Sustainable Urban Landscapes

Dutch Elm Disease

AND DISEASE-RESISTANT ELMS

Dutch elm disease (DED) has had a devastating impact on the urban landscape of North America. The American elm (*Ulmus americana*) was at one time the most extensively planted shade tree in the United States. Unfortunately, all elm species native to North America, especially American elm, are susceptible to DED. The disease was first described in the Netherlands in 1919. By the early 1930's the first outbreaks of DED in North America had occurred in Cleveland and Cincinnati, Ohio. The first reported cases in Iowa were in Lee and Scott Counties in 1956. Since that time, DED has been detected in all 99 counties, and approximately 95 percent of Iowa's urban American elms have been killed.

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DED has destroyed a similar percentage of urban elms throughout the United States. Millions of native elms in the countryside also have died from the disease, and trees continue to die every year. Threatened elm trees can be preserved only when an intensive, cooperative effort is made to control Dutch elm disease.

A hopeful development in the war against DED is the commercial release of a number of elm cultivars and species that possess genetic resistance or tolerance to the disease. The characteristics of these elms will be discussed in the second part of this bulletin.

Symptoms The first symptom of Dutch elm disease is wilting leaves on one or a few branches in the upper canopy of the tree (*Figures 1 and 2*). Affected leaves usually turn yellow, then brown, and fall from the tree prematurely. Sometimes the leaves dry out very quickly and turn dull green, remaining on the tree for weeks or months before falling. Once a branch has lost its leaves, it usually dies quickly. If a tree infected in one season survives to the next season, it will produce smaller-than-normal leaves during spring growth. Depending on when and how the tree was infected, its branches may die progressively, or the entire tree may die within a few weeks of infection.

Elm leaves also can wilt or turn brown for other reasons, including mechanical injuries, feeding damage by elm leaf beetles (*Figure 3*), or infection by elm yellows, a common northeastern U.S. disease caused by a type of bacterium called a phytoplasma. For this reason, you need to look closely to determine if Dutch elm disease is causing the wilting. When the bark is stripped from recently wilted branches of DED-infected trees, brown streaks are usually present in the outer sapwood (*Figure 4*).

Laboratory testing of branch segments is the best way to confirm whether a wilting elm tree has DED. In Iowa, samples can be submitted to the Plant and Insect Diagnostic Clinic at Iowa State University. Samples for testing should be branch segments 1/4 to 1 inch in diameter and 6 to 12 inches in length, collected from recently wilted areas of the tree. At least four branch segments that show brown streaking should be collected. The DED fungus cannot be isolated from dry, dead branches. To mail samples to the Plant and Insect Diagnostic Clinic, wrap them in dry newspaper, place in an open plastic bag, and then in a box. Include a plant problem submission form with your name and information, and specify that you want the branches tested for DED. A small fee is assessed for this service. Visit the clinic website for current services, submission forms and fees at www.ent.iastate.edu/pidc.

Causal Agent Dutch elm disease is caused by the fungi *Ophiostoma ulmi* and *Ophiostoma novo-ulmi*. *0. ulmi* is the original species introduced to the United States and Europe. *O. novo-ulmi* is a more aggressive species that has become more prevalent in recent decades, virtually replacing *O. ulmi* in Iowa. *Ophiostoma* grows in the xylem (water-conducting tissue) of elms. In an attempt to fight invasion by the fungus, an infected tree will produce gums and cell outgrowths that block its own xylem vessels. Blockage of a tree's water supply causes the characteristic wilting symptoms.

1

Wilting caused by DED has progressed into several branches of this tree.

2

A single wilted branch in the canopy of an American elm is an early symptom of DED infection that has been spread by elm bark beetles.

3

Damage to leaves caused by elm leaf beetles is unrelated to DED but is sometimes mistaken for wilting symptoms of this disease.

4

Discoloration of the xylem (water-conducting tissue) caused by DED infection often results in a dark brown discoloration of one-year-old xylem in a ring pattern (center branch) or dark brown streaks in xylem vessels in the outer sapwood (branch at right). The branch at left displays the normal cream color of healthy wood.


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3 4

Disease Transmission The fungus is transmitted from infected to healthy trees either by elm bark beetles or by root grafts formed between neighboring trees.

Bark beetle transmission. Transmission by elm bark beetles is a key component of the DED disease cycle. Two species of beetles spread the fungus from infected to healthy elms: the European elm bark beetle *(Scolytus multistriatus)* (*Figures 5 and 6*) and the native elm bark beetle *(Hylurgopinus rufipes)*. These two beetles are similar in size (approximately 1/8 inch long) and appearance, but they have different habits and life cycles.

European elm bark beetles, the more common of the two beetle species in Iowa, survive the winter as larvae in recently killed elm wood. The DED fungi grow into the beetles' brood galleries (tunnels in the inner bark where eggs are laid). The sticky spores of the DED fungi (*Figure 7*) will adhere to adult beetles as they emerge in late April through June. The beetles then fly to a live elm tree and bore into small branch crotches to feed. Germinating spores on the beetle's body enter the vascular system of the tree through feeding wounds. After maturing, adult females seek out sick or dead elm wood in which to lay eggs. The female lays her eggs in brood galleries tunneled parallel with the wood grain in the inner bark. Larvae hatched from these eggs bore tunnels from the main brood gallery into the surrounding inner bark (*Figure 8*).

Native elm bark beetles overwinter as larvae in dead wood or as adults in the lower trunks of healthy elms. Overwintering adults emerge in the spring and tunnel into the inner bark of branches two to four inches in diameter. As the weather turns warmer, the beetles leave their branches to find suitable dead wood in which to lay their eggs. The brood galleries of the native bark beetle are bored perpendicularly to the grain of the wood, and developing larvae bore away from the gallery in the direction of wood grain. Larvae of the native elm bark beetle mature and emerge as adults in late July and August.

Root Graft Transmission. The second way DED fungi can enter healthy elm trees is through root grafts (*Figure 9*). The root systems of elms whose trunks are within approximately 50 feet of one another tend to fuse together, producing a continuous vascular network between trees. If one of the trees in the network becomes infected with *Ophiostoma,* the fungus can move rapidly within the xylem to any other elm tree which is root-grafted to the infected tree. This is the reason neighborhoods with colonnades of adjacent elms lining streets lost many trees very rapidly (*Figures 10 and 11*). It has been estimated that more than 90 percent of urban elms killed in DED epidemics became infected through root grafts.

Control Strategies ***Sanitation***. Prompt, thorough sanitation is vital for controlling Dutch elm disease. DED sanitation programs can be successful only when they are applied to the entire community, including trees in parks, fencerows, cemeteries, and other sites as well as in residential areas. Removing sources of the DED fungus and breeding grounds for the beetles is essential. Any tree that has died due to DED should be cut down and destroyed promptly. Branches pruned from infected trees also should be destroyed. All infected wood should be burned, buried, or chipped. Do not store firewood from DED-infected elms with the bark attached, because logs with attached bark provide breeding sites for beetles. Available evidence indicates that wood chips made from DED-infected trees pose no risk of transmitting the disease.

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Size comparison of elm bark beetles with the end of a pencil.

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Close-up of a European elm bark beetle, the major insect vector of DED in Iowa.

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Sticky spores of the DED fungi, produced in the bark beetle galleries of an infected elm, adhere to the bodies of elm bark beetles before the beetles emerge from these trees and fly to healthy trees.

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Larvae (white semicircles) are visible in tunnels they bored through the inner bark of an elm tree from the brood gallery (large vertical tunnel), where eggs that hatched into the larvae were laid.

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7 8

Disrupting Root Grafts. When the trunk of a DED-infected elm is within 50 feet of the trunks of other susceptible elms, root grafts can be disrupted to block the spread of the disease. Determine the line of root graft disruption between adjacent trees by marking a line or an arc equidistant between the two trees. This is the line along which trenching should be done, or soil fumigants placed. Trenching can be done with a chain trencher, a vibratory plow, or a sharp spade. The trench should be at least four feet deep. Be sure to contact local authorities about the possibility of buried utilities before digging (In Iowa, call 1-800-292-8989). In areas where trenching is not an option due to sidewalks, fences, or buried utilities, chemical fumigants can be an effective way to disrupt root grafts. Holes two feet deep and close to an inch in diameter should be dug along the equidistant line every six to twelve inches. A properly labeled fumigant such as Vapam can be poured into these holes, which are then sealed. When working around sidewalks and driveways, holes should be angled underneath these features to more effectively distribute the fumigant. Be sure to follow label directions carefully.

Fungicide injection. Fungicide injections have been used to defend against DED for more than 50 years. Fungicide injections have been most successful in controlling Dutch elm disease when used as a preventive treatment on uninfected trees. Success in treating trees with crown symptoms is much less certain. Trees with more than 10 percent of the crown infected are unlikely to be rescued by fungicide injection.

Several methods are used for injecting fungicides into elms. One method is to pump a dilute solution of fungicide into a tree through holes drilled in the root flare. The root flare, the zone where the trunk meets the roots, is exposed by excavating soil around the trunk to a depth of 6 to 12 inches. Small (7/32- to 9/32-inch-diameter) holes are drilled less than 1 inch deep into the root flares around the entire circumference of the tree at specified spacing. After tapered injection tees are tapped into the holes, the tees are connected to each other and to a pump with plastic tubing (*Figure 12*). The fungicide is pumped into the tree through the manifold of plastic tubing and injection tees. An alternative injection technique involves the use of plastic capsules containing concentrated fungicide. These capsules can be pressurized by hand after their injection tees are tapped into holes in the root flare. Although it is legal for homeowners to apply injection treatments to their own trees, it is strongly recommended that injections be done by a reputable professional arborist who also is a licensed pesticide applicator.

Fungicide injections are costly. A single mature elm will often cost hundreds or even thousands of dollars to inject. The protective effect of fungicide injections may last one to three years, so repeat injections may be needed. Therefore, only very valuable trees are treated with fungicides. Fungicide treatments alone cannot save an elm tree from succumbing to DED, but along with prompt, thorough sanitation they can help save high-value trees that would otherwise be killed.

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Excavated roots of two adjacent elms showing grafting between the roots. Root grafting joins together the vascular systems of adjacent trees, allowing DED fungi to pass through grafts from an infected tree into its neighbor.

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Rows of adjacent American elms arching over a city street provided a beautiful colonnade effect. This distinctive landscape feature was common before DED epidemics killed most such plantings.

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Extensive colonnades of American elms were killed rapidly during DED epidemics. Most trees in such colonnades were killed when the DED fungi spread between neighboring trees through root grafts.

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The root flare of this American elm has been excavated to permit installation of plastic tees and tubing for injection of fungicides to protect against DED.

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DED-resistant Elms

Fungicides and sanitation have had only occasional success in deterring DED. Researchers have therefore redirected their efforts to developing DED-tolerant or DED-resistant elms. European and Asiatic elms have played a significant role in the breeding, selection, and cultivar release efforts, but considerable emphasis also has been given to breeding and selecting American elms. The goal of finding or creating a DED-tolerant American elm was viewed skeptically in the past, but hopes have been revived with the release of several cultivars showing high levels of DED tolerance.

The new American elm cultivars, '**Valley Forge**' (*Figure 13*) and '**New Harmony**' (*Figure 14*), are products of the U.S. National Arboretum tree genetics program that have demonstrated high levels of tolerance to both *O. novo-ulmi* and *O. ulmi*. Tolerance to DED is characterized by reduced wilting and crown dieback after fungal inoculation. In fact, these trees have the ability to recover from DED infection even after symptom expression.

Of the thousands of American elms screened, 'Valley Forge' has shown the best tolerance to DED. The tree has an upright, arching, broadly vase-shaped branching structure with a full, dense canopy of leaves. Clones from the original parent tree are 26 feet tall with an average crown spread of 30 feet after 12 growing seasons. Summer leaves are green, turning yellow in autumn. The bark is typical of the species, with grayish, flat-topped ridges separated by diamond-shaped fissures. 'Valley Forge' is considered hardy in USDA zones 5 (southern Iowa) through 7.

While not as disease-tolerant as 'Valley Forge,' 'New Harmony' still ranks in the top three among the thousands of American elms subjected to intensive inoculation with the DED fungus. The parent tree of 'New Harmony' displays a broad, vase-shaped crown and has grown approximately 68 feet tall and 72 feet wide. Leaf and bark characteristics are similar to those of 'Valley Forge', but because of its acceptable performance in Minnesota, 'New Harmony' is considered hardy in USDA zones 4 through 7 (includes all of Iowa).

'**Independence**' *(Ulmus americana* 'Moline' x *Ulmus americana* W *185-21)* (*Figure 15*) is one of six clones that comprise the much-heralded 'American Liberty' multiclone variety. Patented by Smalley and Lester (Univ. of Wisconsin, Madison), 'Independence' develops an upright, vase-shaped crown typical of the species and has demonstrated tolerance to DED, but may be quite susceptible to elm yellows (a relatively rare disease in the Midwest).

The combination of environmental adaptability, DED tolerance, and the highly prized vase-shaped crown form will make these selections extremely popular in the future. However, it will probably take a number of years before these trees become commonplace in nurseries and retail garden centers. It also is important to remember that none of the new American elm cultivars are completely immune to DED, and that DED tolerance of mature trees has not yet been evaluated.

Homeowners and professional arborists also should consider the many commercially available hybrid elms for augmenting and diversifying their plantings. These hybrids are the results of crosses made with species of elms from Asia and Europe which have very high levels of resistance to DED. Some of the more important introductions are described below.

Accolade™ *(Ulmus japonica* x *Ulmus wilsoniana)* (*Figure 16*) — Also known as Thornhill elm. This hybrid was released by the Morton Arboretum, Lisle, IL.

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'Valley Forge,' a DED-tolerant American elm cultivar developed at the U.S. National Arboretum.

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'New Harmony,' a DED-tolerant American elm cultivar developed at the National Arboretum.

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'Independence,' a DED-tolerant American elm hybrid developed at the University of Wisconsin.

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Accolade™, a hybrid elm developed at the Morton Arboretum.

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The tree displays a handsome vase-shaped canopy, deep green glossy leaves, and has shown resistance to DED, elm leaf beetle, and leaf miner, but only moderate tolerance of urban soil conditions such as high clay content and seasonal wetness. It is hardy through USDA zone 4. Other elms from the Morton Arboretum that show promise include Danada Charm™, 'Vanguard,' and 'Triumph.'

'**Cathedral**' *(Ulmus pumila* x *Ulmus japonica)* (*Figure 17*) — One of several excellent cultivars developed at the University of Wisconsin, 'Cathedral' has demonstrated good tolerance to DED, experiencing only branch tip injury when infected with the fungus. The tree has a broad vase shape, medium to light green leaves in summer, and yellow fall foliage. In addition, 'Cathedral' is highly tolerant to Verticillium wilt and is resistant to attack by the elm leaf miner. It is reliably hardy through USDA zone 4.

'**Frontier**' *(Ulmus carpinifolia* x *Ulmus parvifolia)* (*Figure 18*) — Released in 1990 by the USDA, 'Frontier' has demonstrated a high degree of resistance to DED, moderate resistance to elm leaf beetle, and high tolerance to the phytoplasma-caused elm yellows.

Emerging leaves in spring are red, gradually changing to yellow-green in summer, finally turning red-purple in autumn. Although 'Frontier' becomes pyramdial instead of vase-shaped as it matures, it still should make a desirable street, park, landscape, or highway tree. Because it has sustained some low-temperature injury in Minnesota, 'Frontier' is considered reliably hardy only through USDA zone 5 (southern Iowa).

'**Homestead**' *(Ulmus pumila* x complex hybrid from the Netherlands elm breeding program) (*Figure 19*) — Another USDA release, 'Homestead' has a symmetrical, somewhat pyramidal crown that becomes arching as the tree ages. Its dark green summer leaves turn golden-yellow in fall and the growth rate is reportedly rapid. 'Homestead', best used in USDA hardiness zones 5 through 8, is considered highly resistant to DED, but is susceptible to elm leaf beetle.

'**New Horizon**' (*Ulmus japonica* x *Ulmus pumila*) (*Figure 20*) — This hybrid has excellent resistance to DED and elm leaf miner and high tolerance to Verticillium wilt. It has an upright habit, strong branch structure, and a dense crown with dark green leaves. 'New Horizon' is hardy through USDA zone 4.

'**Patriot**' *(Ulmus* 'Urban' x *Ulmus wilsoniana* 'Prospector') (*Figure. 21*) — Developed at the U.S. National Arboretum and released by the USDA, 'Patriot' has a moderately vase-shaped crown, resembling a more upright American elm. It has shown a high level of resistance to DED, high tolerance to elm yellows, and reduced susceptibility to the elm leaf beetle. 'Patriot' is adapted to a wide variety of soil conditions, grows best in full sun, and is considered cold hardy through USDA hardiness zone 4.

'**Pioneer**' *(Ulmus glabra* x *Ulmus carpinifolia)* (*Figure 22*) — 'Pioneer' is a vigorous, fast-growing USDA selection with large, dark green leaves and a globe-shaped crown. Hardy in USDA zones 5 through 8, it has proven resistant to DED and elm yellows, but elm leaf beetle feeding may be a problem. Because of its broad, spreading habit, 'Pioneer' is best suited to spacious grounds like those found in parks, golf courses, and large commercial properties.

'**Prospector**' *(Ulmus wilsoniana)* (*Figure 23*) — This seedling selection was released in 1990 by the USDA. 'Prospector' elm has an American elm-like vase-shaped crown but its branches become pendulous at a much lower height. Newly expanding leaves are orange-red, but gradually darken to green, finally turning yellow in autumn. 'Prospector' is resistant to DED, tolerant to elm yellows, resistant to elm leaf beetle, and is considered adaptable in USDA hardiness zones 4 through 7.

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'Cathedral,' a hybrid elm developed at the University of Wisconsin.

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'Frontier,' a hybrid elm developed by the USDA.

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'Homestead,' a hybrid elm released by the USDA.

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'New Horizon,' a hybrid elm cultivar released by the University of Wisconsin.

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'**Regal**' (*Ulmus* 'Commelin' x *Ulmus* 'Hoersholmiensis') (*Figure 24*) — Selected at the University of Wisconsin, 'Regal' develops a strong central leader with an upright or columnar growth habit when young, becoming more ovate with age. Leaves are dark green in summer, show no appreciable fall coloration, and because they are rather sparsely borne, cast a honeylocust-like light shade that makes possible the successful culture of turfgrass in the vicinity of the tree. 'Regal' is considered highly resistant to DED and Verticillium wilt, and is hardy in USDA zones 4 through 7.

Over the past 30 to 40 years, plant breeders have spent considerable time, effort, and resources searching for elms having resistance to DED and other pests, and possessing the graceful crown architecture of the revered American elm. The recent release of *Ulmus americana* 'Valley Forge' and 'New Harmony' and the improved availability of many excellent hybrid elms are certain to spark renewed interest for elms of all kinds. However, the sad experience of the DED epidemic has taught some hard lessons about using elms in urban sites. It is clearly important to avoid colonnade-type plantings of elms, since adjacent trees will root-graft and potentially spread DED. The new elm cultivars and species are best used as specimen trees rather than as large-scale monocultures as in the past. With genetic tolerance and resistance, together with judicious planting practices, the elm may be ready for a major comeback in Iowa landscapes.

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'Patriot,' a hybrid elm developed by the National Arboretum and released by the USDA

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'Pioneer,' a hybrid elm released by the USDA.

23

'Prospector,' a seedling elm released by the USDA.

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'Regal,' a hybrid elm released by the University of Wisconsin.

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