method of application of the compound.

Fungicides are available for effective control of a variety of diseases including many fungal root rots, foliar blights and leaf spots. However, selecting the appropriate compound is important. For example, a fungicide selected for effective control of *Alternaria* blight would have virtually no ability to control *Pythium* root rot of petunias. There are still other instances where pesticides are not effective or even available for disease control—diseases associated with some fungi and bacteria, viruses, and mycoplasmalike organisms fall into this category. In these cases, growers must rely on nonchemical means for disease control.

In summary, effective control of diseases in the greenhouse can be achieved through the understanding of how diseases develop and through the implementation of strict sanitation, cultural manipulation, genetic resistance, and appropriate use of pesticides. However, accurate diagnosis and early detection of the disease problem are also critical components of control. The sooner a problem is detected, the greater the chances for successful control. The Plant Disease Information Office is ready to provide clinical diagnosis and information on control strategies for specific problems in the greenhouse.

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