Identification and Management Recommendations of Common Fungal Diseases of Eastern Black Walnut

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Introduction

Eastern black walnut (*Juglans nigra* L.) is a hardwood tree species native to portions of the eastern and midwestern US. (Figures 1 & 2) [1]. The tree is often grown in plantations for its valuable wood, which is used to make furniture, veneers, paneling and gun stocks [2, 3]. To a lesser extent, its edible nuts are valued for potential health benefits, including anti-cancerous properties. [4-6]. Sap from these trees can even be used to make syrup that is similar in taste to maple syrup. [7]. Due to the economic value of this species, eastern black walnut is grown extensively within the midcentral and midsouthern US, including Tennessee. The tree is common in woodlands and planted throughout urban areas across the central and eastern US. Eastern black walnut has also been introduced into the western US.

Figure 1. Eastern black walnut *(Juglans nigra)* tree.

Photo Credit: Robert Vidéki, Doronicum Kft., Bugwood.org; Image 5396389.

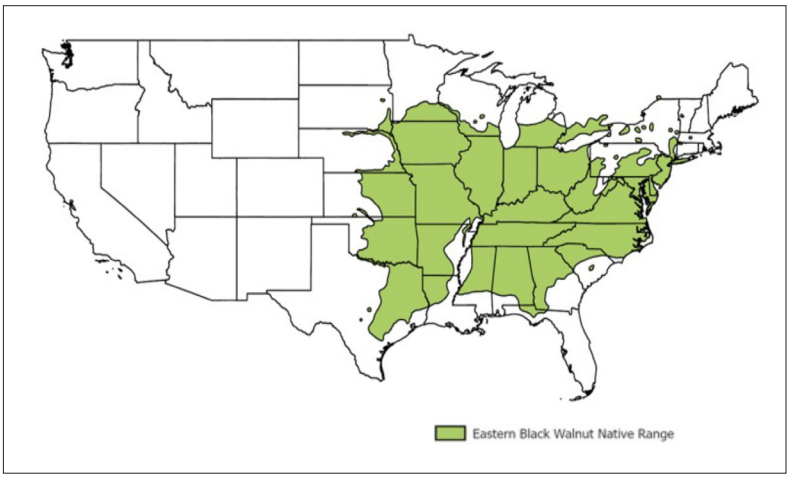

Figure 2. Native range of eastern black walnut *(Juglans nigra)* in the US [1].

Identifying Characteristics

Mature eastern black walnut trees can grow to be 90 feet tall and 2 to 3 feet in diameter [8]. Leaves of eastern black walnut have a sharply fragrant odor and are composed of nine to 24 oval- to lance-shaped leaflets, each having slightly saw-toothed edges and slightly pubescent (fuzzy) undersurfaces (Figure 3A) [3, 8, 9]. The terminal leaflet is often underdeveloped or absent. Leaflets are attached to the central leaf stem (rachis) at typically alternating positions (Figure 3A). The bark on mature trees is greyish-black with elevated ridges and deep grooves that create a somewhat diamond-shaped pattern (Figure 3B) [3, 8]. The center of twigs and stems (pith) contains hollow, brown or black chambers (Figure 3C) [9]. A single tree produces both male and female flowers. Male flowers are chain-like and emerge from the previous growing season's branch sections (Figure 3D) [9]. Female flowers are pubescent and bulb-like and emerge from green growth that forms during the current growing season (Figure 3E) [10]. At maturity, a tree will produce both male and female flowers that are active at different times in the growing season to prevent self-pollination. After fertilization, the tree produces round fruits with a green skin and husk (Figure 3F). Fruits may be produced from branches singly, or in clusters of two-to-three fruits. Fruits contain hard, ridged, brown to black nuts with a husk that can stain skin dark brown to black when handled (Figure 3G) [9]. Fruit production begins when trees are approximately 12 years old [9].

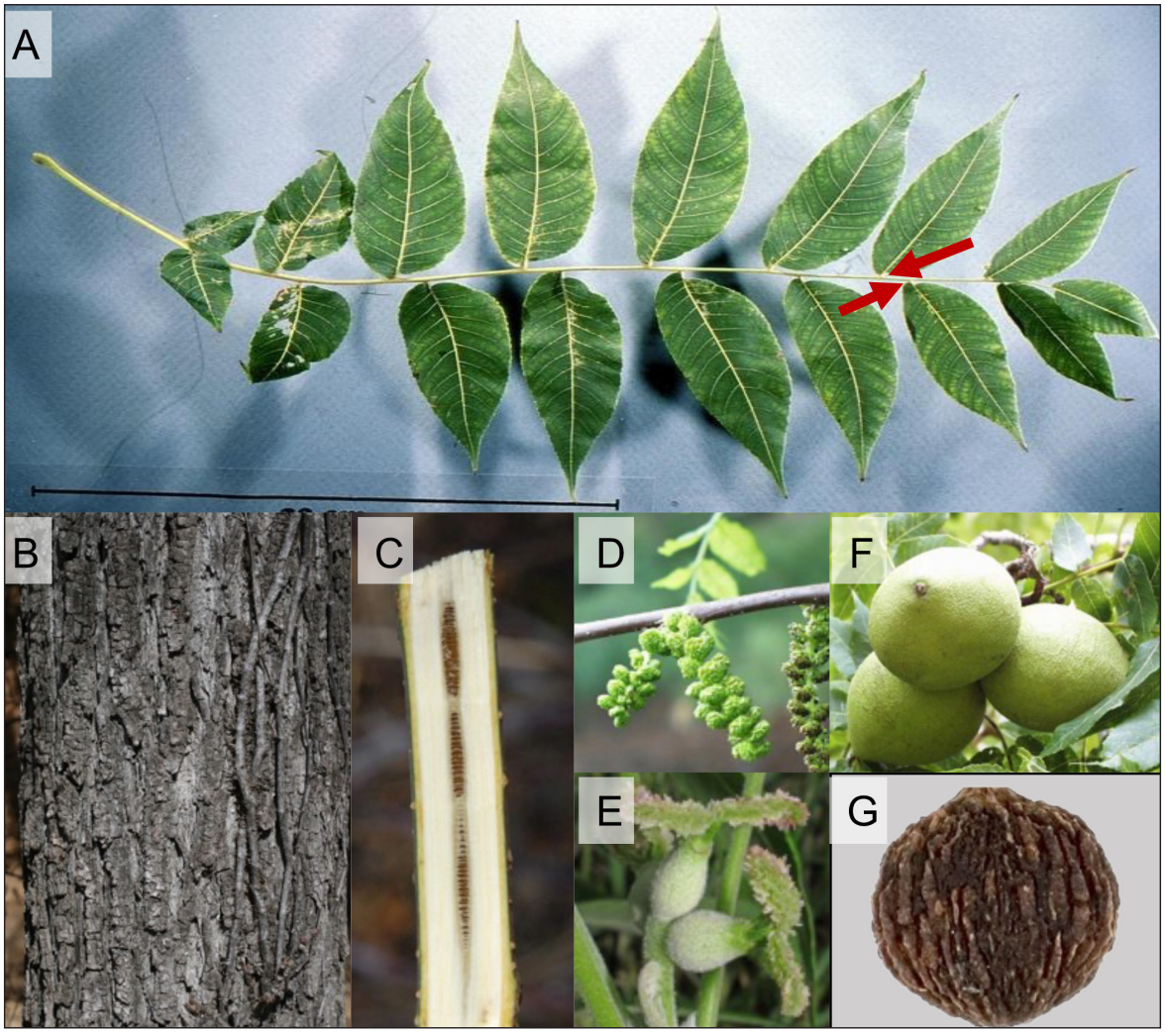

Figure 3. Identifying characteristics of eastern black walnut *(Juglans nigra)* including (A) leaf comprised of multiple lance-shaped leaflets with red arrows indicating the staggered attachment of the leaflet to the rachis, (B) greyish-black bark, (C) pith containing brown hollow chambers, (D) male chain-like flowers, (E) female bulb-like flowers, (F) green fruit and (G) ridged nuts.

Photo Credits: (A) T. Davis Sydnor The Ohio State University, Bugwood.org, Image 5509645; (B) Chris Evans, University of Illinois, Bugwood.org, Image 5560497; (C) T. Davis Sydnor, The Ohio State University, Bugwood.org, Image 5509639; (D) Paul Wray, Iowa State University, Bugwood.org, Image UGA0008151; (E) Alan Cressler, Lady Bird Johnson Wildflower Center; (F) Paul Wray, Iowa State University, Bugwood.org, Image UGA0008277; (G) Lyndon Photography, Bugwood.org, Image 5470912.

Habitat and Phenology

Eastern black walnut trees typically grow individually or in small groups. Trees are common in areas prone to periodic flooding, such as those adjacent to streams. [3]. Established trees have a long tap root, and, as a result, grow best in deep, fertile, well-drained and pH neutral soils [3, 9]. Eastern black walnut trees grow poorly in the shade and trees are sensitive to water availability (whether excessive or absent) [11]. For instance, trees will drop leaves early to reduce water loss during drought [11]. Eastern black walnut has a relatively short growing season, developing leaves later and losing leaves earlier than other broad-leaved deciduous trees [11]. The tree also produces juglone, a chemical that is excreted by roots and released by decaying plant litter that can prevent growth of other plants such as tomatoes, paper birch, azaleas and red pine [3].

Common Fungal and Oomycete Diseases of Eastern Black Walnut

Eastern black walnut is affected by a variety of fungal diseases. These diseases can occur within the leaves, stems or roots of trees. In severe instances, these diseases can reduce plant growth, tree structural integrity and timber and nut quality. In some cases, these diseases can kill eastern black walnut trees. Accurate diagnosis of any disease is crucial for determining the appropriate management strategy. The following section describes the symptoms and signs of common fungal and oomycete diseases of eastern black walnut trees.

Foliar Diseases

Currently, there are four diseases (Mycosphaerella leaf spot, Walnut anthracnose, Downy spot and Bull's-eye leaf spot) commonly observed affecting eastern black walnut leaves. All four of these diseases can infect trees multiple times throughout a single growing season. Diseases often occur in response to excessive rain or high humidity [12]. The first or primary infections for these diseases generally appear in the spring. Disease is initiated when fungal spores that have overwintered in dead leaves and fruits are spread by wind or splashing water to new, fully developed leaves (Figure 4). Secondary infections in late summer or early fall are spread from newly infected host tissues by wind or water. All four of the following diseases are common in areas that experience high humidity and rainfall.

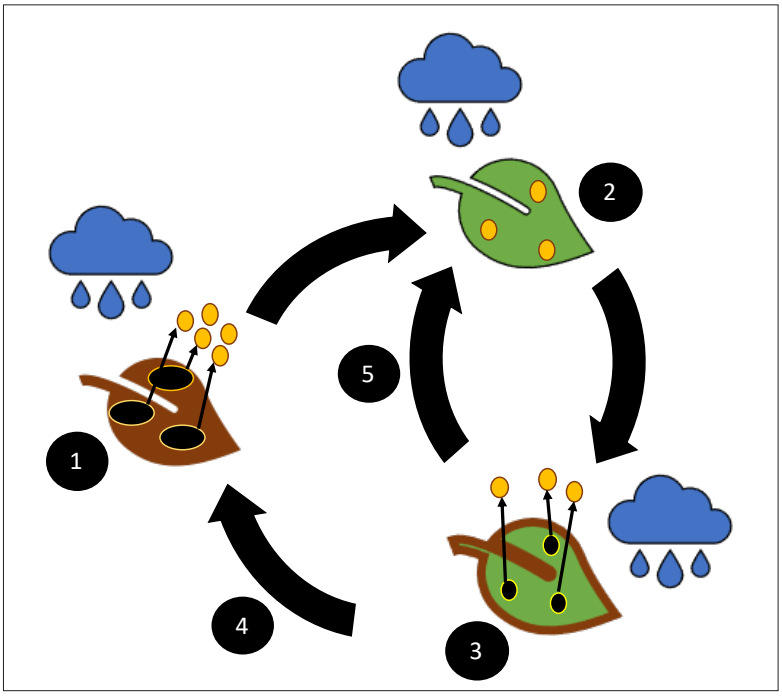

Figure 4. Example polycyclic disease cycle of foliar diseases of eastern black walnut *(Juglans nigra).* (1) Rain triggers the release of fungal spores from dead leaves from previous growing season. (2) Released fungal spores land on newly formed leaves in spring and rain promotes initial or primary infection. (3) Fungal infections result in (4) lesions that can cause early leaf drop or (5) produce fungal spores that cause secondary infections later in growing season during rain events.

Mycosphaerella Leaf Spot

Mycosphaerella leaf spot is caused by the fungal pathogen *Mycosphaerella juglandis.* This disease has been detected in the midwestern US and North Carolina [13, 14]. Mycosphaerella leaf spot can be identified by the presence of small black lesions (less than 0.25 inches in diameter) with yellowish margins on the upper sides of leaflets. If the infection is severe, leaves can turn yellow and drop from trees early.

Walnut Anthracnose

Walnut anthracnose is caused by the fungal pathogen *Ophiognomonia leptostyla* [15]. The disease is found throughout the US and is considered the most damaging foliar disease of eastern black walnut [16]. Symptoms include brown circular lesions (0.2 inches to 0.5 inches in diameter) on leaflets that are typically larger than those seen in Mycosphaerella leaf spot (Figure 5A) [17]. Leaflets with a large number of lesions can turn yellow, develop brown margins and drop from the tree prematurely (Figure 5A) [17]. Heavily infected trees can lose a large number of leaves, potentially reducing plant growth [17]. Lesions can also affect fruits, appearing on the husk as small, sunken, blackish-brown spots. Fruits also may drop prematurely if spots are abundant. Furthermore, nut quality can be diminished on fruits that reach maturity [17]. Grayish-brown lesions (less than 0.25 inches in diameter) can also appear on new shoots of affected trees, which can serve as sources for primary and secondary infections [17]. Walnut anthracnose can be identified by small fungal fruiting bodies that form in leaf veins and create blackish-brown raised bumps (Figure 5B) [17].

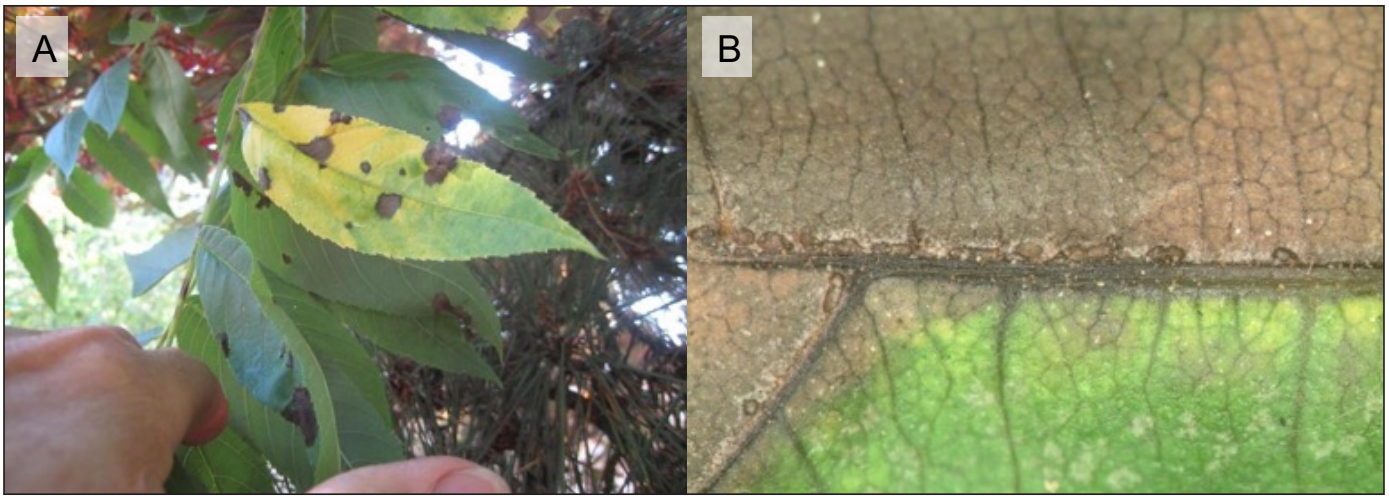

Figure 5. Symptoms and signs of walnut anthracnose of eastern black walnut *(Juglans nigra)* (including (A) brown lesions on leaflets with leaf yellowing and (B) raised bumps along leaf veins caused by the fungal fruiting bodies of *Ophiognomonia leptostyla.*

Photo Credit: (A) Scott Selby, Bartlett Tree Experts, Bugwood.org, Image 5434303; (B) Lorraine Graney, Bartlett Tree Experts, Bugwood.org, Image 5434304.

Downy Spot

Downy spot, also known as yellow-leaf blotch, white mold or Microstroma leaf spot, is caused by the fungal pathogen *Microstroma juglandis* [17]. The disease typically does not cause early leaf loss or defoliation of infected trees. Disease symptoms of downy spot include yellowish raised leaf spots on the upper sides of fully formed leaflets that mirror the fungal induced lesions on the under sides of leaflets (Figure 6A) [17]. Lesions can merge to form large irregular spots that are present on both sides of leaflets (Figure 6B) [17]. A notable sign of downy spot includes fuzzy, white asexual fungal spore masses on the under sides of leaflets (Figure 6C-D) [17].

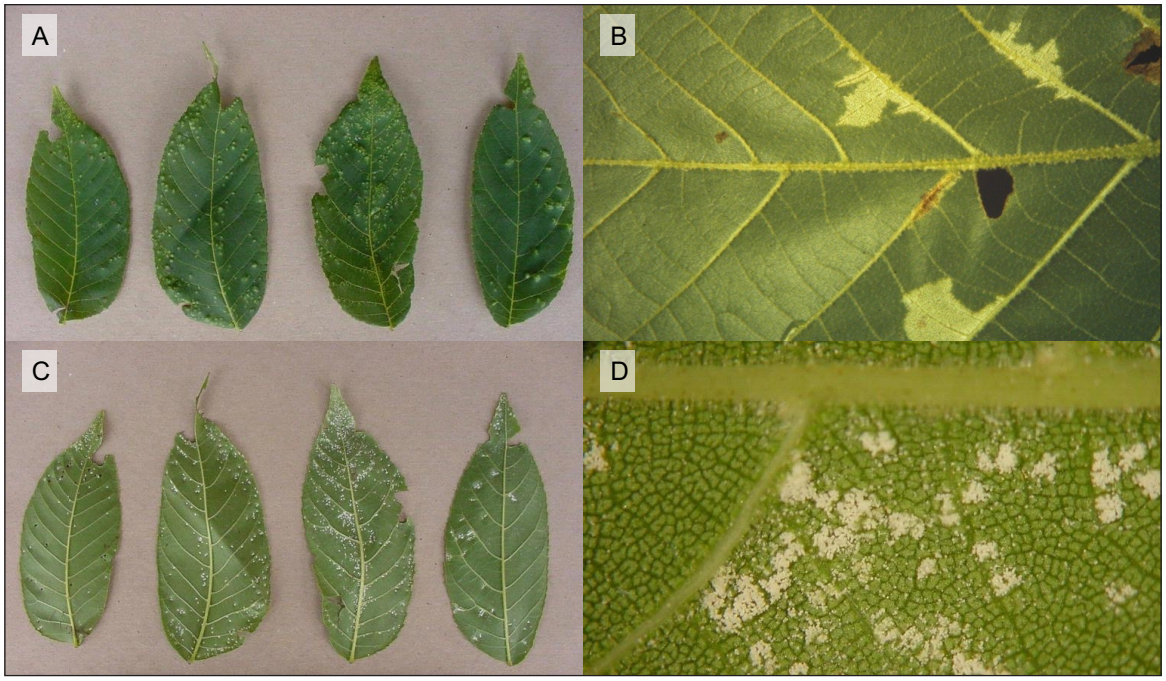

Figure 6. Symptoms and signs of downy spot of eastern black walnut *(Juglans nigra)* including (A) lesions on the upper surface of eastern black walnut leaflets mirroring the lesions formed on the under sides of leaflets, (B) irregular lesions formed when multiple downy spot lesions merge, and (C,D) white fuzzy growth on the under sides of eastern black walnut leaflets.

Photo Credit: (A) Paul Bachi, University of Kentucky Research and Education Center, Bugwood.org, Image 5369813; (B) Penn State Department of Plant Pathology & Environmental Microbiology Archives, Penn State University, Bugwood.org, Image 5549069; (C) Paul Bachi, University of Kentucky Research and Education Center, Bugwood.org, Image 5368714; (D) Paul Bachi, University of Kentucky Research and Education Center, Bugwood.org, Image 5368715.

Bull's-Eye Leaf Spot

Bull's-eye leaf spot is caused by the fungal pathogen *Grovesinia pyramidalis* [12]. The disease can cause significant defoliation on infected hosts (Figure 7A) [18]. Symptoms of bull's-eye leaf spot include brownish-grey, target-shaped lesions that are ringed with alternating light-dark sections that originate from a light brown pinpoint center (Figure 7B) [17]. Leaflets with a large number of lesions can turn yellow and drop prematurely from infected trees [17]. Signs of Bull's-eye leaf spot include stalked asexual fruiting bodies that emerge from lesions and can be observed on the under-sides of leaflets with a hand-lens (Figure 7C) [17].

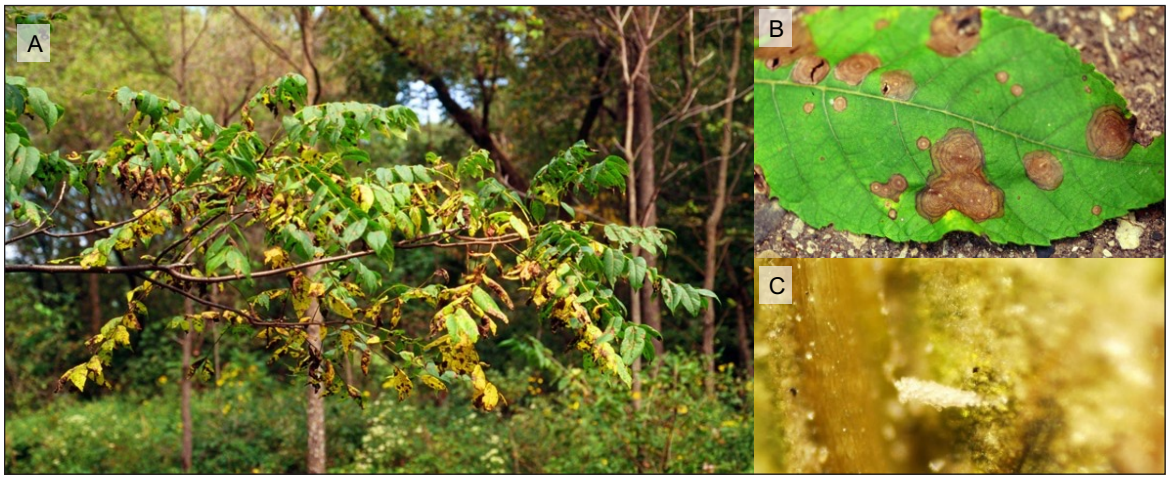

Figure 7. Examples of symptoms and signs of Bull's-eye leaf spot of eastern black walnut *(Juglans nigra)* including (A) yellowing of leaves, (B) target shaped lesions and (C) stalked fungal spore produced on the under sides of affected eastern black walnut leaflets.

Photo Credit: (A) Linda Haugen, USDA Forest Service, Bugwood.org, Image UGA1400171; (B) Linda Haugen, USDA Forest Service, Bugwood.org, Image UGA1400172; (C) Bruce Watt, University of Maine, Bugwood.org, Image 5503776.

Management of Eastern Black Walnut Foliar Diseases

Cultural Practices: All of the foliar diseases described above are capable of overwintering in fallen leaf litter, serving as sources for initial spring infections [12]. To reduce the amount of inoculum and likelihood of future infections, fallen leaf litter should be removed from the base of trees [19]. Additionally, initial infections often require wet leaves to initiate disease and secondary infections can be spread to uninfected leaves by dripping or splashing water. Thus, trees should be grown in areas with good air circulation to increase leaf drying [12]. Dense stands should be thinned, with poorly-formed and closely spaced trees removed to improve air flow and the growth of remaining trees [12]. Weeds can also serve as sources for foliar fungal pathogens and should be removed mechanically or with herbicides [12]. Lastly, available soil nutrients affect the severity of the above foliar pathogens, and, as a result, soils should be screened for suitability and fertility prior to planting trees. Soils can be supplemented with nitrogen to reduce disease severity [12]. For more information on soils suitable for the growth of eastern black walnut trees, consult "Black Walnut Suitability Index: A Natural Resources Conservation Service National Soil Information System Based Interpretive Model," which provides a method for determining the rating suitability of soils for eastern black walnut trees [20].

Chemical Control: Typically, the foliar diseases described here are not severe enough to warrant chemical control treatments. If premature leaf drop begins to affect plant growth, foliar sprays of chemical fungicides can be applied [21]. The first treatment should occur prior to disease onset in early spring when leaflets are approximately half of their full size [21]. Treatments may be applied multiple times throughout the growing season to prevent disease recurrence. For current chemical fungicide recommendations, consult "UC IPM Pest Management Guidelines: Walnut" [19]. Label instructions for individual fungicides should be reviewed to determine the number of applications, application rates, and reentry and preharvest intervals. When selecting and using a chemical control product, ensure it is labeled both for use on eastern black walnut and the disease of interest, and follow all instructions on the label. For guidance on the use of chemical fungicides, contact your local extension agent.

Canker Diseases

Eastern black walnut can be infected by a number of fungal pathogens that create cankers, or sections of dead tissues, along the trunk and branches of trees. Pathogens that cause cankers in eastern black walnut include: *Botryosphaeria dothidea, Fusarium* species, *Ophiognomonia clavigignenti-julgandacearum* and *Geosmithia morbida* (Figure 8A-D) [22, 23]. These fungal species can reduce wood quality and weaken tree stems and branches, making trees vulnerable to wind damage and insect pests. In severe cases of disease, canker pathogens can kill host trees by inhibiting sugar and water transport. Canker-forming pathogens may affect host plants only after host defenses are compromised [24]. Increased disease susceptibility can occur if the tree is experiencing nutrient or water stress, or when the plant is being affected by another disease. For instance, the fungal pathogen *Fusarium solani* is often isolated from cankers in eastern black walnut trees concurrently affected by thousand cankers disease (TCD) (Figure 8D) [25].

Other canker inducing pathogens can cause severe growth abnormalities, including *Neonectria ditissima* (formerly *Nectria galligena;* Figure 8E) [17]. This pathogen produces target cankers, which are cankers that expand each year with recurring pathogen activity when trees are inactive in the winter (Figure 8E). Canker-causing pathogens often infect hosts indirectly, entering through natural breaks in the bark such as leaf and branch scars or through wounds caused by mechanical, frost, insect or other animal damage [17]. Similar to foliar pathogens, canker pathogens are typically spread by water and wind, but may also be spread by wood-boring insects, such as bark and ambrosia beetles. Currently, the most devastating canker disease of eastern black walnut is thousand cankers disease.

Thousand cankers disease has been detected throughout the US and appears to be more severe in the western US (Figure 9) [26]. Quarantines, which restrict the transport of eastern black walnut materials, have historically been enacted by several states, including Tennessee. For current information on quarantines in Tennessee contact the Tennessee Department of Agriculture. Thousand cankers disease is caused by the fungal pathogen *Geosmithia morbida* and is spread to walnut trees by the walnut twig beetle *(Pityophthorus juglandis)* (Figure 11) [27]. Symptoms of the disease include discrete brown to black cankers that form beneath the bark of infected trees alongside walnut twig beetle galleries (Figure 12A) [25]. When the disease is severe, cankers girdle host trees causing yellowing

and wilting of leaves and death of individual branches or the entire tree (Figure 12B) [25]. Heavily infested trees die within three years following the initial infection. Signs of TCD include pin-prick sized walnut twig beetle entry and exit holes on tree branches and trunks, galleries of walnut twig beetles beneath the bark, and fuzzy white fungal masses lining the galleries or attached to walnut twig beetles (Figure 12C-E) [25].

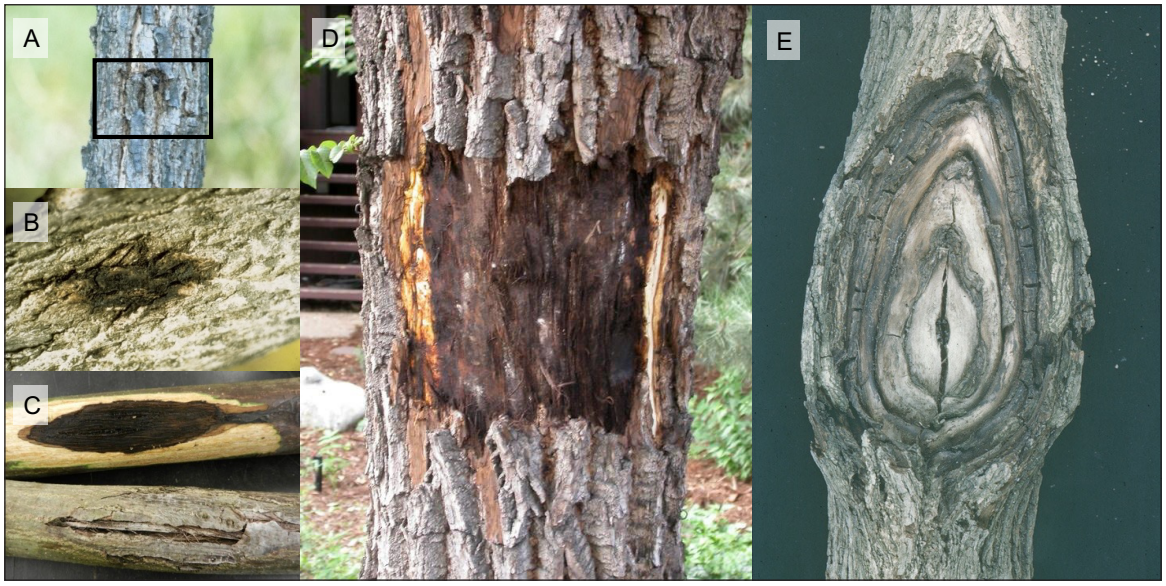

Figure 8. Examples of symptoms associated with canker diseases including (A) sunken bark caused by a *Fusarium* spp. in eastern black walnut *(Juglans nigra),* (B) stained bark characteristic of butternut canker caused by *Ophiognomonia clavigignenti-julgandacearum* in butternut *(J. cinerea),* a relative of eastern black walnut, (C) dead tissue beneath the bark caused by butternut canker in butternut, (D) late stage thousand cankers disease canker where secondary pathogens such as *Fusarium solani* can be recovered from eastern black walnut and (E) target canker caused by *Neonectria ditissima* on eastern black walnut.

Photo Credit: (A) Joseph O'Brien, USDA Forest Service, Bugwood.org, Image UGA5061018; (B) Joseph O'Brien, USDA Forest Service, Bugwood.org, Image UGA5049049; (C) Tom Creswell, Purdue University, Bugwood.org, Image 5483039; (D) Whitney Cranshaw, Colorado State University, Bugwood.org, Image 5406066; Penn State Department of Plant Pathology & Environmental Microbiology Archives , Penn State University, Bugwood.org, Image 1634128.

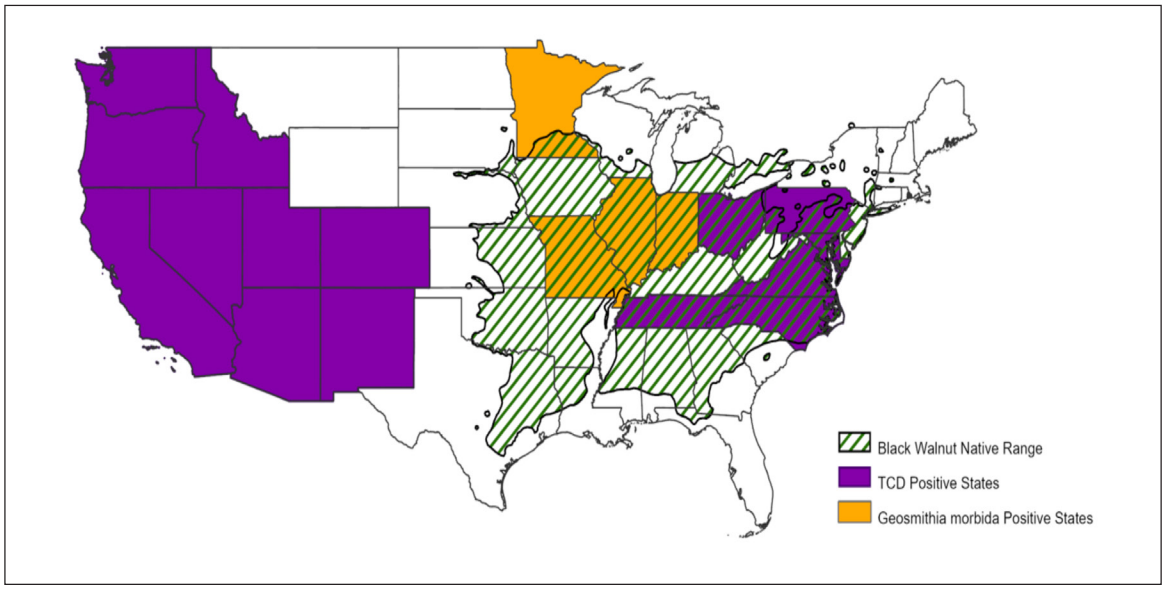

Figure 9. States where thousand cankers disease has been detected as of 2022. States colored in orange are those states within which *Geosmithia morbida* has been detected as of 2022, but unassociated with *Pityophthorus juglandis* or thousand cankers disease symptoms.

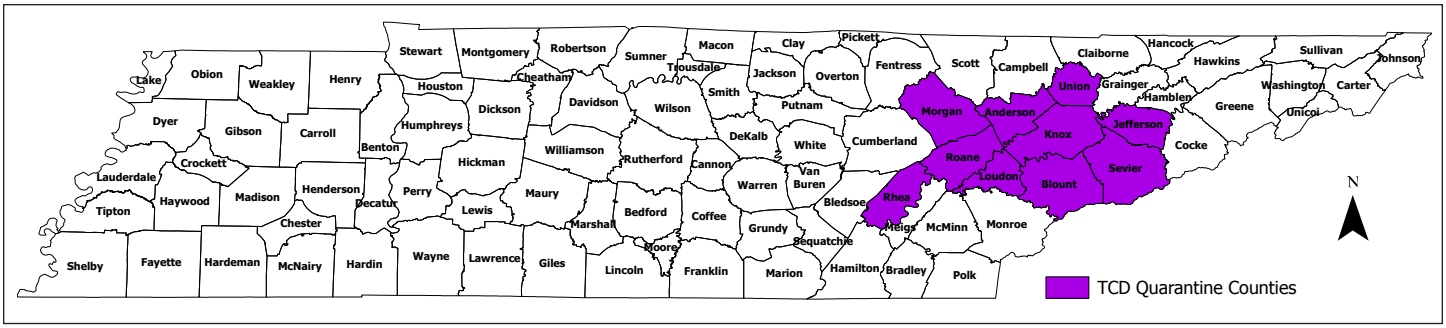

Figure 10. Counties within the state of Tennessee that were previously under a quarantine that restricted the movement of *Juglans nigra* across county lines. This quarantine was lifted in 2021.

Figure 11. Walnut twig beetle *(Pityophthorus juglandis)* adults serve as the principal method by which the fungal pathogen, *Geosmithia morbida* is introduced to eastern black walnut trees, resulting in thousand cankers disease. Spores of the fungus are carried on the outer surface of adult beetles and are introduced into the tree when beetles burrow into the bark of the tree to reproduce. Several adult walnut twig beetles are grouped on a penny for scale.

Figure 12. Examples of thousand cankers disease symptoms and signs including (A) cankers formed beneath the bark of eastern black walnut *(Juglans nigra),* (B) leaf yellowing and branch death, (C) walnut twig beetle *(Pityophthorus juglandis)* entry and exit holes on branches, (D) walnut twig beetle galleries beneath the bark and (E) fuzzy white fungal tissue growing from walnut twig beetle gallery.

Photo Credit: (A) Ned Tisserat, Colorado State University, Bugwood.org, Image 5406089; (B) Troy Kimoto, Canadian Food Inspection Agency, Bugwood.org, Image 5516670; (C) Mary Ann Hansen, Virginia Polytechnic Institute and State University, Bugwood.org, Image 5491424; (D) Whitney Cranshaw, Colorado State University, Bugwood.org, Image 5382183; (E) Ned Tisserat, Colorado State University, Bugwood.org, Image 5406098.

Management of Eastern Black Walnut Canker Diseases

Cultural Control: For cultural control of canker diseases, including TCD, diseased branches should be pruned in late winter or early spring when trees are dormant using equipment sterilized with 10 percent bleach or 70 percent ethanol. For a description of proper pruning, refer to "Best Management Practices for Pruning Landscape Trees, Shrubs and Ground Covers", UT Extension document PB 1619. For instances of disease where the structural integrity of the tree has been severely compromised, trees should be removed to prevent potentially hazardous breakage of limbs by wind and to reduce sources of additional fungal inoculum [19]. Additionally, TCD-compromised trees should be removed to prevent spread of disease to healthy, uninfected trees. To reduce tree stress, water and nutrient availability should be optimized and the suitability of the site determined prior to planting eastern black walnut trees [19, 28]. For more information on soils suitable for the growth of eastern black walnut trees, consult "Black Walnut Suitability Index: A Natural Resources Conservation Service National Soil Information System Based Interpretive Model," which provides a method for determining the suitability of soils for eastern black walnut trees [20].

Chemical Control: Chemical control of canker diseases is typically limited to preventative treatments that protect healthy trees from infection and not recommended for trees with existing infections [28]. For current chemical fungicide recommendations, consult "UC IPM Pest Management Guidelines: Walnut" [19]. Label instructions for individual fungicides should be reviewed to determine the number of applications, application rates, and reentry and preharvest intervals. When selecting and using a chemical control product, ensure it is labeled both for use on eastern black walnut and the disease of interest, and follow all instructions on the label. For guidance on chemical fungicide recommendations, contact your local extension agent.

Root Diseases

The primary root disease that affects eastern black walnut is Phytophthora root rot caused by *Phytophthora* species [17]. Phytophthora root rot primarily infects young trees in orchard and nursery settings. The disease typically starts in the roots and can occasionally spread to above ground portions of the plant [17]. Root diseases are spread by water in poorly drained soils [17]. Symptoms of Phytophthora root rot include blackening of the taproot and upper stem, leaf yellowing, stunted growth and, in some cases, tree death [17].

Another root disease that causes similar symptoms in nursery settings is Cylindrocladium root rot caused by *Cylindrocladium* species [29]. Cylindrocladium root rot is more common in warmer temperatures [30]. Symptoms of Cylindorocladium root rot are similar to Phytophthora root rot with vertical cracking and blackening of taproot (Figure 13).

Figure 13. Taproot blackening of eastern black walnut seedlings caused by Cylindrocladium root rot (*Cylindrocladium* spp.).

Photo Credit: Edward L. Barnard, Florida Department of Agriculture and Consumer Services, Bugwood.org, Image UGA4824085.

Management of Eastern Black Walnut Root Diseases

Cultural Control: The primary method of controlling Phytophthora root rot is to ensure good soil drainage and avoid overwatering [30]. Maintaining well-drained soils is helpful because the pathogen is spread by water and prolonged soil flooding can cause roots to become oxygen stressed, increasing susceptibility to disease. Also, soil solarization has been used to heat soils and kill pathogens, preventing infection. For more information on soils suitable for the growth of eastern black walnut trees, consult "Black Walnut Suitability Index: A Natural Resources Conservation Service National Soil Information System Based Interpretive Model," which provides a method for determining the suitability of soils for eastern black walnut trees [20].

Chemical Control: Several phosphorus acid fungicides are labeled for the treatment of Phytophthora root rot in eastern black walnut [19]. These treatments can be applied as preventative or curative treatments to reduce the severity of disease in infected trees. For current chemical fungicide recommendations, contact your local extension agent. Label instructions for individual fungicides should be reviewed to determine the number of applications, application rates and reentry and preharvest intervals. When selecting and using a chemical control product, ensure it is labeled both for use on eastern black walnut and the disease of interest, and follow all instructions on the label. For guidance on chemical fungicide usage, contact your local extension agent.

Conclusion

Eastern black walnut is an economically and ecologically important forest tree species. The ability to accurately identify diseases afflicting eastern black walnut trees is crucial for the proper management and conservation of this species. Upon diagnosis, an integration of multiple disease management strategies can be used, including combinations of cultural and chemical management.

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