Ulmus americana L. American Elm

Ulmaceae Elm family

Calvin F. Bey

American elm *(Ulmus americana),* also known as white elm, water elm, soft elm, or Florida elm, is most notable for its susceptibility to the wilt fungus, ***Ceratocystis ulmi.*** Commonly called Dutch elm disease, this wilt has had a tragic impact on American elms. Scores of dead elms in the forests, shelterbelts, and urban areas are testimony to the seriousness of the disease. Because of it, American elms now comprise a smaller percentage of the large diameter trees in mixed forest stands than formerly Nevertheless, the previously developed silvical concepts remain basically sound.

Habitat

Native Range

American elm (figs. 1, 2) is found throughout Eastern North America. Its range is from Cape Breton Island, Nova Scotia, west to central Ontario, southern Manitoba, and southeastern Saskatchewan; south to extreme eastern Montana, northeastern Wyoming, western Nebraska, Kansas, and Oklahoma into central Texas; east to central Florida; and north along the entire east coast.

Climate

Within the natural range of American elm, the climate varies from warm and humid in the southeast to cold and dry in the northwest. Average temperatures are as follows: January, from –18° C (0° F) and below in Canada and 16" C (60" F) in central Florida; July, from 16" C (60" F) in Manitoba to 27" C (80° F) in the Southern States; annual maximum, 32" C (90° F) to 35" C (95" F) in the Northeast and 38" C (100° F) to 41" C (105" F) in the South and West; annual minimum, from -40" C (–40° F) to –18° C (0° F) in the North and -18" C (0° F) to -1" C (30" F) in the South.

Average annual precipitation varies from a scarce 380 mm (15 in) in the Northwest to a plentiful 1520 mm (60 in) on the gulf coast. Over the central part of the species range there are about 760 to 1270 mm (30 to 50 in) per year. Throughout the range most of the precipitation comes during the warm (April-September) season. Average annual snowfall generally varies from none in Florida to about 200 cm (80 in) in the Northeast. A few areas, mainly around the Great Lakes, get 254 to 380 cm (100 to 150 in) of snow per year.

The average frost-free period is about 80 to 160 days for the northern tier of States and Canada to about 200 to 320 days for the gulf coast and Southeastern States.

Soils and Topography

American elm is most common on flats and bottom lands throughout its range but is not restricted to these sites. On the southern bottom-land region, it is found widely in first bottoms and terraces, especially on first bottom flats, but not in deep swamps. At higher elevations in the Appalachians, it is often limited to the vicinity of large streams and rarely appears at elevations above 610 m (2,000 ft). In West Virginia, however, it does appear in high coves at elevations of 760 m (2,500 ft). In the Lake and Central States, it is found on plains and morainal hills as well as on bottom lands and swamp margins. Along the northwestern edge of the range, it is usually restricted to valley bottoms along watercourses.

Although American elm is common on bottom-land soils, it is found on many of the great soil groups within its range. The soils include well-drained sands, organic bogs, undifferentiated silts, poorly drained clays, prairie loams, and many intermediate combinations.

American elm grows best on rich, well-drained loams. Soil moisture greatly influences its growth. Growth is poor in droughty sands and in soils where the summer water table is high. In Michigan, on loam and clay soils, growth is good when the summer water table drops 2.4 to 3.0 m (8 to 10 ft) below the surface, medium with summer water table at 1.2 to 2.4 m (4 to 8 ft), and poor when topsoil is wet throughout the year. On sandy soils underlain with clay, growth is medium to good where the summer water table is 0.6 m (2 ft) or more below the soil surface. Organic soils are usually poor sites, but those with a summer water table at least 0.6 m (2 ft) below the surface are classed as medium sites for American elm.

In the South, American elm is common on clay and silty-clay loams on first bottoms and terraces; growth is medium on wetter sites and good on well-drained flats in first bottoms *(8).* In the arid western end of the range, it is usually confined to the silt or clay

The author is Staff Assistant, Office of Deputy Chief for Research, USDA Forest Service, Washington, DC.

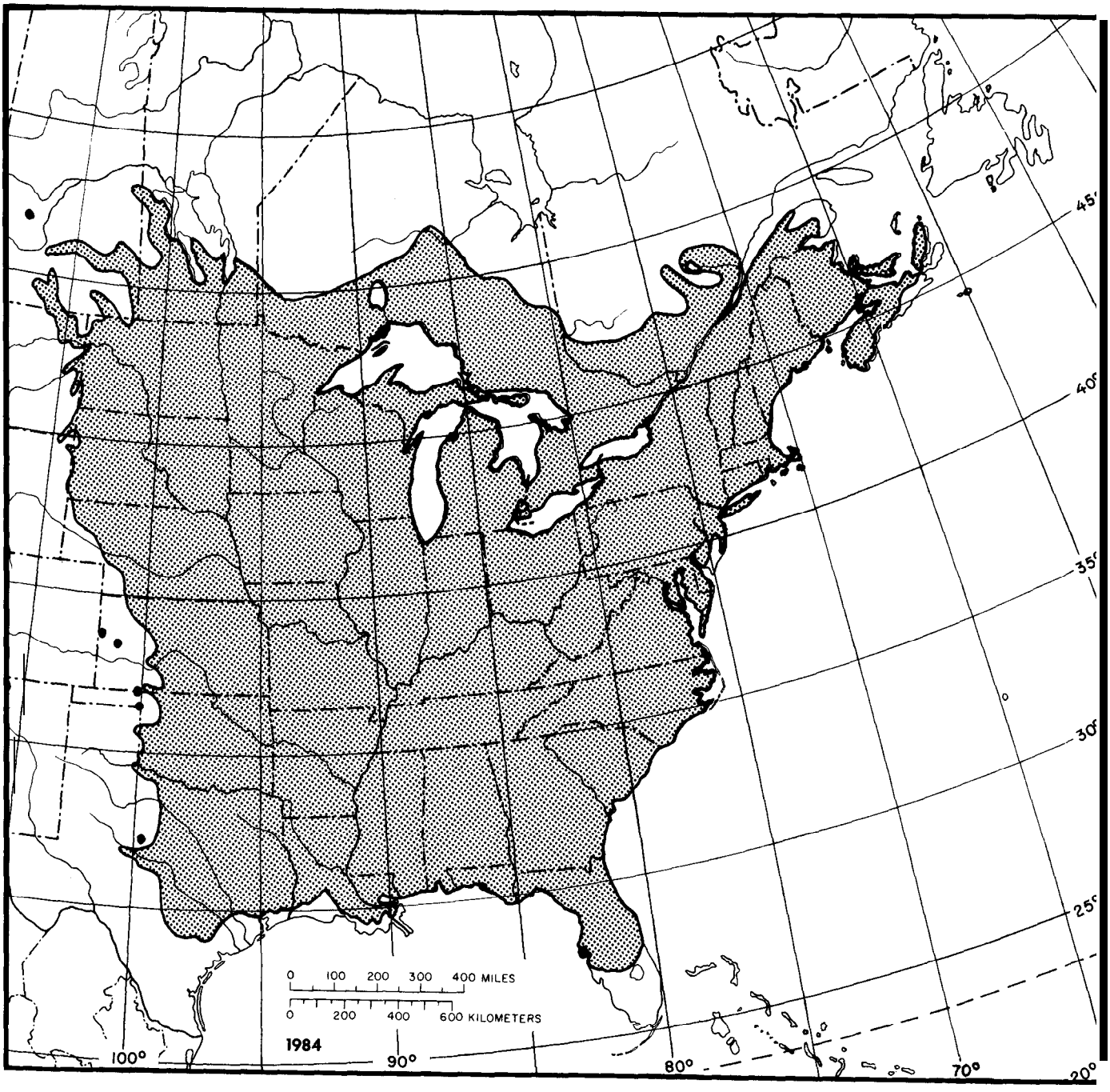

Figure *1-The native range of American* **elm.**

loams in river bottoms and terraces. In shelterbelt plantings on the uplands, however, survival is generally best on sandy soils where the moisture is more evenly distributed to greater depths than in fine-textured soils. American elm most commonly grows on soils of the orders Alfisols, Inceptisols, Mollisols, and Ultisols.

Soil acidity under stands of American elm varies from acid on some of the swamp margin sites in the Lake States to mildly alkaline on the prairie soils. A soil reaction considered suitable for this species ranges from pH 5.5 to 8.0.

Leaf litter of American elm decomposes more rapidly than that of sugar maple *(Acer saccharum)*,

Figure *2-Forest-grown American elm.*

shagbark hickory *(Carya ovata)*, white oak *(Quercus alba),* and northern red oak *(Q. rubra).* Under Missouri conditions, the leaves crumble readily after 18 months on the ground. They have a relatively high content of potassium and also of calcium (1 to 2 percent). Because its litter decomposes rapidly and contains many desirable nutrients, American elm is considered a "soil-improving" species.

Associated Forest Cover

Throughout its range, American elm seldom grows in pure stands and is usually found in mixture with other species. It is a major component of four forest cover types: Black Ash-American Elm-Red Maple (Society of American Foresters Type 39), Silver Maple-American Elm (Type 62), Sugarberry–American Elm-Green Ash (Type 93), and Sycamore–Sweetgum-American Elm (Type 94). It is a minor component in 20 other forest types.

Black Ash-American Elm-Red Maple (Type 39) appears throughout the Northern Forest and into the Boreal Forest in Canada, and throughout the Lake States and into the northern edge of the Central Forest. In this type the most common associates, other than the type species, are as follows: In the Lake States and Canada, balsam poplar *(Populus balsamifera),* balsam fir *(Abies balsamea)*, and yellow birch *(Betula alleghaniensis);* in Ohio and Indiana, silver maple *(Acer saccharinurn),* swamp white oak *(Quercus bicolor),* sycamore *(Platanus occidentalis),* pin oak *(Quercus palustris)*, black tupelo *(Nyssa sylvatica)*, and eastern cottonwood *(Populus deltoides)*; in New England and eastern Canada, sweet birch *(Betula lenta),* paper birch *(B. papyrifera),* gray birch *(B. populifolia),* silver maple, and black spruce *(Picea mariana);* and in New York, white ash *(Fraxinus americana),* slippery and rock elms *(Ulmus rubra* and *U. thomasii),* yellow birch, black tupelo, sycamore, eastern hemlock *(Tsuga canadensis)*, bur oak *(Quercus macrocarpa),* swamp white oak, and silver maple.

Silver Maple-American Elm (Type 62) is common throughout the Central Forest and extends into Canada. Major associates in this type are sweetgum *(Liquidambar styraciflua),* pin oak, swamp white oak, eastern cottonwood, sycamore, green ash *(Fraxinus pennsylvanica),* and other moist site hardwoods.

Sugarberry-American Elm-Green Ash (Type 93) is found throughout the Southern Forest within the flood plains of the major rivers. Hackberry *(Celtis occidentalis)* replaces sugarberry *(C. laevigata)* in the northern part of the range. Major associates are water hickory *(Carya aquatica),* Nuttall *(Quercus nuttallii),* willow *(Q. phellos),* water *(Q. nigra),* and overcup *(Q. lyrata)* oak, sweetgum, and boxelder *(Acer negundo).*

Sycamore-Sweetgum-American Elm (Type 94) appears as scattered stands throughout the Southern Forest region and lower Ohio River Valley. Common associates include green ash, sugarberry, hackberry, boxelder, silver maple, cottonwood, black willow *(Salix nigra),* water *oak,* and pecan *(Carya illinoensis).*

Life History

Reproduction and Early Growth

Flowering and Fruiting-The process of flowering, seed ripening and seed fall in American elm

takes place in the spring throughout the range. The glabrous flower buds swell early in February in the South and as late as May in Canada. The flowers appear 2 to 3 weeks before leaf flush. Soon after wind pollination occurs, the fruit ripens, and seed fall is usually complete by mid-March in the South and mid-June in the North.

American elm flowers are typically perfect and occur on long, slender, drooping pedicels, about 2.5 cm (1 in) long, in 3- or 4-flowered short-stalked fascicles. The anthers are bright red, the ovary and styles are light green, and the calyx is green tinged with red above the middle. With controlled pollinations, floral receptivity is greatest when stigma lobes are reflexed above the anthers. The trees are essentially self-sterile. A test in Canada showed only 1.5 percent viable seed from self-pollinated flowers. Pollination may be hampered in a wet spring since the flower anthers will not open in a saturated atmosphere (9).

Seed Production and Dissemination-Seed production in American elm may begin as early as age 15 but is seldom abundant before age 40. When mature, American elm is a prolific seed producer. Trees as old as 300 years have been reported to bear seeds. In closed stands, seed production is greatest in the exposed tops of dominant trees. The winged seeds are light and readily disseminated by the wind. Although most seeds fall within 91 m (300 ft) of the parent tree, some may be carried 0.4 km (0.25 mi) or more. In river-bottom stands, the seeds may be waterborne for miles. Cleaned but not dewinged seeds average 156,000/kg (70,900/lb).

Adverse weather may reduce the seed crop. Spring frosts can injure and kill both flowers and fruit. Observations in Minnesota showed that while nearly ripe seeds were not injured by night temperatures of -3" C (27" F) for several successive nights, most were killed a week later when the temperature dropped to -7" C (19" F) and remained below freezing for 60 hours.

Mammals and birds also may reduce the seed crop. The flower buds, flowers, and fruit are eaten by gray squirrels. The seeds are also eaten by mice, squirrels, opossum, ruffed grouse, Northern bobwhite, and Hungarian partridge.

Seedling Development-Germination in American elm seed is epigeal. It usually germinates soon after it falls, although some seeds may remain dormant until the following spring. While germination may extend over a period of 60 days, most of the seeds germinate in 6 to 12 days. Germination is best with night temperatures at 20" C (68" F) and day temperatures of 30" C (86° F). However, germination is almost as good when daily temperatures range between 10" C (50° F) and 21" C (70° F). Seeds can germinate in darkness, but germination increases in light. Seeds also can lie on flooded ground for as long as 1 month with little adverse effect on germination, except possibly where siltation occurs in flooded bottoms.

American elm seedlings can become established on moist litter, moss, and decayed logs and stumps, but do best on mineral soil. Although they do grow in full sunlight, seedlings perform best with about one-third of full sunlight during the first year. After the first year or two, they grow best in full sunlight. Seedlings that develop in saturated soils are stunted and characterized by early yellowing and loss of the cotyledons, extremely short internodes, and small leaves.

American elm can withstand flooding in the dormant season but dies if the flooding is prolonged into the growing season. Compared with other bottomland species, American elm is intermediately tolerant to complete inundation. Some may be killed by early fall frosts, but those that survive soon are hardened by temperatures alternating between 0" C (32" F) and 10" C (50° F). A constant temperature of 0° C (32" F) for 5 days also hardens the seedlings enough to avoid frost killing (7).

Studies in Iowa and southeastern Michigan on wet lowland and upland mesic sites show that despite high mortality from Dutch elm disease, the next generation will be much like the last. Although American elm has been essentially eliminated from the overstory, it is a significant part of the understory and seedling layers. Some observations suggest that there will be a shift toward more intolerant species under the dead elms. American elm may be perpetuated for generations, even though the average life span of the trees is likely to be reduced. Where seeds are available, American elm is a prominent early invader of abandoned fields. On upland sites in the Midwest, fire, as a natural component of the environment, has kept American elm from invading the prairies *(1,2,12,13)*.

In determining vegetational patterns and succession, allelopathy is apparently not as important for species coming in under American elm as it is for species coming in under sycamore, hackberry, northern red oak, and white oak. In a test in Missouri, there was lower productivity and higher percent soil moisture under all test species but American elm. This apparently was due to toxic leaf leachate present from the four test species, but not present in leachate from American elm *(11)*.

Vegetative Reproduction-Small American elm trees produce vigorous stump sprouts. Although not documented, some observations suggest that replacement in dense, undisturbed bottom-land stands in Minnesota may be by root suckers of mature trees.

American elm can be propagated by softwood cuttings taken in June and treated with indolebutyric acid or by leaf bud cuttings. In a test, greenhouse-grown stock rooted easier than field-grown stock. Propagation by dormant root cuttings has not been effective.

Sapling and Pole Stages to Maturity

Growth and Yield-American elm seldom grows in pure stands and there is no information on stand yields. On good sites in dense forest stands, American elm may reach 30 to 38 m (98 to 125 ft) in height and 122 to 152 cm (48 to 60 in) in d.b.h., with a 15 m (49 ft) clear bole. On medium sites, heights of 24 m (80 ft) are common. On very wet soils or on the very dry soils of the Plains, however, the species is often only 12 to 18 m (40 to 60 ft) tall at maturity. In open-grown or sparse stands, the trees usually fork near the ground and form wide arching crowns. American elm is a long-lived species, often reaching 175 to 200 years, with some older than 300 years.

Rooting Habit-The depth of rooting varies with soil texture and soil moisture. In heavy, wet soils the root system is widespread and within 0.9 to 1.2 m (3 to 4 ft) of the surface. On drier medium-textured soils, the roots usually penetrate 1.5 to 3.0 m (5 to 10 ft). In deep, relatively dry sands in the Dakotas, American elm may develop a taproot reaching 5.5 to 6.1 m (18 to 20 ft) down to the water table.

Reaction to Competition-American elm is classed as intermediate in shade tolerance among the eastern hardwoods. Usually it responds well to release, often growing more rapidly than its associates at advanced ages. Once it becomes dominant in a mixed hardwood stand, it is seldom overtaken by other species. It can persist in the understory of pioneer species such as eastern cottonwood, black willow, and quaking aspen *(Populus tremuloides)* but dies if suppressed by tolerant sugar maple or American beech *(Fagus grandifolia).*

Damaging Agents-Since 1930, when Dutch elm disease reached the United States in a shipment of elm logs from Europe, it has spread to 41 States from coast to coast. The causal fungus, *Ceratocystis ulmi,* is introduced into the sap stream of twigs or small branches during feeding by the smaller European elm bark beetle, *Scolytus multistriatus,* and the native elm bark beetle, *Hylurgopinus rufipes.* Dutch elm disease is characterized by a gradual wilting and yellowing of the foliage, usually followed by death of the branches and eventually the whole tree *(5,14).*

In addition to Dutch elm disease, several other diseases also are responsible for losses in shade and forest elms. Phloem necrosis, caused by a virus *(Morsus ulmi)* is detected by flagging or browned leaves and butterscotch-colored phloem with a wintergreen odor. It is transmitted by the whitebanded elm leafhopper *(Scaphoideus luteolus)* and through root grafts. Trees usually die within a year after symptoms appear. Verticillium wilt *(Verticillium albo-atrum)* is soil borne and usually enters host plants through the roots. Trees show dieback symptoms similar to Dutch elm disease *(10).* Other diseases include diebacks caused by *Cephalosporium* spp. and *Dothiorella ulmi;* a leaf black spot *(Gnomonia ulmea);* twig blight *(Cytosporina ludibunda);* cankers *(Nectria* spp., *Sphaeropsis ulmicola,* and *Phytophthora inflata);* elm wetwood *(Erwinia nimipressuralis);* and elm mosaic virus *(3,4).* Some of the common wood rot fungi are *Pleurotus ulmarius, P. ostreatus, Armillaria mellea, Ganoderma applanatum, Phellinus igniarius,* and numerous species of *Polyporus.*

American elm is attacked by hundreds of insect species including defoliators, bark beetles, borers, leaf rollers, leaf miners, twig girdlers, and sucking insects. The carpenter-worm *(Prionoxystus robinae)* bores into the sapwood and degrades the wood. Among the insects that defoliate elm are the spring cankerworm *(Paleacrita uernata),* the forest tent caterpillar *(Malacosoma disstria),* the elm leaf beetle *(Pyrrhalta luteola),* the whitemarked tussock moth *(Orgyia leucostigma),* the elm spanworm *(Ennomos subsignaria),* and many other leaf-eating insects that attack elm and other hardwoods. The elm cockscombgall aphid *(Colopha ulmicola)* forms galls on the leaves but does little damage to the tree. Several scale insects attack elm and may cause damage. Both the elm scurfy scale *(Chionaspis americana)* and the European elm scale *(Gossyparia spuria)* are widely distributed. Among the leafhoppers, the whitebanded elm leafhopper is classed as a serious pest since it is the vector for phloem necrosis *(15).*

Besides insect and disease losses, animal damage, and fire, climatic factors also can have an impact on survival and growth of American elm. Young forest trees may sunscald when exposed by harvesting or thinning operations. Open-grown American elm forks and develops a widespread crown that is susceptible to injury by heavy, wet snows and glaze storms. Of 37 tree species examined after an ice storm in Il-

linois, American elm ranked fourth in susceptibility to ice damage. In dense stands, such injuries are less severe and are not generally a management problem. Although American elm is shallow rooted in wet soils, it is fairly windfirm because the roots are widespread.

The species is reasonably drought resistant, but prolonged drought reduces growth and may cause death. During the drought of 1934, in the Midwest prairie region, losses of American elm and associated species ran as high as 80 to 90 percent. The 1951-54 drought also caused severe losses in the bottom lands of the South where American elm was more susceptible to drought than the lowland red oaks. Prolonged spring floods may cause death or growth loss. Despite suitable temperatures, in Minnesota bottom lands root elongation does not begin until the spring floods recede and soil aeration increases. On these sites and where trees are planted between street and sidewalk, buttress roots often are a result of inadequate soil aeration.

Fire damage is not a major management problem in the North; however, in southern bottom lands, fall and sometimes early spring fires are extremely damaging. Fires can kill seedling- and sapling-size trees and wound larger trees, thus admitting heart-rot fungi.

Animal damage to American elm, from the sapling stage to maturity, is not a serious problem except for sapsucker injury that degrades the wood.

Special Uses

Before the advent of Dutch elm disease, American elm was prized for its use as a street tree. It was fast growing, hardy, tolerant to stress, and appreciated for its characteristic vaselike crown. Beautiful shaded streets in many cities attested to its popularity.

The wood of American elm is moderately heavy, hard, and stiff. It has interlocked grain and is difficult to split, which is an advantage for its use as hockey sticks and where bending is needed. It is used principally for furniture, hardwood dimension, flooring, construction and mining timbers, and sheet metal work. Some elm wood goes into veneer for making boxes, crates, and baskets, and a small quantity is used for pulp and paper manufacture.

Genetics

The study of genetics in American elm has been primarily directed toward combining resistance to Dutch elm disease with desirable growth characteristics. Only a few selections from American elm look promising at this time. Noteworthy is the "American Liberty" elm, a multiclonal variety selected from second-generation crosses of the most resistant parents. Despite high selection intensity, their resistance is still inferior to resistant cultivars derived from Asian or European sources.

A few horticultural forms have been recognized. These are ***Ulmus americana columnaris,*** a form with a narrow columnar head, ***U. americana ascendens,*** with upright branches, and *U. americana pendula*, with long pendulous branches.

Hybridization within the genus *Ulmus* has been aimed primarily at breeding for Dutch elm disease and phloem necrosis resistance. Because of the difficulty of hybridizing American elm, which has a chromosome number twice that of all the other elms (56 versus 28), most of the breeding and selection work does not include American elm. Thousands of attempts to cross the American with the Siberian elm have failed. Reports of successful artificial hybridization and verification of hybridizing American elm with other elms are rare.

Literature Cited

1. Barnes, B. V. 1976. Succession in deciduous swamp communities of southeastern Michigan formerly dominated by American elm. Canadian Journal of Botany 54:19–24.
2. Bragg, T. B., and L. C. Hulbert. 1976. Woody plant invasion of unburned Kansas bluestem prairie. Journal of Range Management 29:19–24.
3. Filer, T. H., Jr., F. I. McCracken, and E. R. Toole. 1968. *Cephalosporium* wilt of elm in lower Mississippi valley. Plant Disease Reporter 52:170–171.
4. Ford, R. E., H. E. Moline, G. L. McDaniel, and others. 1972. Discovery and characterization of elm mosaic virus in Iowa. Phytopathology 62:987–992.
5. Gibbs, J. N. 1978. Intercontinental epidemiology of Dutch elm disease. Annual Review Phytopathology 16:287–307.
6. Guries, Raymond P., and Eugene B. Smalley. 1986. Elms for today and tomorrow. *In* Proceedings Third National Urban Forestry Conference. p. 214-218. Orlando, FL.
7. Harvey, R. B. 1980. Length of exposure to low temperatures as a factor in the hardening process in tree seedlings. Journal of Forestry 28:50–53.
8. Johnson, W. C., R. L. Burgess, and W. R. Keammerer. 1976. Forest overstory vegetation and environment on the Missouri River floodplain in North Dakota. Ecological Monographs 46:59–84.
9. Lee, M. J. T., and D. T. Lester. 1974. Floral receptivity in American elm. Canadian Journal of Forest Research 4:416–417.
10. Lester, D. T. 1975. Variation in tolerance of American elm to the *Verticillium* wilt fungus. Forest Science 21:227–231.

11. Lodhi, M. A. K. 1976. Role of allelopathy as expressed by dominating trees in a lowland forest in controlling the productivity and pattern of herbaceous growth. American Journal of Botany 63:1–8.
12. McBride, Joe. 1973. Natural replacement of disease-killed elms. American Midland Naturalist 90:300–306.
13. Richardson, C. J., and C. W. Cares. 1976. An analysis of elm *(Ulmus americana)* mortality in a second-growth hardwood forest in southeastern Michigan. Canadian Journal of Botany 54:1120–1125.
14. U.S. Department of Agriculture, Forest Service. 1975. Dutch elm disease. In Proceedings, International Union of Forest Research Organization. D. A. Burdekin and H. M. Heybroek, comps. USDA Forest Service, Northeastern Forest Experiment Station, Upper Darby, PA. 94 p.
15. U.S. Department of Agriculture, Forest Service. 1979. A guide to common insects and diseases of forest trees in the Northeastern United States. USDA Forest Service, Forest Insect and Disease Management NA-FR-4. Northeastern Area, State and Private Forestry, Broomall, PA. 127 p.