

RECENT ADVANCES AND SETBACKS IN DUTCH ELM DISEASE RESEARCH¹

by Charles L. Wilson²

Interpretive Summary

There have been a number of setbacks, as well as advancements, in Dutch elm disease (DED) research. The setbacks have resulted from the variability of the DED fungus. Resistance to benomyl has been found in natural populations of the DED fungus. Also, considerable variability has been found in the pathogenicity of the DED fungus, which threatens some of our DED-resistant trees. The most recent advancement in DED research has been an apparent cross between a tetraploid *Ulmus pumila* and *Ulmus americana* that yielded viable seed.

Keywords — *Tree-disease* — *variability* — *benomyl* — *pathogenicity*

When I was asked to talk to you about "Recent Advances in Dutch Elm Disease Research", I immediately became defensive. The most recent happenings in Dutch elm disease (DED) research have been a number of setbacks, not advancements. After all, if I told you about them it might destroy what confidence you have in those of us in this research.

From the outside looking in, laymen often view research as a steadily advancing force against ignorance. We who are involved in the daily routine of research are forced to have an entirely different perspective. Our world is a combination of high hopes, dashed expectations, fear, exhilaration, and often despair. We rarely have the opportunity to enjoy success. We have learned not to enjoy such emotions for long, because there is no absolute success in science. There is always a better way and a better explanation.

Understandably, the public does not know about the practical world of research because researchers want it that way. The public provides us with funds for research, and in turn, we want to present ourselves in the best possible light. We tell you about the advances in our research,

not the setbacks. However, I have an uneasy feeling that this might not be the right approach. Because we do not share our setbacks, you might interpret our slow progress as incompetence or laziness. Also, the public must realize that frequently our technology is not advanced enough to allow a rapid solution to a particular problem.

I would like to share with you a number of new developments in DED research that are actually setbacks in our timetable to eventual control of DED. To offset this bad news, I also have some good news.

The Adaptability of the Dutch Elm Disease Fungus

Our recent problems in Dutch elm disease (DED) research have come from underestimating the DED fungus. We failed to make allowances for its adaptability, its ability to skirt the traps we were laying for it. We have relied heavily on two approaches toward DED control: 1) the development of resistant trees, and 2) chemical control by systemic fungicides. The DED fungus recently proved it could adapt to both approaches.

DED-Resistant Trees. Recent outbreaks of DED in Britain alerted us that the DED fungus can overcome natural genetic resistance in elm trees. Dutch elm disease was first detected in western Europe around 1918. In Britain it was most severe between 1931 and 1937, after which its incidence mysteriously declined. However, in 1971 the incidence and severity of the disease in southern Britain increased rapidly. When researchers compared strains of the fungus in the outbreak areas with strains in other areas, they found them more aggressive.

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The discovery alarmed elm breeders in Europe. The Dutch have relied heavily on the breeding and selection of resistant trees to control DED. Would the aggressive strains again wipe out the Dutch elm tree population after such a long and arduous effort to develop and plant resistant trees? In this country, we wondered whether the resistant trees we had developed would withstand more aggressive strains of the fungus. From the evidence that has been gathered so far, the aggressive strains of the DED fungus indeed appear to threaten resistant trees developed by the Dutch. Fortunately, the European aggressive strains do not appear to be any more aggressive than the most aggressive ones already present in the United States and Canada. Because we initially used aggressive strains to test for resistance, we are not as fearful that DED-resistant trees released in this country will come down with the disease.

Now that we know the DED fungus varies in its ability to cause disease, more attention is being given to strain differences in our breeding programs. This effort will result in a slower timetable for the release of resistant trees. However, the warning that we have received may be a fortunate one. If we had proceeded in the release of trees that would eventually fall to DED, nothing would really have been gained.

Resistance to Benomyl. The systemic fungicide, benomyl [methyl 1-(butylcarbamoyl-2-benzimidazole carbamate)] has provided us with new hope in the control of DED. It is highly toxic to the DED fungus, moves effectively throughout elm trees, and in a soluble form can be effectively injected into trees. Recent research has shown that the disease can even be stopped in its early stages by the injection of soluble benomyl. Unfortunately, the DED fungus has also dampened our hopes with this approach to control.

Benomyl is a highly effective fungicide against a variety of plant pathogens. However, where it has been used for extended periods, resistance to this fungicide has evolved in the pathogen being treated. A number of such cases have been documented; it has recently happened with the DED fungus. In fact, Drs. Schreiber and Townsend at the Agricultural Research Service,

Delaware, Ohio lab have found some wild strains of the DED fungus that have a natural resistance to benomyl. Thus, if we treat trees extensively with benomyl, we run the risk that these strains may become widespread and render benomyl worthless.

These findings show that we must proceed more slowly in recommending the injection of soluble benomyl for the control of DED. We have to evaluate our use of this fungicide in the same way that the medical profession has to evaluate the prescription of antibiotics. Is the risk of promoting the evolution of resistant strains worth the immediate benefits of the treatment? Evidently, we should not rely on benomyl alone for the chemical control of DED.

Phloem Necrosis. Phloem necrosis resistance in American elm must be considered in our DED breeding programs. We gain nothing by releasing DED-resistant trees if they eventually die of phloem necrosis. I wrote an article in 1971 entitled "Phloem Necrosis is Waiting in the Wings." Since then, phloem necrosis has come to "center stage" in a number of areas. It is now epidemic in New York and areas of Pennsylvania. It is more of a threat to American elms in some areas of the United States than DED.

When we started our elm breeding programs we did not give enough attention to elm phloem necrosis. This mistake was dramatically brought to our attention when the trees in one breeding program that were most resistant to DED succumbed to phloem necrosis. This event caused that breeding program to end and studies on phloem necrosis to begin. It is fortunate that most elm species are resistant to phloem necrosis, but the important American elm is not. We lack adequate information on the complete host range and life cycle of the phloem necrosis pathogen, and we must invest "DED research time" in order to fill these gaps. This problem represents a further setback in our timetable to release DED-resistant trees.

During the past 5 years our breeding and selection program for DED resistance has accelerated. Increased research on resistance could not have come at a better time. The new knowledge derived may allow us to meet the new chal-

lenge posed by aggressive strains of the DED fungus.

Siberian elm (*Ulmus pumila*) is very resistant to the DED fungus. Until recently we held little hope of tapping this resistance for use in breeding resistant American elms. The American elm has twice the chromosome number of the Siberian elm and it does not cross with it. In 1968, Drs. Haig Derman and Curtis May reported that they had doubled the chromosome number in *Ulmus pumila* and produced a tetraploid elm. However, because these trees were not old enough to produce flowers, geneticists could not cross them with the American elm until 1974. Dr. Jack Hull, a cytogeneticist at the Agricultural Research Service Shade Tree and Ornamental Plants Laboratory in Delaware, Ohio has apparently been successful this year in making this cross. If these findings are confirmed, a rich source of genetic resistance has been opened in elm breeding.

In the past 5 years a number of new elm hybrids have been produced. These new trees have been developed primarily by Dr. Townsend at the Delaware, Ohio Laboratory, Dr. Frank Santamour at the National Arboretum, and Dr. E.B. Smalley at the University of Wisconsin. These new trees may be released to nurserymen themselves, or serve as material for further breeding and selection.

Injection of Systemic Fungicides. Federal and state researchers have been working intensively for the past 3 years on ways to control DED through pressure injection of benomyl. Although much more research is needed, some hopeful results are emerging. It is apparent that: 1) only soluble forms of benomyl are effective; 2) trees can be protected up to one year, if properly injected; and 3) infected trees cannot be "cured" unless injected during very early stages of the disease.

Some important questions remain in regard to pressure injection with soluble benomyl. Among these are: 1) What is the long-range effect of the treatment on elm trees? 2) What are the optimum concentrations of fungicide to use? 3) At what pressure should they be applied? 4) How often should you treat trees? Until some of these ques-

tions are resolved we cannot answer the all important question, "How much will it cost?"

At best, the pressure-injection procedure is only a partial answer for DED control. Recent excitement over this approach should not distract us from concomitantly pursuing other, perhaps more useful, means of control.

Control of the Insect Vectors of Dutch Elm Disease. While DDT was available, many communities kept their DED disease losses to a minimum through sanitation programs and DDT sprays for the vector. After the banning of DDT in the late 1960's, methoxychlor [1,1,1 trichloro-2,2-bis (P. methoxyphenyl) ethane] became the insecticide of choice. Dutch elm disease control programs with methoxychlor have not been satisfactory in many municipalities. Therefore, the search to find other means of controlling the insect vectors of DED has continued.

Other approaches toward insect vector control include the introduction of parasites and predators of the beetle vector, the use of feeding stimulants and deterrents, beetle pathogens and attractants (pheromones). To date, research has not shown the effectiveness of any of these in DED control.

Current research in insect control has emphasized the use of sex attractants (pheromones). A sex attractant for wild, flying beetles has been purified. Attempts are now being made by the U.S. Forest Service at Delaware to decrease the spread of DED by luring the insect vectors with pheromones and trapping them. The basic unanswered question is, "To what level must the vector population be reduced in order to affect spread of DED?"

Biological Control of Dutch Elm Disease. Obviously we need more weapons if we are going to win our battle against Dutch elm disease. One area of research that we have almost completely neglected is the use of biological controls against the disease-causing fungus. The Agricultural Research Service in the Plant Pathology Department at Ohio Agricultural Research and Development Center at Wooster, Ohio has recently started research on the biological control of DED. The purpose of this program is to find non-chemical ways to manipulate and control the DED fungus.

Initial studies in this program have involved introducing bacteria into the vascular system of elms that are antagonistic to the DED fungus. We hope that we can find bacteria that will become permanent residents in elm tree vessels and prevent the DED fungus from becoming established.

Integrated Control. It is popular in complicated disease situations like DED to indicate that an integrated control program is needed. With inte-

grated control a variety of control procedures are used together. It must be remembered that the integration of control procedures that do not initially work will not enhance their inherent effectiveness. Adequate control of Dutch elm disease will not come about integrating present procedures, but rather through research to improve these procedures and to find new ones.

PHYSICAL PROPERTIES OF CONTAINER MEDIA

by J.R. Havis and W.W. Hamilton

Most container nurserymen use soil-less media in the containers. Elimination of soil reduces the weed problem. Until recently, the most common medium was a mixture of sphagnum peat from Europe or Canada with either fine sand, as suggested in the "U.C. System", or coarse sand (builder's concrete grade) as is more commonly used in the East. More recently container nurserymen have been interested in finding less expensive substitutes for at least part of the sphagnum peat in the mix. Shredded bark is a popular material for this use. Hardwood bark, mostly oak, is available in the Midwest; softwood is available on the West Coast and in the Southeast. The bark in the Northeast may be largely softwood, but usually contains some hardwood species other than oak. Sawdust is used commonly by container growers in Western Canada.

This study was undertaken to compare water retention and aeration properties of mixes prepared from some of the above materials. Mixes studied were 1) peat and coarse sand 1:1, 2) bark (screened to maximum $\frac{1}{2}$ inch) and coarse sand 1:1, 3) bark-peat-coarse sand 2:1:1, 4) bark-peat-fine sand 2:1:1, 5) sawdust-peat-coarse sand 2:1:1, and 6) sawdust-peat-fine sand 2:1:1. The mixes were studied in 1-gallon containers, which held 2.1 liters of mix, and in specially constructed tension funnels in the laboratory.

A container mix is made up of two parts: the "dry" material and pores, the latter being filled with either air or water. It is desirable that the pore phase constitute more than 50% by volume. All of the mixes studied met this qualification.

When the mix is saturated, all of the pores are filled with water. *Large* pores empty of water and fill with air when the containers drain by gravity (container capacity). Since air is essential for plant roots, a container mix should contain 20 to 25% air by volume after drainage. All of the mixes contained more than 20% air-filled pores one hour after overhead irrigation.

After drainage, water continues to be removed from the container mix by evaporation and the process of absorption by plant roots and transpiration from leaves. Water in *medium* size pores is easily removed by the plant, and can be called "readily available" water. After this readily available water is removed, the remaining water is held in *small* pores with sufficient tension that the plant has difficulty in extracting it. This condition results in slight wilting, closure of stomata and some reduction in growth. Further drying of the mix removes all water except that held with high tension in *very small* pores, and this condition results in severe wilting.

For best growth of plants, the objective is to keep the water in the container mix at the readily available stage. This is more easily done if the