Double Jeopardy for Elms: Dutch Elm Disease and Phloem Necrosis

by David F. Karnosky[1]

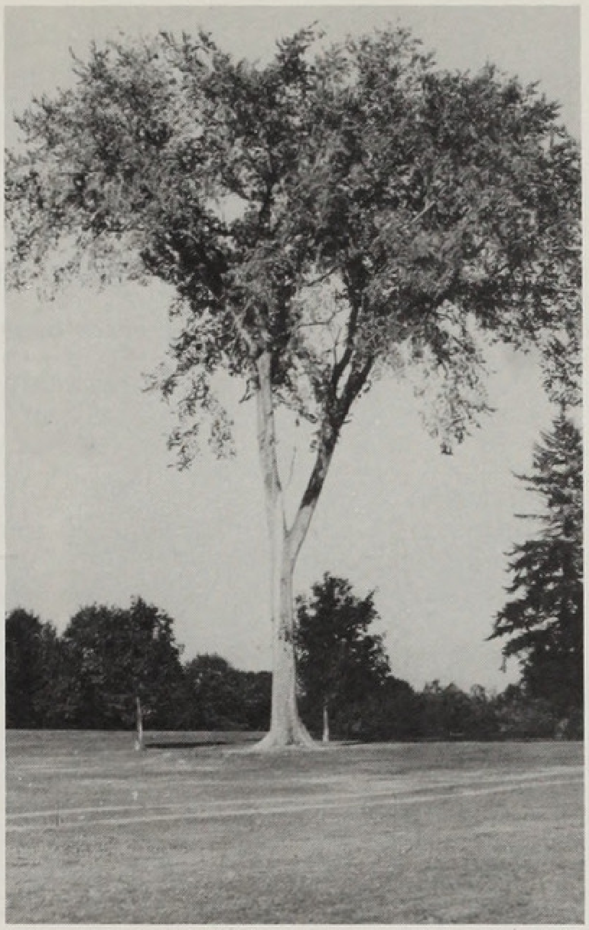
American elm (*Ulmus americana*) populations across the United States are in double jeopardy. The Dutch elm disease, caused by the fungus *Ceratocystis ulmi*, continues to spread in North America and has developed more aggressive strains in recent years. Now, a second major disease is threatening elms. Called phloem necrosis, it is caused by mycoplasma-like organisms.

Dutch Elm Disease

Dutch elm disease is a vascular wilt disease transmitted primarily by bark beetles. It was first found in northwestern Europe around 1918. The disease was identified, and the causal agent described, by Dutch scientists. Rather unfortunately for the Dutch, the common name for the disease came to be "Dutch elm disease." Actually, the disease is thought to have originated in the Far East.

By 1939 Dutch elm disease had spread rapidly across Europe, killing over 50% of the elms in Holland alone. The Dutch countryside was particularly vulnerable to the ravages of Dutch elm disease because the vast majority of elms planted in Holland belonged to one susceptible clone, *Ulmus* × *hollandica* 'Belgica'.

[1] New York Botanical Garden Cary Arboretum, Millbrook, New York 12545.



A specimen American elm (Ulmus americana) *tree, showing the vase-shaped crown characteristic of the species. Photo by D. F. Karnosky.*

The first report of Dutch elm disease in North America came from Ohio about 1930. The causal fungus and its primary vector, the small European elm bark beetle (*Scolytus multistriatus*), had been carried to the United States on elm logs imported from Europe. The knots in its wood made it popular for making a burled veneer for furniture. Large ports and the railroads that transported the logs inland were the points of entry and routes of spread of the disease.

After its rapid initial sweep across Europe, and apart from local "flareups," Dutch elm disease came to be regarded there as an endemic disease of little importance. However, this tranquil situation came to an abrupt end in the late 1960's, when a new and more devastating Dutch elm disease epidemic began. The new epidemic appears to have originated in Britain and, as in the United States, can be traced to the importation of elm logs. This more aggressive and far more pathogenic strain of *Ceratocystis ulmi*, which developed via mutation in North America, was introduced into Europe on elm logs imported from Canada for boat building.

This second Dutch elm disease epidemic is now widespread in Europe and threatens to be more serious than the original one of the 1930's, since there appears to be much less resistance among European elm species and selections to the aggressive strain of Dutch elm disease than there was to the non-aggressive strain that had developed in Europe.

During the approximately 50 years when Dutch elm disease has been present in the United States, its range has steadily increased and it has devastated elm populations from coast to coast killing an estimated 50 to 100 million elms. Elm losses in metropolitan areas have been particularly severe (see Table 1) because the American elm's elegant vase-shaped crown, rapid growth rate, and urban-hardiness had made it a favored urban planting.

Table 1. Elm losses in some cities of the United States.

City	Estimated Number of Elms Prior to 1950	Estimated Number of Elms Remaining in 1977
Binghamton, NY	5,000	100
Buffalo, NY	180,000	10,000
Champaign-Urbana, IL	14,000	40
Chicago, IL	159,000[1]	88,000
Des Moines, IA	252,000	14,000
Evanston, IL	22,000	13,000
Milwaukee, WI	145,000	28,000[2]
New York, NY	55,000	33,000
Poughkeepsie, NY	5,000	50
Rochester, NY	15,000	200
St. Paul, MN	132,000	83,000[3]
Syracuse, NY	53,000	400
Washington, D.C.	20,000	20,000[4]
Yonkers, NY	12,000	200

[1] Greater Chicago area parkway elms.

[2] The Milwaukee figures include many non-diseased trees removed to begin reforestation efforts following the inevitable devastation by Dutch elm disease.

[3] The number of elms remaining in St. Paul has been dramatically reduced since 1977, because the disease has only recently reached epidemic proportions there.

[4] Washington, D.C., lost about 7,000 elms due to Dutch elm disease but has replaced them with additional elms.

Phloem Necrosis

Phloem necrosis, also commonly called "elm yellows," is indigenous to the United States and was first reported over 30 years ago. It now occupies a range from New York to Nebraska and south to the Gulf Coast states. It seems unlikely that the disease will move farther north since the pathogen does not appear to be adapted to cold climates. Transmitted by leafhopper insects, phloem necrosis kills the tree's phloem cells; the rest of the tree usually dies within one year after symptoms appear, except in the case of resistant species such as Chinese elm (*Ulmus parvifolia*) and Siberian elm (*U. pumila*).

Epidemics of phloem necrosis can rapidly destroy elm populations. However, the disease often remains endemic for several years between flareups, as did Dutch elm disease in Europe before the 1960's. Dutch elm disease and phloem necrosis sometimes infect the same elm populations, as occurred, for example, in several Illinois communities. In these situations, trees killed by phloem necrosis provide plentiful breeding sites for the bark beetles that transmit Dutch elm disease.


Left: Dieback of the upper crown of an American elm (Ulmus americana), *a symptom of the early stages of Dutch elm disease. Right: Advanced stages of Dutch elm disease on an American elm in Central Park. Photos by D. F. Karnosky.*

Symptoms

The symptoms of Dutch elm disease and their sequence and rate of development are variable depending on a number of tree, fungal, and environmental characteristics. However, the drooping or wilting of foliage (commonly referred to as flagging) in the upper crown on small twigs is the most common indicator of the presence of Dutch elm disease. Elms are usually infected between late spring and early summer. Brown streaks in the outermost xylem of twigs, exposed by a slanting cut or by peeling of the bark are good indicators of the presence of Dutch elm disease in branches showing flagging. Symptom progression through a given American elm tree may occur in one year or may take several years to occur.

Phloem necrosis generally kills small fibrous roots before foliar symptoms develop. As the phloem is destroyed by the disease along the length of the tree, infected tissue first becomes flecked with brown and then turns uniformly brown. This discoloration is best seen beneath the bark of the lower trunk and root-flare areas. The first external symptoms of phloem necrosis usually develop in mid- to late summer and include yellowing, leaf droop, and premature leaf drop. In contrast to Dutch elm disease, where the disease begins in a small number of branches, nearly all branches on a tree with phloem necrosis show symptoms at once. The discolored phloem of phloem necrosis-infected American elms may also have a faint wintergreen odor, especially if small branches are warmed by cupping them in the palm of the hand for a few minutes. Elms resistant to phloem ne-

Table 2. **Relative Dutch elm disease (DED) and phloem necrosis (PN) resistance of elms.**

Species	Origin	DED Resistance[1]	PN Resistance[1]
Ulmus alata	North America	– –	– –
U. americana	North America	– –	– –
U. crassifolia	North America	–	– –
U. rubra	North America	– –	– –
U. serotina	North America	– –	– –
U. thomasii	North America	–	?
U. carpinifolia	Europe	–[2]	+ +
U. glabra[3]	Europe	– –	+ +
U. × *hollandica*	Europe	–	+ +
U. laevis	Europe	–	+ +
U. plottii	Europe	–	?
U. procera	Europe	– –	?
U. bergmanniana	Asia	–	?
U. davidiana	Asia	+	?
U. densa	Asia	–	?
U. elliptica	Asia	–	?
U. japonica	Asia	+	?
U. laciniata	Asia	–	?
U. macrocarpa	Asia	+	?
U. parvifolia	Asia	+ +	+ +
U. pumila	Asia	+ +	+ +
U. turkestanica	Asia	–	?
U. villosa	Asia	+	?
U. wallichiana	Asia	+ +	?
U. wilsoniana	Asia	+ +	?

[1] (– –) very little resistance; (–) little resistance; (+) moderate resistance; (+ +) much resistance; (?) unknown.

[2] While *U. carpinifolia* is generally thought to be not very resistant, some clones of this species (such as 'Christine Buisman') have shown moderate resistance.

[3] *Ulmus glabra* includes *U. campestris*.

crosis (Table 2) sometimes develop witches' brooms (tufts of growth with short internodes) when infected but are not killed by the disease.

Control

While there are no guaranteed cures for either Dutch elm disease or phloem necrosis, there are control measures that have proven effective in slowing the spread of these diseases through elm populations. The most important control measure and the cornerstone of all successful programs is sanitation, including the prompt removal and disposal of dead and dying elms and the pruning of dead wood from healthy ones. Elimination of the dead wood decreases bark beetle breeding sites and prevents buildup of disease inoculum. Elm logs that are going to be used for some later purpose (e.g., for firewood) should be either debarked or sprayed with Lindane[2] to make them inimical to bark beetles.

Besides spreading the Dutch elm disease fungus, elm bark beetles can become a nuisance for homeowners if they are allowed to develop

[2] Reference to products does not imply product endorsement, nor are these necessarily the only ones available.

Dr. David F. Karnosky is shown attempting to hybridize the Siberian elm with American elm pollen. Photo by R. Mickler.

large populations. I recently received a call from a distraught homeowner whose house was being invaded by thousands of elm bark beetles; because of their small size, they had passed through his window screens, entered through his attic vents, and clogged his air conditioner. The cause of this localized problem was a large pile of elm logs and branches left with the bark on after the removal of a number of large American elm trees.

Left uncontrolled, Dutch elm disease can destroy a city's elm population within 10 years. When phloem necrosis is also present, the time may be even shorter. However, sanitation programs can effectively reduce the rate of loss from Dutch elm disease and phloem necrosis. For example, the city of Syracuse, New York, maintained elm losses at less than 2% per year from 1951 through 1964 by conducting strict sanitation for Dutch elm disease control. After the program was dropped in 1965, Dutch elm disease quickly reached epidemic proportions and the elm population in Syracuse was reduced from about 46,000 to less than 1,000 within 14 years. United States Forest Service researchers have established the fact that it is more economical in the long run to minimize elm losses with a sanitation program than to allow the disease to run its course.

Spraying elms with Methoxychlor to reduce twig-crotch feeding by the small European elm bark beetle is a good supplemental control procedure. New York City has long maintained a Dutch elm disease control program based on sanitation plus Methoxychlor spraying. The effectiveness of this program ranks among the best in the nation. Some 33,000 elms still grow in New York City and the annual loss rate is less than 0.5%. Results from Evanston, Illinois, also confirm the effectiveness of sanitation in combination with spraying for bark beetle control. The results are particularly impressive when compared to the devastation of other Illinois communities such as Champaign-Urbana (Table 1), where little or no control was attempted.

Pheromone trapping to determine when bark beetle broods (especially the summer broods) appear is useful in determining when insecticide sprays should be applied. Pheromone trapping may eventually become a practical means of reducing bark beetle populations in areas of low population densities. Recently, the use of cacodylic acid to kill elms has also been suggested for reducing bark beetle populations, especially in "non-control" areas surrounding control areas. Cacodylic acid rapidly kills elms and renders them useless to bark beetles as the beetles' larval development cannot be completed in the dry conditions created below the bark of treated trees.

When a small number of highly valuable elms are endangered by Dutch elm disease, a series of stop-gap measures may be attempted for control. These measures are all expensive, however, and should only be considered in special situations. Pruning as a therapeutic measure to remove Dutch elm disease from elm trees is possible if the disease is detected and treated early enough. Preferably, an infected branch should be pruned back a minimum of 10 to 15 feet from all sapwood showing fungal discoloration.

Fungicide injections may also be used therapeutically, either alone or in combination with pruning. Again, only trees showing early stages of disease infection should be treated, and even then there is no assurance of success. Fungicide applications should not be used as preventive treatments because the wounds created by drilling the holes necessary for injection can be damaging. Recent reports that the bacterium *Pseudomonas syringae* have therapeutic antifungal activity have given hope for a biological control for Dutch elm disease. However, additional research is needed to determine the effectiveness of these bacteria.

When elm trees are growing in close proximity to one another as they often are along streets, in parks, and in hedgerows, both Dutch elm disease and phloem necrosis can be transmitted from tree to tree by root grafts. The frequency of root-graft transmission can be substantially reduced by either chemically killing (with Vapam) tree roots in a narrow zone or mechanically trenching between infected and healthy trees. Both methods are expensive, and neither can be effectively utilized in the narrow tree lawns commonly found along street sides where tree roots are found below cement or blacktop.

Planting disease-resistant trees is an indirect method of controlling Dutch elm disease and phloem necrosis. The effects of these two diseases on elms have emphasized the highly vulnerable nature of single species planting programs in cities. Further diversification of plant material is clearly indicated because Norway maples, honeylocusts, and London planetrees are currently being overplanted in many cities.

Although the American elm and other elms native to the United States are very risky plantings because of their high susceptibility to both Dutch elm disease and phloem necrosis (see Table 2), there are elms that have excellent disease resistance. They include the species *Ulmus parvifolia*, *U. pumila*, *U. wallichiana*, and the recent selections 'Sapporo Autumn Gold' and 'Urban' elm. Unfortunately, these trees do not have the vase-shaped crown of the American elm. Furthermore, *U. wallichiana* and *U. pumila* selections are needed with improved cold hardiness and better resistance to *Nectria* canker. *Ulmus pumila* trees are also weak wooded and suffer storm breakage.

The task before the tree breeder is to develop hybrid elms with the disease resistance of the Asian elms and the ornamental characteristics and the urban hardiness of the American elm. Work has begun at several research stations to develop improved Asian elm selections and hybrids. A species that has excellent urban hardiness and that often has a very attractive exfoliating bark is *Ulmus parvifolia*. This species should be more commonly planted in the United States.

Recently released Dutch clones such as 'Groenveld', 'Plantyn', 'Dodoens', and 'Lobel' are only moderately resistant to the aggressive strain of Dutch elm disease, while 'Commelin', an early Dutch selection, has no resistance to it. Thus, these elms should be used only sparingly in the United States.

In conclusion, there are no simple solutions to the diseases affecting some of America's finest elms. The best hope lies in hybridization experiments that may produce a hardy, resistant hybrid elm with outstanding ornamental characteristics. In the meantime, planting selected alternatives and pursuing an integrated program of pest management and sanitation, are the disturbing facts of life for the elm in America.

References

Braun, E. J. & Sinclair, W. A. 1979. Phloem necrosis of elms: symptoms and histopathological observations in tolerant hosts. *Phytopathology* 69: 354–358.

Cannon, W. N. Jr. & Worley, D. P. 1980. Dutch elm disease control: performance and costs. *USDA Forest Serv. Res. Pap.* NE-457.

Gibbs, J. N., Burdekin, D. A., & Brasier, C. M. 1977. Dutch elm disease. *Forestry Commission Forest Record (England)* No. 155.

Holmes, F. W. 1980. Bark beetles, *Ceratocystis ulmi* and Dutch elm disease. Chap. 8 *in: Vectors of Plant Pathogens*. Harris, K., & Maramarosch, K., eds., New York: Academic Press.

Karnosky, D. F. 1979. Dutch elm disease: a review of the history, environmental implications, control, and research needs. *Environ. Cons.* 6: 311–322.

Santamour, F. S., Jr. & Felix, R., eds. 1977. The current state of the art of Dutch elm disease control. *National Arborist Assoc. Symp.* No. 1.

Schreiber, L. R. & Peacock, J. W. 1979. Dutch elm disease and its control. *USDA Agr. Infor. Bull.* No. 193.

Sinclair, W. A. & Campana, R. J. 1978. Dutch elm disease perspectives after 60 years. New York State Agric. Exp. Station, Cornell University.

Sinclair, W. A., Braun, E. J., & Larsen, A. O. 1976. Update on phloem necrosis of elms. *J. Arboric.* 2: 106–113.