VASCULAR WILT DISEASE UPDATE[1]

by Dan Neely

In preparation for this review, over 100 papers published since 1977 have been perused. Many researchers continue actively to seek information on vascular tree diseases. Most research continues to be on Dutch elm disease (DED), but Verticillium wilt, oak wilt, and elm phloem necrosis also receive attention. Much of the published work is on the components of disease, that is, the causal agent, the host, or the environmental factors influencing disease development, but some work continues the search for better control measures.

For those of you who wish more information than can be presented here, I have three reference sources. The most detailed is a northeast regional research publication entitled *Dutch elm disease: perspective after 60 years,* Search 8(5): 1-55 printed in 1978 by Cornell University, Ithaca, New York. The second reference is entitled *Dutch elm disease — a bibliography,* compiled by John Laut and Theresa Stieger of the Colorado Forest Service, Colorado State University, Fort Collins, Colorado. John Hart has a review of DED control measures in the November, 1980 issue of Weeds, Trees & Turf. (Also Compendium of Elm Diseases, Am. Phytopath. Soc., St. Paul, MN)

We have long believed that, although Dutch elm disease was first described by the Dutch, it originated in China or Siberia, since elms native to these regions are resistent to the disease. Chinese laborers brought to Europe during World War I were believed to have carried the disease with them in infected elm wood baskets or carts. John Gibbs of England has researched the labor records and states that the wicker-basket theory will not hold water. DED was found throughout France, Holland, and Belgium by 1918 (or 1917). The first arrival of Chinese laborers was in 1916, not sufficient time for the infection of trees and the subsequent dissemination of the disease to occur.

Dutch elm disease continues to spread. Our western states now contend with the disease. It was reported in North Dakota and Idaho in 1967, South Dakota and Wyoming in 1969, Oregon and Montana in 1973, California in 1975, and Washington in 1977.

In areas where *Ceratocystis ulmi,* the causal agent of Dutch elm disease, has been present for many years, we are concerned with the ability of the fungus to change and become even more virulent. This is most likely to occur in recombinations resulting from sexual reproduction or in mutations. The fungus requires two mating types for sexual reproduction. The unusual situation of both mating types being present in the same tree was confirmed in the Capitol Mall area of Washington, D.C. In Massachusetts, tests with both mating types revealed that certain isolates contribute better to sexual union when they are effectors (male) and others when they are receptors (female).

The extensive DED losses in England in the 1970's led to the discovery of aggressive and nonaggressive isolates of *C. ulmi.* This distinction has now been confirmed in the United States. Unfortunately, most of the isolates from the Midwest are in the aggressive category. In New England and Canada the nonaggressive isolates are frequently recovered. The aggressive strains grow faster in culture, and more aerial mycelium is observed on agar colonies. The more aggressive isolates also produce more coremia. Thus, colony characters are related to virulence. The distinction between the aggressiveness of the strains is more easily differentiated on Asian species of elm than on American species (the American species being too susceptible to all strains of the fungus). Changes in the fungus can occur in the tree, since colony characters of the recovered fungus are not always the same as those of the introduced

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fungus.

The search is now on to determine the causal differences between aggressive and nonaggressive strains. So far, nucleic acid (chromosomal) distinctions have not been found. Particles that may be parasitic on the fungus have been observed in nonaggressive or weakly virulent isolates and not observed in aggressive isolates. The presence of L-phase bacteria within *C. ulmi* has been observed in New York, but the significance of this finding has not been established.

Another variability of the fungus becomes important when chemotherapy for disease control is widespread. This factor is the environmental selectivity for fungal mutants that are tolerant of the fungicide being used. A few fungi have become tolerant of benomyl. Since benzimidazole fungicides have been used for DED control, tolerant *C. ulmi* strains have been sought. Screening tests with *C. ulmi* on agar amended with the fungicide have isolated tolerant strains. Rarely, however, are tolerant strains isolated from naturally infected trees. Tolerance in one strain found in Wisconsin was controlled by a single gene.

The elm bark beetle, a primary vector of *C. ulmi* continues to be studied by pathologists and entomologists. Hart, in Michigan, stated that DED was more frequent in areas where elms were pruned during the summer. In California, sticky traps placed near pruning wounds established that beetles were attracted to them. California specialists now suggest that elm trees should be pruned in the fall or winter.

Researchers in California believe that they have the explanation why adult beetles feed in the crotches of elm twigs after they emerge from elm wood even though this feeding is not essential for survival. It appears that the feeding cavities are used during the courtship and mating of beetle pairs.

The most extensive recent research on elm bark beetles has involved insect attractants, called pheromones. Several pheromones have been identified chemically and even created synthetically. Tests to measure the potency of attraction are being standardized. Tests on beetles in America and beetles in Europe have not always given comparable results. Pheromones have also been used near sticky traps in an effort to reduce the bark beetle population in specific areas. Millions of beetles have been caught, but to my knowledge, no one is yet recommending the technique as a DED control procedure. Pheromones are potent, however, when tagged beetles were released, 98% were caught in pheromone traps only 5 feet from the release site. The maximum distance of capture was 500 feet.

Elm leaf-feeding insects have been contaminated with labeled *C. ulmi* for evaluation as possible vectors of DED. It was concluded that these insects were of little or no consequence as vectors.

The chain saw has also been suggested as a vector for *C. ulmi*. The fungal spores can survive in chain saw oil. Tests in New England have demonstrated that this method of transmission is very unlikely, however.

The spread of the disease over distances greater than the range of the elm bark beetle have revealed the importance in England of long- and short-distance transport of diseased logs.

The Canadians and the Dutch are doing more than the Americans in studying host-parasite interactions during the development of DED. Ouellette in Canada has made extensive use of the electron microscope in observing diseased elm tissues. He has noticed extensive cell wall disruption in xylem vessels even in early stages of the disease. This disruption apparently releases fibers which congregate in the pit areas where xylem sap passes from vessel to vessel. The pit cavities become plugged and water transport is slowed.

Other Canadians are convinced that toxins, not mechanical plugging, are responsible for wilt. Takai and his co-workers have named the toxin cerato-ulmin. It was isolated from culture filtrates and appears to be a protein containing carbohydrate components with a molecular weight of about 12,000 Daltons. The toxin is metabolized during active spore development and does not appear to be a staling product.

The Dutch have watched the development of the disease in the tree using fluorescing dye techniques. They have never observed *C. ulmi* outside the vessels. The hyphae of the pathogen penetrate the pit membrane during growth from vessel to vessel. No direct cell wall penetration was observed.

Species of elm that are resistant to DED have been shown to have vessels (the large cells in the xylem that translocate most of the water and solutes from the roots to the leaves) in widely scattered groups. Apparently trees with this anatomy are better able to localize and contain the fungal infection. Shigo states that trees resistant to DED are also good compartmentalizers of discoloration and decay organisms.

When young American elm seedlings were inoculated with *C. ulmi* at the USDA laboratory in Delaware, Ohio, the water flow in roots was found to be inhibited within 2 days, and up to 90 % of the water flow was inhibited within 29 days, when symptoms first appeared. These scientists suggested that root physiology should receive more attention than it has in the past. Other researchers in Virginia found a temperature increase in leaves within 24 hours after inoculation with *C. ulmi.*

The measures recommended for control of DED are continually being evaluated and assessed. Sanitation, the thorough scouting and prompt removal of publicly owned and privately owned diseased elms, is the foundation for a successful control program. Illinois, Colorado, Ohio, and Canadian studies substantiate this statement. Ohio data indicate an annual cost saving of 25% when intensive sanitation is practiced.

Through the application of methoxychlor spray, in addition to sanitation, annual elm losses have been further reduced from 4.1% to 3.2% of the elm population over the last 10 years in several Illinois municipalities. Unfortunately, methoxychlor sprays have not been as effective as were the earlier DDT sprays.

Several researchers have been involved in the testing of injection systems and injected compounds to determine their potential value as controls. The benzimidazole fungicides, Lignasan and Arbotect, are effective against the Dutch elm disease fungus. The commercial formulations now available do move in the sap stream of injected trees. It now is known that, within an established range, the quantity of fungicide distributed within the tree is more important than the volume of water injected. Most of the published results establishing the efficacy of Lignasan report the use of the pre-1980 rate (therapeutic = 1 qt/4 gal water). This rate of usage (X) was not nearly as efficacious as a 6X rate. At the label rate of Arbotect (therapeutic = 4 oz/1¼ gal water) more active ingredient of fungicide is injected into the tree. In 1980 Arbotect and Lignasan had comparable label rates. Usage for Arbotect at 2X and 3X the label rate have substantially increased the ability to detect the fungicide throughout the crown of injected trees. The distribution of the fungicide throughout the crown at a concentration toxic to *C. ulmi* is essential to prevent infection (prophylaxis) or stop infection (therapy). Tests comparing the two chemicals indicate that Arbotect is somewhat more persistent in the tree than Lignasan (in California 14 months vs. 10 months). *C. ulmi* isolates tolerant to the fungicide are not affected regardless of the rate of application.

Forest Service pathologists have compared the effectiveness of injection alone (7.5X) versus injection plus pruning in therapy treatments in cities in Illinois and Ohio. Pruning alone saved one-third of the treated trees, while pruning plus trunk and limb injection saved half of them. In Washington, D.C., the success rate for injection and pruning was 60%. Most pathologists now making recommendations for the control of Dutch elm disease state that injection with a fungicide is no substitute for sanitation, spraying, or root-graft control. It can be an additional tool for use in high-value elms. Injection for prophylaxis is questioned since wounding of trees every 1 or 2 years is necessary. Injection for therapy is not often effective when over 10% of the crown has wilt symptoms.

Progress continues to be made in obtaining elms resistant to DED. In testing seedlings in the greenhouse, a temperature of 26°C (79°F) was found to be the most important environmental requirement. Ten-year-old cuttings from resistant clones are much more likely to give a similar disease reaction to that of the parents than will 1-to 2-year-old cuttings.

Santamour at the National Arboretum has established that (1) 2n, the diploid number of chromosomes, for Siberian and Chinese elms is 28, (2) 2n for American elm is 56, (3) the American x Siberian hybrid is a triploid that will mate with other triploids, (4) fall and spring flowering elms can be crossed, (5) DED resistance in

Asian elms is easily heritable, and (6) *U. villosa* (Himalayan elm) is a good resistant parent for crosses. Townsend with the USDA at Delaware, Ohio, has determined that male parents in crosses do not contribute as much to resistance as do female parents. He recommends specific combinations of elm clones for trials.

Elms are still an important landscape plant, and work on their diseases is substantial and continuing. DED is but one disease. Most of the recent research on elm phloem necrosis is carried out at Cornell University in New York. This disease of elm is enlarging its range. It was first found in the Mississippi delta in 1966, Pennsylvania in 1971, New York in 1972, New Jersey in 1974, Massachusetts in 1977, and Michigan in 1978. Elm phloem necrosis is caused by a mycoplasma-like organism. It kills *U. americana* and *U. rubra,* causes chlorosis on *U. laevis,* and witches'-brooms on *U. carpinifolia* and *U. parvifolia.* Translocations of "food" in the phloem from leaves throughout the plant is slowed due to deposition of callus and sieve tube collapse.

Verticillium wilt as a disease of landscape plants is now receiving more attention. One unresolved problem is the proper name for the causal organism. *Verticillium albo-atrum* and *V. dahliae* are both used, sometimes interchangeably. The establishment of the relative susceptibility of host plants and the possibility of strains within the fungus are areas of current research. The fungus is aggressive in plants stressed by low moisture levels but does not invade tissue in flooded plants.

The oak wilt research continues to be carried on chiefly by scientists in Wisconsin, Ohio, and West Virginia. Oak wilt receives the attention of forest pathologists more than of shade tree pathologists. Since the long-distance spread of oak wilt may be due to bark beetle vector activity, trials have been conducted to determine the value of cacodylic acid as a silvicide to prevent beetle colonization of diseased trees and the formation of fungal mats beneath the bark. This treatment has reduced by 75% the number of trees with beetles, 61% the number of trees with mats, and 48% the number of trees with disease. Due to root-graft connections with neighboring trees, flashback has occurred on trees pressure injected with this chemical. In one area 31% of the neighboring untreated trees showed evidence of chemical injury.

Oak wilt is a wilt disease in which inadequate water reaches the leaves. Work measuring the amount of water loss from stomata of individual leaves showed that stomatal resistance to transpiration occurred 3 days before visual evidence of wilt was present.

The search for oaks resistant to oak wilt includes recent studies comparing differential colonization of red, white, and chestnut oaks and the inoculation of 1200 selections of red oak. In the latter case 1.5% of the selections survived two inoculations.

In conclusion let me reemphasize that this presentation has not been an attempt to include all current research or an attempt to bring a specific area of research into focus. It does establish that vascular diseases of midwestern shade trees are considered very important and that many aspects of these diseases are of interest to scientists throughout the world.

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