Planting and Care of Fine Hardwood Seedlings

Hardwood Tree Improvement and Regeneration Center
Northern Research Station
USDA Forest Service
Department of Forestry and Natural Resources
Purdue University

Diseases in Hardwood Tree Plantings

***Paula M. Pijut**, Northern Research Station, USDA Forest Service*
Department of Forestry and Natural Resources
Purdue University

Purdue Extension
Knowledge to Go
1-888-EXT-INFO

Introduction

Hardwood trees planted for timber production, wildlife habitat, riparian buffers, native woodland restoration, windbreaks, watershed protection, erosion control, and conservation are susceptible to damage or even death by various native and exotic fungal or bacterial diseases. Establishment, growth, and the quality of the trees produced can be affected by these disease outbreaks. Planting a mixture of tree species will help create a diverse community that could better withstand outbreaks of disease occurrences, and help minimize the risks associated with growing single-species plantings. Healthy, vigorously growing trees are *generally* more capable of surviving attack from diseases. Proper site, species selection, planting, maintenance, and protection may have significant impacts on tree establishment, growth, vigor, production, and economic or ecological value. This publication is intended to provide the landowner with an *overview* of *some* of the disease problems (or potential problems) associated with growing hardwood tree species in the Central Hardwood Region. It is by no means comprehensive, as there are numerous diseases associated with hardwood tree species (see Other Resources). Other factors (genetics, environment, climate, and stress) can predispose trees to these and other problems, and new outbreaks may arise or subside over time. Therefore, landowners should consult their local Department of Natural Resources or University Extension personnel to confirm a suspected disease problem and for current disease control measures, or if questions about management or control strategies arise.

Diseases of Maple (*Acer* spp.)

Bacterial leaf scorch affects *Acer rubrum* (red maple) and *A. saccharum* (sugar maple) (Gould and Lashomb 2005). *Xylella fastidiosa* (Wells et al. 1987) is a gram-negative bacterium that lives in an infected tree's water conducting tissue (xylem) and is transmitted to other healthy trees by insects that feed on xylem fluid, such as leafhoppers, treehoppers, and possibly spittlebugs (Bentz and Sherald 2001). The bacterium multiplies in the xylem tissue and, together with the overproduction of defense compounds produced by the tree in response to infection physically, blocks the xylem. Water transport then becomes limited to leaves, branches, and roots. Symptoms of bacterial leaf scorch first appear in late summer to early fall and can be identified by a characteristic marginal leaf scorch (Gould and Lashomb 2005). Maple leaves develop an irregular pattern of light and reddish brown tissue separated from green tissue by a yellow halo. As the disease progresses, leaves curl and drop prematurely, branches die, and the tree declines. Symptoms of other physiological or cultural problems can be mistaken for bacterial leaf scorch.

Therefore, suspected infections should be confirmed by a diagnostic plant disease clinic before concluding the tree is infected with the bacterium.

Verticillium wilt affects *A. nigrum* (black maple), red, and sugar maple. The causal agent, *Verticillium dahliae* is a soil-borne fungus that induces a vascular [xylem and phloem (nutrient conducting tissue)] wilt in maples (Sinclair et al. 1981). The fungus produces microsclerotia (thick-walled viable fungal cells) that can survive in soil for many years and invade the tree directly through the root system or through root wounds (Hiemstra and Harris 1998; Tjamos et al. 2000). Trees grown on land formerly used for susceptible vegetable (e.g. potato, tomato), fruit (e.g. grape, raspberry), or field (e.g. mint, alfalfa) crops are at high risk for infection. Laboratory tests can estimate the population of *Verticillium* in the soil. The fungus spreads in the vascular tissue via spores, produces toxins that kill cells, and blocks the trees ability to transport nutrients and water. The tree in turn produces defense compounds that attempt to isolate infected cells to limit fungal movement in the tree. The isolation of infected vascular tissue reduces the flow of water from the roots upward. Symptoms of Verticillium wilt can develop any time during the growing season. Leaves may wilt in portions of the canopy or on scattered branches and may become chlorotic and necrotic (faded green, yellow, or brown); branch dieback may occur, and a general decline of the tree ensues. Peeling back the bark on infected branches may reveal a greenish-brown discoloration (streaking) of the sapwood (Fig. 1). Submit samples to a plant disease clinic for isolation and confirmation of the pathogen.

Anthracnose leaf spot affects red, black, and sugar maple and is caused by several species of fungi, the most common on maple being *Aureobasidium apocryptum* (synonym *Kabatiella apocrypta*) and *Colletotrichum gleosporioides* (Berry 1985; Sinclair and Lyon 2005). The fungus overwinters on diseased leaf or stem tissue, and produces infectious spores in the spring. During cool, rainy periods of spring, the fungal spores are carried by wind and rain to newly emerging leaves of trees. Symptoms on infected leaves appear as scattered dead areas (red, black, brown, or tan) developing along and between leaf veins. These lesions may enlarge rapidly and kill

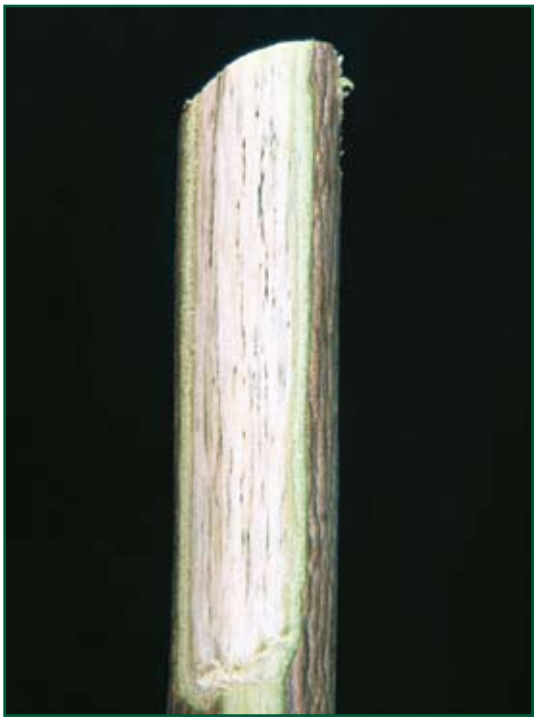

Figure 1. *Verticillium wilt streaking on maple branch with bark removed. (R.L. Anderson, USDA Forest Service. Reproduced with permission, www.forestryimages.org)*

Figure 2. *Tar spot damage on maple. (Clemson University-USDA Cooperative Extension Slide Series. Reproduced with permission, www.forestryimages.org)*

large areas of leaf tissue. Leaves may become distorted, and significant leaf drop can occur in late spring. Severe infection can result in extensive defoliation. The fungus can infect beyond the leaf surface into twigs causing cankers, which may eventually kill small branches. Anthracnose is usually considered an aesthetic issue, but severe infections may cause permanent damage or even tree death. Healthy trees usually recover and new leaves emerge in mid-summer.

Tar spot affects the leaves of sugar and red maple trees and is caused by three species of the fungus *Rhytisma*. The fungus survives on diseased leaves, and the spores are carried by wind to young maple leaves where new infections start. Infection occurs during periods of high humidity during spring and summer. Symptoms of tar spot first appear as light green and yellow-green areas on the leaf surface. As the fungus (*R. americanum*) grows, round to irregular black, raised,

Figure 3. *Phyllosticta leaf spot. (B. Gruber, University of Wisconsin-Madison, Reproduced with permission)*

large, tar-like spots surrounded by yellow-orange zones appear on the upper surface of the leaves (Fig. 2). The underside of the leaf below a tar spot turns brown, and premature defoliation can occur especially if infection is severe. Tar spot does not cause tree death. Another species, *R. punctatum*, produces patches of smaller tar-like spots (speckled tar spot disease).

Phyllosticta leaf spot or "purple eye spot" disease affects red and sugar maple and is caused by the fungus *Phyllosticta minima*. The fungus survives on diseased leaves and plant material. Symptoms first appear as discrete, small, circular, brown dots on the leaf surface. As the spots enlarge, the center becomes tan with a distinct red or purple margin (Fig. 3). Black fungal fruiting bodies (pepper-like dots) may be present inside the tan spots. This disease usually does not cause harm to the tree.

Nectria canker is a disease of red and sugar maple caused by the fungus *Neonectria galligena* (synonym *Nectria galligena*). This slowly growing pathogen usually does not kill the tree, but reduces the value of the tree for veneer and weakens the tree causing breakage at the point of the canker on the main stem. The fungus overwinters in the callus (wound-closing) tissue produced by the tree in response to infection. Infections occur on twigs, branches, and trunks in spring or early summer during moist periods, and the spores are dispersed by wind or rain. Infection occurs naturally through leaf scars or through wounds from improper pruning, storm damage, frost cracks, and other mechanical damage. Symptoms of Nectria canker appear as dark, water-soaked, depressed areas of the bark on stems or branches. Infected small twigs may become girdled, wilt, and die suddenly. The tree responds to infection by trying to isolate the fungus by the production of a ridge of callus tissue. As the fungus continues to grow from these perennial cankers into healthy wood, the tree produces another ridge of callus tissue. Concentric ridges of callus tissue then develop over time producing a round or elongated target-like canker on the tree. This canker disease grows slowly when the tree is dormant or under stress, and kills the bark, cambium, and outer sapwood. *Nectria cinnabarina* also causes cankers and dieback on maples, called coral-spot dieback and canker.

Eutypella canker is also common on red and sugar maple (occasionally on black maple) and is caused by the fungus *Eutypella parasitica*. This disease causes mortality by girdling trees and the elliptical perennial cankers are entry points for decay fungi. The resulting decay and malformation of the trunk of the tree results in wood useless for veneer and makes the tree susceptible to wind breakage. Symptoms of Eutypella canker

appear as depressed areas of the bark surrounded by callus tissue, most often around small branch stubs. White to tan "fans" of fungal growth is present in the bark at the canker margin. After several years of damage by this fungus and production of callus tissue by the tree, a typical canker is formed with flared edges and a large callus ridge (Fig. 4). Cankers usually occur less than 3 meters from the ground. *Eutypella* cankers are often colonized by the decay causing fungus *Oxyporus populinus* which causes a major heart rot of maples. The white fruiting bodies (conks) of this fungus are spongy, shelf-like in appearance, and are often covered with green moss.

Figure 4. *Eutypella canker causes severe deformation in the stems of maples, and often has the general appearance of a cobra head. (J. O'Brien, USDA Forest Service. Reproduced with permission, www.forestryimages.org)*

Sapstreak disease is a disease of the living sapwood of sugar maple caused by the fungus *Ceratocystis virescens* (Houston 1993). The fungus produces a distinctive banana oil odor; noticeable if profuse sporulation is found. Infection occurs through roots, buttress roots, or lower stem wounds. Symptoms of sapstreak disease are a sparse crown with unusually small leaves. Branch dieback occurs, trees may fail to leaf-out the next year, or the tree may die suddenly. The diseased wood has a yellow-green stain with red flecks that darkens after exposure to air, and eventually turns to a light brown (Fig. 5). Cankers develop where the cambium comes in contact with the spreading stain fungi. Trees dying of sapstreak disease are invaded and colonized at their roots or root collars by *Armillaria* or *Xylaria* species.

Figure 5. *Sapstreak disease of sugar maple (wood stain). (USDA Forest Service-Northeastern Area Archives. Reproduced with permission, www.forestryimages.org)*

Decay fungi cause stem, trunk, root, and butt rots on red and sugar maple. The fungi develop slowly in trees and their presence may only be evident once trees start to die or produce conks. *Inonotus glomeratus* causes a white to light brown, spongy canker rot on maple. Branch stubs or wounds are the primary entry point for infection by this canker rot fungus. *Phellinus igniarius* causes trunk rot of red and sugar maple. Fruiting bodies are perennial, generally hoof-shaped, and the presence of a single fruiting body indicates considerable decay. *Climacodon septentrionalis* infects through wounds and causes a spongy white rot, especially of sugar maple. Decay is extensive by the time conks appear. *Ganoderma lucidum* causes a butt and trunk decay, and *Laetiporus sulphureus* more commonly causes rot in butt and stem.

Armillaria root disease is a destructive disease of the roots and butts of maple trees (and other hardwoods), and the fungus most often associated with this disease is *Armillaria mellea* (Shaw and Kile 1991), although other species (*A. calvescens*, *A. gallica*, *A. ostoyae*, and *A. sinapina*) have been reported to be associated with this

disease of hardwoods in the Lake States (Kromroy 2004). Trees infected with *Armillaria* can have reduced growth, rapid mortality, wood decay (white rot), and susceptibility to windthrow. *Armillaria* can infect non-wounded root systems of trees, and the fungus spreads from tree to tree through roots, and via rhizomorphs [a thick strand of organized hyphae (tubular cell array) resembling a fine root] which infect intact bark. These fungi produce a honey-colored mushroom around the base of the tree in late summer or fall during moist periods (Fig. 6). Disease caused by *Armillaria* species contribute to tree decline by the interaction with other factors such as site, tree age, drought, insects, etc.

Figure 6. *Fruiting bodies (mushrooms) of an Armillaria species. (USDA Forest Service-Northeastern Area Archives. Reproduced with permission, www.forestryimages.org)*

Diseases of Pecan (*Carya* spp.)

Bacterial leaf scorch (see diseases of maple) affects pecan and can cause significant defoliation, reduction in growth, and nut yield (Sanderlin 2005). Symptoms on pecan are a necrosis (tan to light brown) of leaflets, followed by disease progression toward the base and midribs of the leaflets, and leaflet defoliation (Fig. 7).

Crown gall is caused by the gram-negative, soilborne bacterium, *Agrobacterium tumefaciens*, which can survive in the soil for several years. The bacterium transforms normal plant cells into large proliferating galls (tumor-like swellings) on the roots and bases of the trunk (Fig. 8). Infection occurs through wounded roots or stems near the soil line. Galls are spherical, white or flesh-colored and darken with age, and can vary in

Figure 7. *Symptoms of bacterial leaf scorch on pecan cultivar 'Cape Fear'. (R.A. Melanson, Louisiana State University. Reproduced with permission, www.forestryimages.org)*

diameter from ¼ inch to several inches in diameter. Galls usually form annually in late spring or early summer, and reduce tree vigor by restricting the flow of water and nutrients. Affected trees may be stunted, produce small chlorotic leaves, or may decline and die with severe infections. The bacterium can be spread from infected trees to other areas by transfer of the soil on equipment (mowing and tilling).

Pecan scab is the most serious disease of pecan and is caused by the fungus *Cladosporium caryigenum*. The fungus overwinters on infected shucks, leaves, leaf petioles, and stems. In the spring, during periods of warm, rainy weather, spores germinate and are dispersed long distanc-

Figure 8. *Crown gall damage on roots of pecan. (Clemson University-USDA Cooperative Extension Slide Series. Reproduced with permission, www.forestryimages.org)*

es by rain and wind. Disease symptoms first appear on immature leaves, leaf petioles, and nut shucks as small, olive-green spots that turn black. Leaf infections do not cause serious defoliation. Nut infections (Fig. 9) may cause the greatest damage resulting in premature nut drop, decrease in nut size, poor kernel development, and adherence of the shuck to the nut surface. Trees whose foliage remain wet for long periods, as a result of compact tree canopies that restrict airflow and sunlight penetration, favor scab infection.

Figure 9. *Pecan scab damage. (Clemson University-USDA Cooperative Extension Slide Series. Reproduced with permission, www.forestryimages.org)*

Bunch disease is caused by a phytoplasma [related to gram-positive bacteria] (Davis and Sinclair 1998) that may be transmitted from tree to tree by insects (leafhoppers). The pathogen can also be transmitted through grafts. Symptoms of bunch disease are branches with excessive lateral stem growth and compacted growth of leaves on these stems (witches'-broom). Upright shoots form on the trunks and main branches. Bunch disease is very obvious in the spring and early summer as the diseased shoots leaf out earlier than non-infected shoots. Symptoms may occur throughout the tree or be limited to individual branches. Terminal branches infected with bunch disease do not produce a normal crop of nuts. Branches may fail to go dormant in the fall and be killed by frost or winter injury.

Anthracnose (see diseases of maple) is a fungal leaf spot of pecan caused by *Glomerella singulata*. The spores are spread in spring and early summer during rainy periods. Symptoms start as brown to black sunken lesions on the leaves and shucks. Cream- to salmon-colored spores in concentric rings may also appear on the shucks. *Gnomonia* leaf spot caused by the fungus *Gnomonia caryae* is characterized by reddish-brown (liver colored) circular spots.

Botryosphaeria canker (branch dieback) results from infection by the fungus *Botryosphaeria dothidea* and is most often associated with stressed trees. Trees affected with this canker disease exhibit leaf wilting on twigs and branches. The infected branch turns black, cankers enlarge, and the pith of the branch is black or dark brown. This fungal disease infects through natural openings in the bark or through pruning wounds. The fungus is dormant in the winter, and spores are spread by wind in the spring. Cankers will girdle and kill twigs and branches. Twig death is usually generalized within a tree, and stress may be caused by defoliation from other pathogens, drought, or shading.

Leaf spots are caused by fungi that overwinter on pecan leaves and can result in minor to severe defoliation. **Zonate leaf spot** (Fig. 10) caused by the fungus *Grovesinia pyramidalis* occurs on mature leaves. Early symptoms appear as small, gray to light brown spots that rapidly expand

Figure 10. *Symptoms of zonate leaf spot. (L. Haugen, USDA Forest Service. Reproduced with permission, www.forestryimages.org)*

producing a target or banded appearance. **Downy spot** caused by the fungus *Mycosphaerella caryigena* first appears as frosty white or pale green circular spots on the underside of the leaflets. **Brown leaf spot** occurs on mature leaves and is caused by the fungus *Sirosporium diffusum*. **Vein spot** infections caused by the fungus *Gnomonia nerviseda* appear similar to the scab fungus only the lesions are linear in shape.

Powdery mildew caused by the fungus *Erysiphe penicillata* can occur on the foliage and nuts of pecan (Fig. 11). Severe disease causes leaflets to become wrinkled and misshapen and nuts can be reduced in size.

Figure 11. *Powdery mildew damage on pecan. (Clemson University-USDA Cooperative Extension Slide Series. Reproduced with permission, www.forestryimages.org)*

Diseases of Chestnut (*Castanea* spp.)

Chestnut blight is a devastating disease caused by the fungus *Cryphonectria parasitica* (Anagnostakis 2000). The fungus enters through cracks or wounds in the bark and eventually kills the cambium. The fungus is spread by wind, rain, insects, and birds (Sinclair and Lyon 2005). Airborne spores carried by birds and insects that visit colonized bark "account" for overland spread of the fungus. Cankers on branches are yellow-brown to orange, oval, or irregular in shape, and slightly swollen (Fig. 12). As the branch becomes girdled, leaves become chlorotic (yellow), and sprouts may develop below the canker. Thick bark may have orange, fungal fruiting bodies in the

Figure 12. *Chestnut blight canker. (R.L. Anderson, USDA Forest Service. Reproduced with permission, www.forestryimages.org)*

fissures, but the most obvious signs of cankers in the bark are the shoot (epicormic) sprouts that form below the canker when the cambium is killed.

Phytophthora root rot incited by the fungus-like organism *Phytophthora cinnamomi* is a soil-borne pathogen that causes root and collar rot. Symptoms appear as root lesions that develop upward in the trunk. The pathogen spreads by spores that can be carried over large distances by water and in soils. Infection occurs through the roots, causes root cell death (rotting), and therefore prevents transport of water from the roots. Moderate levels of soil compaction and moisture contribute to the susceptibility of root rot on American chestnut (*Castanea dentata*) seedlings (Rhoades et al. 2003). Root rot reduces tree vigor and causes mortality.

Diseases of Beech (*Fagus* spp.)

Beech bark disease is caused by the interaction between the beech scale insect (*Cryptococcus fagisuga*) and two fungal pathogens (*Neonectria coccinea* var. *faginata* and *N. galligena*) (Houston 1994; Evans et al. 2005). The beech scale feeds on the outer bark of American beech (*Fagus grandifolia*) creating wounds where the fungal pathogens then infect the tree. The beech scale excretes a white, waxy coating while feeding on the bark. Eggs are laid from June to September and hatch in about 25 days. The fungus produces reddish spores, and circular to horizontal elliptical

cankers form on the bark (Fig. 13). As large areas of the tree are affected, the tree becomes girdled. Heavy infestations of the scale allow the *Nectria* spp. to spread rapidly within the bark. It has been reported that death of stem bark by *N. coccinea* var. *faginata* predisposes the roots and root collar to attack by *Armillaria* spp. Bark exudates are a sign that the bark has been killed by *Nectria*. Beech bark disease reduces tree vigor and causes mortality.

Figure 13. *Beech bark disease on American beech. (M. Ostry, USDA Forest Service. Reproduced with permission, www.forestryimages.org)*

Heart rot caused by the sulfur fungus, *Laetiporus sulfureus*, is a brown heart rot of living trees that will also decay dead trees. The fungus can invade through bark wounds and dead branch stubs. Symptoms include a slightly depressed or cracked bark in areas of the tree with dying branches. Massive clusters of bright, sulfur-yellow to orange, shelf-like conks are produced annually (usually in fall), and become brittle and white with age (Fig. 14). Conks do not appear until many years after extensive decay.

Phytophthora bleeding cankers are large cankers on the major roots and trunk of beech caused by several species of *Phytophthora*. The soil-borne fungus-like pathogens (*P. cactorum*, *P. cambivora*, *P. citricola*, or *P. psuedosyringae*) invade through wounds and succulent roots. Cankers

Figure 14. *Fruiting bodies (conks) of Laetiporus sulphureus. (R.L. Anderson, USDA Forest Service. Reproduced with permission, www.forestryimages.org)*

may ooze a reddish-brown liquid from the dead areas of the bark. New leaves on the tree tend to be small and yellow, and branches will begin to die as the disease spreads through the tree. Not all bleeding cankers cause death of the tree.

Armillaria root rot (see diseases of maple) attacks and girdles the roots of weak beech trees.

Over 70 species of **decay fungi** have been reported to infect beech trees. The most important decay fungi include *Daedalea unicolor* (butt rot), *Ganoderma applanatum* (white mottled rot), *Fomes fomentarius* (white spongy trunk rot), *Phellinus igniarius* (trunk rot), *Hericium erinaceus* and *H. coralloides* (trunk and limb rot), *Hypoxylon deustum* (= *Ustilina vulgaris*) (root and butt rot), *Steccherinum septentrionale* (spongy white rot), and *Inonotus glomeratus* (canker rot).

Anthracnose (see diseases of maple) caused by *Discula* spp. affects beech causing irregular areas of brown, dead tissue spots on the leaves. Damaged areas vary in size and infected leaves fall prematurely. The fungus may kill tissue down to the petiole and into young twigs. Anthracnose fungi overwinter on fallen infected leaves which

can then infect trees the following year. Trees are seldom killed by anthracnose, but may be weakened and predisposed to other damage.

Botryosphaeria canker (see diseases of pecan) is a fungal disease that causes branch dieback of beech.

Diseases of Ash (*Fraxinus* spp.)

Ash yellows is a disease caused by a phytoplasma (bacteria-like organism lacking a cell wall) that inhabits the phloem (Sinclair and Griffiths 1994; Griffiths et al. 1999) and substantially reduces growth, induces premature decline, and death of *Fraxinus* spp. Both green (*F. pennsylvanica*) and white (*F. americana*) ash are susceptible to ash yellows, in addition to other ash species. The phytoplasma is spread by phloem-feeding insects such as leafhoppers (Hill and Sinclair 2000). The phytoplasma is introduced into the phloem tissue, via the insect saliva, and spreads throughout the tree killing the tissue. Symptoms of ash yellows include small, chlorotic leaves growing in tufts at the end of branches, branch dieback, bark cracks, thin chlorotic crowns, epicormic sprouting (along branches or at ground level), early fall coloration, loss of dominant growth habit, general decline, and witches' brooms (cluster of spindly shoots) on the trunk of the tree (Fig. 15). Ash yellows can cause significant loss of volume growth in young stands, and trees may die within one to three years after infection.

Figure 15. *Witches' broom produced by ash yellows on ash (Fraxinus spp.). (Minnesota Department of Natural Resources Archives. Reproduced with permission, www.forestryimages.org)*

Ash decline results from multiple and accumulative causes. Symptoms of ash decline are chlorotic foliage, branch dieback, and stunted growth (similar to ash yellows). The exact cause of ash decline is unknown, but stress factors such as drought, winter injury, severe temperature fluctuations, poor soil conditions, and pathogens combine to weaken the tree.

Verticillium wilt (see diseases of maple) affects ash trees. Symptoms include chlorotic leaves, wilting, and scorched leaf margins. Leaves may drop from the tree without other visible symptoms. The greenish discoloration (streaking) as seen in the sapwood of infected maples is usually absent in ash trees.

Anthracnose (see diseases of maple), caused by the fungus *Gnomoniella fraxini*, is a foliar disease that affects ash trees. Round to irregular, greenish-brown to necrotic leaf blotches appear along the margins and midribs of the leaflets, and leaves may appear distorted. Small cankers may occur on twigs, and trees may be severely defoliated year after year. Disease severity is usually on the lower portion of the crown. Affected trees usually produce a flush of new leaves later in the growing season.

Heart rot (see diseases of beech) affects ash trees. Several other **wood-rotting fungi** attack living ash trees. The most common is *Fomes fraxinophilus*. *Polyporus* spp., *Phellinus* spp., *Rigidoporus* spp., *Laetiporus sulphureus*, *Pleurotus ostreatus*, *Ganoderma lucidum*, and *Tyromyces spraguei* also cause heart and butt rots in living ash trees.

Nectria canker (see diseases of maple) affects ash trees.

Ash rust, caused by the fungus *Puccinia sparganioides*, occurs throughout the eastern United States (mainly coastal), but does not cause serious damage or death to ash trees. The fungus survives the winter on cordgrass (*Spartina* sp.) and marsh grass (*Distichlis* sp.), and in the spring the spores are released and wind blown to infect ash trees. Wet leaves, petioles, and shoots are then infected by the fungus in the spring. Leaves and petioles become twisted and bright orange. Powdery fruiting structures (spores) form on the

petioles, twigs, and the underside of leaves (Fig.16). Severe disease can defoliate and weaken trees making them susceptible to other stressful factors.

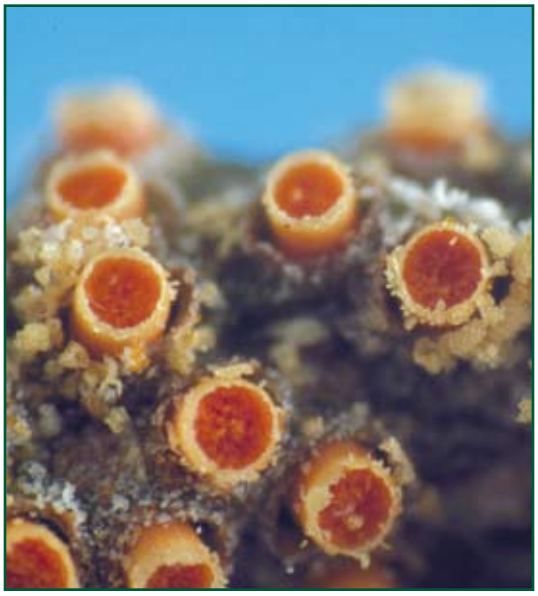

Figure 16. *Closeup of ash rust fruiting structures proliferating from the surface of infected tissue. (E.L. Barnard, Florida Department of Agriculture and Consumer Services. Reproduced with permission, www.forestryimages.org)*

Diseases of Walnut and Butternut (*Juglans* spp.)

Bacterial blight, caused by the bacterium *Xanthomonas arboricola* pv. *juglandis* (=*Xanthomonas campestris* pv. *juglandis*), only infects species of the genus *Juglans*. The bacterium overwinters in twig cankers, and dormant buds and catkins. The bacteria invade new young shoots, leaves, catkins, and fruit through natural openings, wounds, or insect damaged areas. During periods of spring rainfall or wet weather, conditions are suitable for bacterial infection. Symptoms of bacterial blight on young walnut shoots appear as black spots or lesions. The lesions may girdle the shoot and extend into the pith to form cankers. The blight causes small, irregular-shaped brown to black spots on all tissues of the leaves (midrib, veins, rachis, and petiole). Unless infection is severe, defoliation does not usually occur and most infected leaves remain on the tree. Infected catkins turn black and become shriveled and distorted. Fruits (nuts) have black lesions or water-soaked spots on the husks, and infected nuts may fall prematurely or have shells and kernels that are blackened.

Bunch disease (see diseases of pecan) affects black walnut (*J. nigra*) and butternut (*J. cinerea*).

Botryosphaeria canker (see diseases of pecan) is a fungal disease that causes branch dieback of walnut.

Nectria canker (see diseases of maple) affects black walnut trees (Fig. 17). The diameter growth rate can be reduced by as much as 30 percent in infected trees (Thomas and Hart 1986).

Figure 17. *Nectria canker on black walnut caused by Neonectria galligena. (J.H. Hart. Reproduced with permission from APSnet, American Phytopathological Society, www.apsnet.org/online/Archive/1998/pdcvr15.htm)*

Anthracnose (see diseases of maple), caused by the fungus *Gnomonia leptostyla*, causes premature defoliation of walnut trees resulting in reduced growth and increased susceptibility to other stressors. Circular, brown spots often surrounded by a yellow halo form on the underside of the leaves. Leaves may become chlorotic, develop brown margins, curl, and drop prematurely. Nuts that become infected do not develop normally, have darkened kernels, and may drop prematurely.

White mold or downy leaf spot, caused by the fungus *Microstroma juglandis*, occurs on walnut,

but does not cause severe damage or defoliation. Downy leaf spot appears as small patches of white fungal growth on the underside of the leaves and a yellowish blotch on the top surface of the leaf. Leaflets may show a slight bulge of the leaf surface, and the fungus occasionally attacks the fruit.

Phytophthora root rot (see diseases of chestnut) causes damage and mortality of walnuts. *Phytophthora cinnamomi* and *P. citricola* are the most common species of this pathogen occurring on walnuts. Walnut seedlings become chlorotic and wilt rapidly. Infected tissues at the root collar and the lower stem become soft and black. Disease incidence is more severe on sites where water drainage is poor.

Cylindrocladium root rot has been linked to the soil-borne fungi *Cylindrocladium scoparium*, *C. floridanum*, and *Cylindrocladiella parva*. Symptoms of Cylindrocladium root rot are black lesions on the tap and lateral roots, wilting and foliar necrosis, and the outer bark of the seedlings will crack and become loose.

Fusarium canker on black walnut is lethal and is caused by several species of *Fusarium* (*F. solani* and *F. lateritium* are the two species most commonly associated; *F. sporotrichiodes* is less often associated). Elongated cankers appear as dead, dark areas in the split bark, usually on the lower portion of the tree near the ground. Cankers can completely girdle a tree, and may also occur on branches in the lower crown of young trees. The wood beneath the bark becomes darkly stained, rotted, and degraded. Infected trees usually produce sprouts near the canker or at the base of the tree. Leaves wilt and dieback of the top of the tree also occur.

Butternut canker, caused by the fungus *Sirococcus clavigignenti-juglandacearum*, is the most serious threat to butternut (Ostry et al. 1996). Spores of this fungus are disseminated by rain splash and can travel by wind to adjacent trees where infections occur on young branches. Several insect species have been found associated with fungal spores on infected trees, and studies are determining if these are possible vectors of transmission. The fungus has also been found on the fruit of butternut and black walnut, causing lesions on the husks. Young cankers on branches and stems are elliptical, sunken areas, later developing an inky black center. The cankers cause the wood to turn dark brown to black in an elliptical pattern, which renders many stands unmarketable (Fig. 18). Multiple, perennial stem cankers often girdle and kill infected trees of all ages. Other *Juglans* species have been found to be susceptible in varying degrees to natural infection and to artificial inoculations.

Figure 18. *Butternut canker (left) and bark removed (right) illustrating damaged wood. (M. Mielke, USDA Forest Service. Reproduced with permission, www.forestryimages.org)*

Leaf spot diseases on walnut are caused by *Mycosphaerella juglandis* and *Grovesinia pyramidalis* (zonate leaf spot; see diseases of pecan). Mycosphaerella leaf spot causes premature defoliation, thus reducing growth and nut production. Symptoms of Mycosphaerella leaf spot are leaf scorch and necrotic flecking among leaf veins. There are several **wood decay** fungi that attack walnut trees (*Schizophyllum commune*, *Hypochnicium vellereum*, *Trametes versicolor*, *Phellinus gilvus*, *Peniophora cinerea*, and *Hericium coralloides*).

Diseases of Cherry (*Prunus* spp.)

Black knot disease is common on black cherry (*Prunus serotina*) and is caused by the fungus *Apiosporina morbosa*. The fungal spores are spread by wind and rain in the spring and infect young twigs and branches, and occasionally trunks become diseased. Small twigs may die within the same year of infection. Larger branches and the main trunk will eventually be girdled and killed by the fungus. Symptoms first appear as

small, dark-brown to black swellings on the branches (Fig. 19). As the disease progresses, the knots (galls) elongate and enlarge becoming rough, hard, black, and render the tree useless for lumber.

Figure 19. *Black knot of black cherry. (J. O'Brien, USDA Forest Service. Reproduced with permission, www.forestryimages.org)*

Leaf spot caused by the fungus *Blumeriella jaapii* attacks the leaves of black cherry, and seedlings may become weakened or be killed. Yearly infections reduce the vigor of larger trees. Symptoms first appear as small, circular, purplish spots on the upper surface of the leaves, eventually turning brown. The infected area may fall out of the leaf producing a "shot-hole" appearance. White, felt-like patches appear in the center of the spots on the underside of the leaves during periods of wet weather. Infected leaves become chlorotic and fall prematurely. Repeated defoliation can result in reduced shoot growth, seedling stunting, or even death.

Cytospora canker caused by the fungus *Leucostoma persoonii* (= *Cytospora leucostoma*) causes branch dieback and perennial cankers on black cherry. The fungal spores are spread by wind and rain, and infect the tree through wounded tissue such as leaf scars, pruning wounds, and winter injury. Symptoms of this disease are dead buds, twigs, and branches; cankers; chlorotic, necrotic, or wilting leaves; and gummosis (exudation of sap in a gummy form) at the site of infection. Infected bark turns reddish brown, and yellow to orange thread-like structure of spores form as the canker progresses. A gummy ooze is commonly seen protruding from the cankers. Infected and dead bark may remain attached to the tree or fall off in large sections.

Brown rot caused by the fungus *Monilinia fructicola* attacks the flower blossoms, fruit, and small branches of black cherry. The fungal spores are spread by wind and rain. Symptoms of brown rot on black cherry are flowers that shrivel and brown quickly; ripening fruits brown, shrivel, and become covered with gray spores; and small cankers form on branches.

Pythium spp. (soil-borne pathogens) cause damping-off type symptoms and black cherry seedling death (Packer and Clay 2000). Infected seedlings may have lesions at or below the soil line. Seedlings may suddenly wilt, collapse, and die.

Decay fungi cause trunk rots of black cherry. *Fomes fomentarius* causes a white, spongy trunk rot. *Fomitopsis pinicola* causes a brown crumbly rot that can cause damage to living trees. *Poria prunicola* and *P. mutans* also causes a trunk rot. **Root and butt rots** of living black cherry trees are caused by *Ganoderma lucidum*, *Laetiporus sulphureus*, *Armillaria mellea*, *Coniophora cerebella*, *Polyporus berkeleyi*, and *Tyromyces spraguei*.

Diseases of Oak (*Quercus* spp.)

Oak wilt affects many species of oaks, and the disease is caused by the fungus *Ceratocystis fagacearum*. Northern red oak (*Quercus rubra*), northern pin oak (*Q. ellipsoidalis*), black oak (*Q. velutina*), southern red oak (*Q. falcata*), blackjack oak (*Q. marilandica*), shumard oak (*Q. shumardii*), and Texas red oak (*Q. buckleyi*) are the most susceptible species to this disease (O'Brien et al. 2000). The oak wilt fungus can spread from tree to tree through root grafts and interconnected root systems or overland by insect vectors (Cervenka et al. 2001). Symptoms of oak wilt progress differently in red oaks, white oaks, and southern oaks (O'Brien et al. 2000). The tips and margins of the leaves of red oaks turn brown (Fig. 20), and the leaves wilt from the top of the tree progressively downward. Defoliation occurs rapidly as the disease progresses. Twigs and branches will die, and a brown discoloration may be present in the sapwood. Red oak species die rapidly after infection while white oak species decline slowly over a period of 2 to 10 years.

Oak decline affects oaks throughout the eastern United States, and is caused by a complex of physical and biological stressors including the fungi *Hypoxylon atropunctatum* and *Armillaria*

Figure 20. *Foliar symptoms of oak wilt disease on northern red oak (D.W. French, University of Minnesota. Reproduced with permission, www.forestryimages.org)*

species (Scarbrough and Juzwik 2004). The interaction of site factors, stress (such as drought or defoliation), insects, and disease causes a slow but progressive decline of oaks leading to tree death. Progressive dieback of the crown of the tree is the main symptom of oak decline. The disease can kill susceptible oaks within 3 to 5 years of the onset of crown symptoms. The fungi associated with oak decline degrade the wood.

Sudden oak death caused by the fungus-like organism *Phytophthora ramorum* affects oaks (*Quercus* spp.) and tanoaks (*Lithocarpus densiflora*) (Davidson et al. 2003). The pathogen is spread via infected nursery stock, such as rhododendron, camellia, and viburnum. Seedling inoculation tests show that chestnut oak (*Q. prinus*), white oak, and northern red oak are

Figure 21. *Bleeding from a Phytophthora ramorum canker on coast live oak. (J. O'Brien, USDA Forest Service. Reproduced with permission, www.forestryimages.org)*

susceptible (Tooley and Kyde 2003). The pathogen causes cankers on stems and branches, and once the crown starts to die back, leaves turn pale yellow to brown within a few weeks. Cankers are black or reddish-brown and seep (bleed) a dark black to red sap (Fig. 21).

Anthracnose (see diseases of maple), caused by the fungus *Apiognomonia quercina*, initiates premature defoliation of oaks. Young leaves and buds appear scorched, and some twig and branch dieback can occur. Small, scattered, necrotic (tan-brown) spots form on the leaves and often concentrate along the leaf veins.

Bacterial leaf scorch (see diseases of maple) affects oak trees. Symptoms on oaks appear as browning of the leaves on a single or on a few branches usually in the lower portion of the tree. A wavy, reddish-brown band occasionally develops between the brown and green leaf tissue.

Oak leaf blister, caused by the fungus *Taphrina caerulescens*, occurs on many oak species especially members of the red oak group. Infection is favored by cool, wet springs; leaves

Figure 22. *Symptoms of oak leaf blister on bur oak. (J. O'Brien, USDA Forest Service. Reproduced with permission, www.forestryimages.org)*

do not usually fall prematurely from the tree, and the disease does not endanger the tree. Symptoms appear as yellow, blister-like, raised areas on the upper leaf surface with gray depressions on the lower surface (Fig.22). The blisters become covered with fungal growth and turn brown with age.

Armillaria root rot (see diseases of maple) affects oak trees.

Botryosphaeria canker (see diseases of pecan) is a fungal disease that causes branch dieback of oak.

Figure 23. *Slime flux (bacterial wetwood) on white oak. (R. Cyr, GREENTREE Technologies. Reproduced with permission, www.forestryimages.org)*

Bacterial wetwood disease (also known as slime flux) affects several oak species. The causal organisms of wetwood are several bacteria, including those in genera *Pseudomonas*, *Klebsiella*, *Bacillus*, and *Enterobacter*. The bacteria are common in nature (soil and water) and can enter the tree through wounds in the trunk, branches, or roots. A gas is produced as a by-product (fermentation) of the bacteria activity within the wood of the tree. This gas creates a high internal pressure that forces a slime to ooze from the trunk, wounds, cracks, or branch crotches. The ooze is slimy, becomes colonized by yeasts and molds which then produce the foul odor upon exposure to air. The seepage results in vertical, dark streaks that run down the bark (Fig. 23). Leaves of infected trees may also curl and wilt, and branches may dieback.

Wood decay fungi cause root and butt rots on many species of oak. *Laetiporus sulphureus*, *Inonotus dryadeus*, *Armillaria* spp., *Ganoderma lucidum*, *Pleurotus ostreatus*, *Hericium erinaceus*, and *Tyromyces fissilis* are some of the most common fungi that attack oak species.

Diseases of Elm (*Ulmus* spp.)

Dutch elm disease (DED) is a destructive vascular wilt disease caused by the fungi *Ophiostoma ulmi* and *O. novo-ulmi*. These fungi can spread naturally through root grafts and the spores are spread over land from tree to tree by elm bark beetles. Infection results in a blocking of the vascular tissues preventing water movement to the crown of the tree. Symptoms of DED are a wilting of leaves followed by yellowing and browning. Multiple branches may become infected and cause leaf wilt in several locations in the crown of the tree. Branches and stems of DED infected trees develop a dark streaking in the vascular tissue (Fig. 24).

Figure 24. *Cut branches of elm showing the Dutch elm disease vascular and outer rings of wood discoloration. (R.S. Cameron, International Paper. Reproduced with permission, www.forestryimages.org)*

Elm yellows (phloem necrosis) affects elms native to North America. The causal agent is a phytoplasma (general characteristics of a bacterium but lack a cell wall). The organism is transmitted to healthy trees by leafhoppers. Foliar symptoms include yellowing, browning, curling, and wilting of the leaves. By the time foliar symptoms occur, the roots of the tree have incurred substantial mortality. Within the roots, parts of the trunk, and branches, the cambial zone changes color from nearly white to yellow, then to a butterscotch or tan color, and eventually dark brown. The inner bark (freshly cut) has a distinctive oil of wintergreen odor. Trees can be killed rapidly by this disease.

Bacterial wetwood (see diseases of oak) is most prevalent on elms and causes the most damage on elm trees.

Black leaf spot caused by the fungus *Stegophora ulmea* is very common on elm and may cause severe defoliation, but usually does not threaten the life of the tree. Young, rapidly growing leaves are most susceptible to infection in the spring. Yellow spots first appear distributed on the upper surface of the leaves. Shiny, black, slightly raised pustules then form around the center of the spots about two weeks after infection. Lower leaves on

the tree are usually infected first, but the disease can spread upward if temperature and moisture conditions are favorable. Leaves will yellow and drop prematurely. Lesions may also girdle petioles and new shoot growth.

Bacterial leaf scorch (see diseases of maple) affects elm. Leaf necrosis resembles symptoms of the later stages of DED, but no wilt or vascular discoloration is seen.

Armillaria root rot (see diseases of maple) attacks elm trees.

Anthracnose on elm is caused by *Asteroma inconspicuum*.

Damping-off causes elm seedling mortality and is caused by *Fusarium* spp., *Pythium ultimum*, *Phytophthora* spp., and *Rhizoctonia solani*.

Verticillium wilt (see diseases of maple) can infect elm trees. Trees with extensive infection show reduced growth and branch dieback. Young trees usually die within one year, and older trees will deteriorate over a period of a few years before dying.

Powdery mildew on elm is caused by *Erysiphe* and *Phyllactinia* species of fungi.

Canker diseases on elm are caused by several pathogens. *Botryosphaeria dothidea* (see diseases of pecan) causes branch dieback. *Botryodiplodia hypodermia* causes a water-soaked, soft, reddish brown to black canker on stressed trees. The diseased bark is sharply defined from the healthy bark and the wood beneath the canker is reddish brown. *Coniothyrium* and *Thyrostroma* spp. cause twig dieback and stem cankers. *Cytospora* spp. cause yellow or orange-brown to black cankers on wounded or stressed elm trees. *Cytosporina ludibunda* and *Dothiorella ulmi* cause cankers, wilt, and dieback. *Nectria* spp. cause cankers and branch dieback on elm (see diseases of maple). *Tubercularia ulmea* infects through wounds on trunks, branches, and twigs and can deform or kill stressed trees.

Wood decay fungi that attack elm trees are *Trametes versicolor*, *Flammulina velutipes*, *Ganoderma applanatum*, *Phellinus* spp., *Pleurotus* spp., *Armillaria* spp. and various *Polyporus* spp.

Literature Cited

Anagnostakis, S.L. 2000. Revitalization of the majestic chestnut: chestnut blight disease. Online (www.apsnet.org). *APSnet Feature*, The American Phytopathological Society, St. Paul, MN. 9p.

Bentz, J. and J. Sherald. 2001. Transmission of the xylem-limited bacterium *Xylella fastidiosa* to shade trees by insect vectors. In: Ash, C.L. (ed.), *Shade tree wilt diseases*, The American Phytopathological Society, St. Paul, MN: 203-208.

Berry, F.H. 1985. Anthracnose diseases of eastern hardwoods. Forest insect and disease leaflet No. 133. USDA Forest Service. Online (www.na.fs.fed.us/spfo/pubs/fidls/anthracnose_east/fidl-ae.htm).

Cervenka, V.J., T.C. Skalbeck, J.F. Kyhl, D.C. Blackford, J.J. Juzwik, and S.J. Seybold. 2001. *How to identify common nitidulid beetles associated with oak wilt mats in Minnesota.* USDA Forest Service, North Central Research Station, HT-71. 13 p.

Davidson, J.M., S. Werres, M. Garbelotto, M. Hansen, and D.M. Rizzo. 2003. Sudden oak death and associated diseases caused by *Phytophthora ramorum*. Online (http://www.plantmanagementnetwork.org/php/shared/sod). Plant Health Progress doi: 10.1094/PHP-2003-0707-01-DG. 23 p.

Davis, R.E. and W.A. Sinclair, 1998. Phytoplasma identity and disease etiology. Phytopathology 88: 1372-1376.

Evans, C.A., J.A. Lucas, and M.J. Twery. 2005. *Beech Bark Disease: Proceedings of the Beech Bark Disease Symposium.* Newtown Square, PA. USDA Forest Service, Northern Research Station, General Technical Report NE-331. 149 p.

Gould, A.B. and J.H. Lashomb. 2005. Bacterial leaf scorch of shade trees. Online (www.apsnet.org). APSnet Feature, The American Phytopathological Society, St. Paul, MN. 18p.

Griffiths, H.M., W.A. Sinclair, C.D. Smart, and R.E. Davis. 1999. The phytoplasma associated with ash yellows and lilac witches'-broom: '*Candiatus Phytoplasma fraxini*'. *International Journal of Systematic Bacteriology* 49:1605-1614.

Hiemstra, J.A. and D.C. Harris. 1998. *A compendium of* Verticillium *wilt in tree species.* Ponsen and Looijen, Wageningen, the Netherlands. 80p.

Hill, G.T. and W.A. Sinclair. 2000. Taxa of leafhoppers carrying phytoplasmas at sites of ash yellows occurrence in New York State. *Plant Disease* 84:134-138.

Houston, D.R. 1993. *Recognizing and managing sapstreak disease of sugar maple.* USDA Forest Service, Northeastern Forest Experiment Station, Research Paper NE-675. 11 p.

Houston, D.R. 1994. Major new tree disease epidemics: beech bark disease. Annual Review of Phytopathology 32:75-87.

Kromroy, K.W. 2004. *Identification of* Armillaria *species in the Chequamegon-Nicolet national forest.* USDA Forest Service, North Central Research Station, Research Note NC-388, St. Paul, MN. 10 p.

O'Brien, J.G., M.E. Miekle, D. Starkey, and J. Juzwik. 2000. *How to identify, prevent, and control oak wilt.* USDA Forest Service, Northeastern Area State and Private Forestry, NA-PR-03-00. 28 p.

Ostry, M.E., M.E. Mielke, and R.L. Anderson. 1996. *How to identify butternut canker and manage butternut trees.* USDA Forest Service, North Central Forest Experiment Station, and State and Private Forestry. HT-70. 8 p.

Packer, A. and K. Clay. 2000. Soil pathogens and spatial patterns of seedling mortality in a temperate tree. *Nature* 404:278-281.

Rhoades, C.C., S.L. Brosi, A.J. Dattilo, and P. Vincelli. 2003. Effect of soil compaction and moisture on incidence of phytophthora root rot on American chestnut (*Castanea dentata*) seedlings. *Forest Ecology and Management* 184:47-54.

Sanderlin, R.S. 2005. Cultivar and seedling susceptibility to pecan bacterial leaf scorch caused by *Xylella fastidiosa* and graft transmission of the pathogen. *Plant Disease* 89(5):446-449.

Scarbrough, D. and J. Juzwik. 2004. *Native and exotic insects and diseases in forest ecosystems in the Hoosier-Shawnee ecological assessment area.* USDA Forest Service, North Central Research Station, General Technical Report NC-244. 14 p.

Shaw, C.G. and G.A. Kile. 1991. *Armillaria* root disease. USDA Forest Service, *Agriculture Handbook* 691, Washington, DC. 233 p.

Sinclair, W.A. and H.M. Griffiths. 1994. Ash yellows and its relationship to dieback and decline of ash. *Annual Review of Phytopathology* 32:49-60.

Sinclair, W.A. and H.H. Lyon. 2005. *Diseases of trees and shrubs.* 2nd edition. Cornell University Press, Ithaca, NY. 680p.

Sinclair, W.A., K.L. Smith, and A.O. Larsen. 1981. *Verticillium* wilt of maples: Symptoms related to movement of the pathogen in stems. *Phytopathology* 71:340-345.

Thomas, C.S. and J.H. Hart. 1986. Relationship between year of infection, tree age, tree growth, and *Nectria* canker of black walnut in Michigan. *Plant Disease* 70(12):1121-1124.

Tjamos, E.C., R.C. Rowe, J.B. Heale, and D.R. Fravel. 2000. *Advances in Verticillium research and disease management.* The American Phytopathological Society, St. Paul, MN. 376p.

Tooley, P.W. and K.L. Kyde. 2003. Susceptibility of some eastern oak species to sudden oak death caused by *Phytophthora ramorum*. *Phytopathology* 93:S84.

Wells, J.M., B.C. Raju, H.Y. Hung, W.G. Weisburg, L. Mandelco-Paul, and D.J. Brenner. 1987. *Xylella fastidiosa* gen. nov., sp. nov.: Gram-negative, xylem-limited, fastidious plant bacteria related to *Xanthomonas* spp. *International Journal of Systematic Bacteriology* 37(2):136-143.

Other Resources

Burns, R.M. and B.H. Honkala. 1990. Silvics of North America. USDA Forest Service, *Agriculture Handbook* 654, Washington, DC. 877 p.

Forestry Images. This is a joint project of The Bugwood Network and USDA Forest Service, The University of Georgia, Warnell School of Forest Resources and College of Agricultural and Environmental Sciences-Department of Entomology. Online (www.forestryimages.org).

Jones, R.K. and D.M. Benson. 2001. *Diseases of woody ornamentals and trees in nurseries.* The American Phytopathological Society, St. Paul, MN. 482p.

Teviotdale, B.L., T.J. Michailides, and J.W. Pscheidt. 2002. Compendium of nut crop diseases in temperate zones. The American Phytopathological Society, St. Paul, MN. 100 p.

USDA Forest Service, State and Private Forestry, Northeastern Area, Online Publications (http://na.fs.fed.us/pubs).

USDA Forest Service, North Central Research Station, Online Publications (http://www.ncrs.fs.fed.us/pubs).

Mention of a trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products or vendors that also may be suitable.

This publication is printed on recycled paper using soy-based inks.

EXPERT REVIEWED

Purdue Extension Knowledge to Go 1-888-EXT-INFO

NEW 5/06

It is the policy of the Purdue University Cooperative Extension Service, David C. Petritz, Director, that all persons shall have equal opportunity and access to the programs and facilities without regard to race, color, sex, religion, national origin, age, marital status, parental status, sexual orientation, or disability.

Purdue University is an Affirmative Action University. This material may be available in alternative formats.

1-888-EXT-INFO

http://www.ces.purdue.edu/extmedia