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Heterobasidion Root Disease in Eastern Conifers

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Introduction

Heterobasidion root disease (HRD) is caused by distinct but closely related fungi in the *Heterobasidion annosum* species complex. Older common names for HRD include annosum, annosus, or Fomes root disease or root rot. This disease causes growth loss, root and butt rot, and mortality of conifers. Damage by HRD in thinned conifer plantations can be especially severe, and it is one of the most economically destructive of all forest tree diseases.

Hosts and Distribution

Heterobasidion irregulare was formerly referred to as the "pine-type" (or p-type) of *H. annosum* due to its frequent association with pines (*Pinus* spp.) in both Eastern and Western North America. Because *H. irregulare* is the only *Heterobasidion* species known in Eastern North America, historical references to *H. annosum* in

Figure 1. Crowns of dead eastern white pine (center) and dying red pine (right) affected by Heterobasidion root disease.

the East are now presumed to refer to *H. irregulare*. A second *Heterobasidion* species, *H. occidentale*, was formerly known as the *H. annosum* "s-type." It is known only in Western North America

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Figure 2. Aerial view of expanding Heterobasidion root disease pockets in a red pine plantation.

and is most common on spruces (*Picea* spp.), true firs (*Abies* spp.), and Douglas-fir (*Pseudotsuga menziesii*).

In the Eastern U.S., HRD is usually found within the historical range of pines and eastern red cedar (*Juniperus virginiana*). Although the known geographic distribution of *H. irregulare* has recently increased, there are still large portions of the Central U.S. and Great Lakes Region occupied by conifer forests where HRD has not been reported. In contrast, the pathogen is widely distributed in the Southeast, where its abundance and the resulting severity of HRD damage vary with site conditions and tree species.

All native pine species occurring in the Eastern U.S. are susceptible to HRD, along with eastern red cedar. In the Southeast, longleaf pine (*Pinus palustris*) is the least susceptible host of *H. irregulare*, while loblolly pine (*Pinus taeda*) is the most susceptible. Eastern white pine (*Pinus strobus*) in the Appalachian Mountains has also experienced severe damage by HRD. In more northern areas, red pine (*Pinus resinosa*) is the most common host, but *H. irregulare* also frequently kills eastern white pine, jack pine (*Pinus banksiana*), and less commonly fir and spruce. Many other native conifers and those introduced to the Eastern U.S. also are likely hosts. Although *H. irregulare* occasionally has been reported in hardwoods, the role of these species in the epidemiology of HRD is not clear.

Symptoms and Signs

Site-level symptoms. Mortality caused by HRD in maturing pine stands often occurs in expanding foci or pockets, usually initiated after thinning and typically increasing in size over a period of years (figures 1, 2). Standing dead trees, snags, and wind-thrown trees may be present in pockets, with unhealthy but still living trees on the margins. Seedlings and saplings in HRD pockets are often killed (figure 3).

Tree symptoms. The health of larger trees with diseased roots often gradually deteriorates over several years. Crown symptoms on pines include short and lighter green or chlorotic needles, poor needle retention, and reduction in annual shoot growth that results in thin crowns (figure 4). As trees die, needles brown and are eventually shed. Colonized lower stems and roots may exhibit resin soaking, and clumps of soil infiltrated with resin may stick to the outside of roots (figures 5, 6). In the lower stems and roots, incipient decay may be indicated by an irregular, pinkish to dull-violet discoloration. The decay progresses to whitish pocket rot that sometimes includes black spots or flecks (figure 7). These small pockets in decayed wood eventually coalesce and reduce the roots and stem wood to a light-yellow to whitish, stringy

Figure 3. Dead loblolly pine seedling growing near a stump colonized by *Heterobasidion irregulare*.

Figure 4. Thinning and dying crowns of loblolly pine affected by Heterobasidion root disease.

Figure 5. Excavated red pine root affected by Heterobasidion root disease, showing resinosis and blackening of the surrounding soil.

Figure 6. Resin soaking of root wood is a response to colonization by *Heterobasidion irregulare*.

mass. This stringy decay is often seen in broken roots of wind-thrown trees (figure 8), in contrast to sharp, firmly splintered breaks of sound roots. Affected seedlings and saplings exhibit similar symptoms, but often die more rapidly.

As is the case with other conifer root diseases, bark beetles and other stem- and root-colonizing insects are commonly associated with trees affected by HRD. Such insects and accompanying mutualistic "stain" fungi are often secondary invaders of conifers stressed by drought or other unfavorable environmental conditions. The presence of beetle galleries, exit holes, frass, and their accompanying fungi should not be assumed to be the primary causes of death.

Fruiting bodies. Fruiting bodies (conks) are the diagnostic signs of *H. irregulare*. Conks are more common in some HRD pockets and scarce in others, and vary greatly in number and size from place to place and year to year. Increased abundance of conks is associated with periods of moist weather. Fresh conks are most frequently found in late summer and autumn in the Northeast and Midwest,

Figure 7. Stringy-white rot typical of advanced root decay by *Heterobasidion irregulare*.

Figure 8. Wind-thrown pine due to root decay by *Heterobasidion irregulare*.

Figure 9. Conk of *Heterobasidion irregulare* on an eastern white pine sapling.

and during autumn and winter in the Southeast (see the Biology and Ecology section). Several years may pass between initiation of an HRD pocket and appearance of conks.

Heterobasidion irregulare conks are variable in appearance, ranging in size and shape from very small conks that resemble popped popcorn, to irregular masses, to brackets several inches wide (figures 9, 10, 11). The upper surfaces of conks can be light gray to dark-grayish brown or reddish brown and smooth to bumpy or fissured. The undersurface of growing and recently formed conks is white to cream colored with tiny, round to irregularly shaped pores (figure 12). The light-colored layer often extends to the upper edge of actively growing conks. The under surface may darken to brown with age. Conks can be perennial, producing new pore layers in subsequent years, or annual, persisting for only a year.

Conks form on root collars and on trunks up to a few feet above the soil on living or standing dead trees, stumps, roots of wind-thrown trees, and slash of previously colonized trees. Conks sometimes emerge within the litter layer, appearing as irregular masses of fungal tissue with embedded needles, twigs, and other debris. Removal of this litter is often necessary to see conks that have grown very low on trees or stumps.

Figure 10. Small conks of *Heterobasidion irregulare*.

Figure 11. Large conks of *Heterobasidion irregulare*.

Figure 12. The lower surfaces of *Heterobasidion irregulare* conks contain pores that vary in size and shape.

Figure 13. Microscopic view of the asexual conidiophores of *Heterobasidion irregulare* with and without conidia.

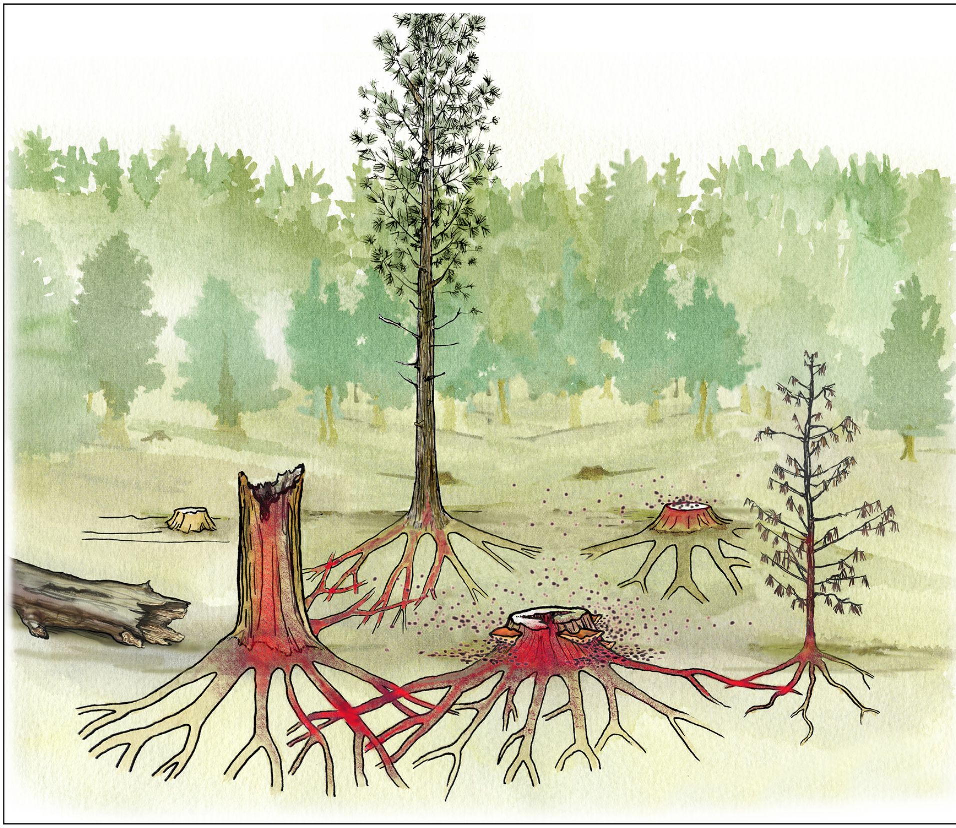

Figure 14. Diagram of Heterobasidion root disease development in a stand. Red shading represents tree roots and stumps infected by *Heterobasidion irregulare*. Basidiospores disseminated from conks are deposited on freshly cut stumps. After infection, the pathogen can decay the stump and roots, and move through colonized roots to infect adjacent trees.

Confirmation. The presence of *H. irregulare* can be confirmed in several ways. Although its conks are variable, they can be recognized by experienced forest pathologists and forest health specialists. When samples of colonized root or stem wood are incubated in moist conditions at cool temperatures or placed onto a semi-selective media, the characteristic conidiophores and conidia of the asexual *Spiniger* stage may form and can be viewed using a microscope (figure 13). Molecular methods are available to confirm *H. irregulare* DNA in wood samples extracted from lower stems and roots colonized by the pathogen or from cultures produced on growth media.

Biology and Ecology

Heterobasidion irregulare frequently infects conifer hosts after airborne basidiospores released from conks land on fresh wounds or stumps and germinate (figure 14). Infection of intact roots is less common, but can occur following percolation of spores through sandy soil. Basidiospore deposition decreases with increasing distance from a source and is influenced by prevailing winds and other environmental conditions. However, detection of viable, windborne basidiospores of other *Heterobasidion* species many miles from known infestations proves the potential for long-distance spread.

The period of susceptibility of conifer stumps to infection varies from a few days to up to 4 weeks after felling. Differences are due to tree species and environmental conditions that affect chemical and physical properties in the wood following harvesting, as well as competition from other fungi.

After infection, the fungus decays the wood of the affected tree or stump. The fungus can grow through and along dying and dead roots to infect adjacent trees, but does not grow long distances through mineral soil. Multiple studies report growth rates in pine roots of up to several feet per year that vary depending on temperature and the tree species involved. The possible role of hardwoods and minor hosts in maintaining *H. irregulare* on sites is unknown.

Midwest and Northeast Specific Information

Because HRD has not been detected in large portions of the Midwest and Northeast that have conifer forests, there is increasing interest in preventing further infestation by *H. irregulare*. Fresh stumps produced during thinning of plantations in these regions are particularly important to initiation of HRD. After *H. irregulare* infects a stump, it may take 5 or more years before a pocket of mortality begins to develop and conks appear. HRD intensifies on sites through expansion of existing pockets via root contacts or grafts. New HRD pockets are also initiated following subsequent thinnings because inoculum spreads from conks on the initially colonized stumps or killed trees.

Basidiospores can be released any time viable conks are present. Extended periods of temperatures below freezing may inactivate the spore-producing layer of conks, so there is usually a period of reduced basidiospore production during winter. Although cold and snow cover restrict spore dispersal, viable spores were detected in heavily infested stands in Wisconsin, and white pine stumps were infected in Pennsylvania, even during the winter months. In both central Wisconsin and upstate New York, peaks of spore production were observed in late spring to early summer and again in fall and early winter. It is not known how the duration of stump susceptibility to infection might vary among species of northern conifers or under different weather conditions.

Information is also limited regarding how long *H. irregulare* may persist at an infested location in the Midwest and Northeast. The pathogen is maintained on a site as new trees are infected and killed, and thus may be supported for as long as susceptible host material is present. Persistence in the Midwest and Northeast is likely to be measured in decades rather than years, and for this reason HRD is considered a "disease of the site."

Southeast Specific Information

Spore production and stump infection by *H. irregulare* are strongly affected by temperature in the Southeastern U.S. Below 34° N latitude, conks and basidiospores are primarily produced in the fall through early spring. In the summer, conk production is inhibited and aerial basidiospores become scarce after daily mean temperatures are above 70° F. High temperatures on stump surfaces during summer also limit infection by killing basidiospores and mycelium.

In the Southeast, damage caused by HRD is related to soil properties, and severe losses are likely if pine stands on high-hazard sites are thinned without preventative stump treatment (figure 15). Loss of loblolly and slash pine to HRD was found to be greater on sites with well-drained, sandy soils (sandy loam, loamy sand) at a depth of 12 inches or greater. Medium-hazard sites are those that have loam or silt loams, or sandy soils with a clay underlying horizon less than 12 inches from the surface. Low-hazard soils for HRD include clay soils and any soil with a high water table for two or more months per year.

The average yearly root spread of *H. irregulare* on a high-hazard site can range from 4.3 feet for loblolly pine, 3.6 feet for slash pine (*Pinus elliottii*), and 2.6 feet for longleaf pine. Longleaf pine mortality has been found to be half that of loblolly pine on a high-hazard site. Losses due to HRD occur over a 10-year period with peak yearly losses occurring between the 4th and 8th year after thinning (figure 16).

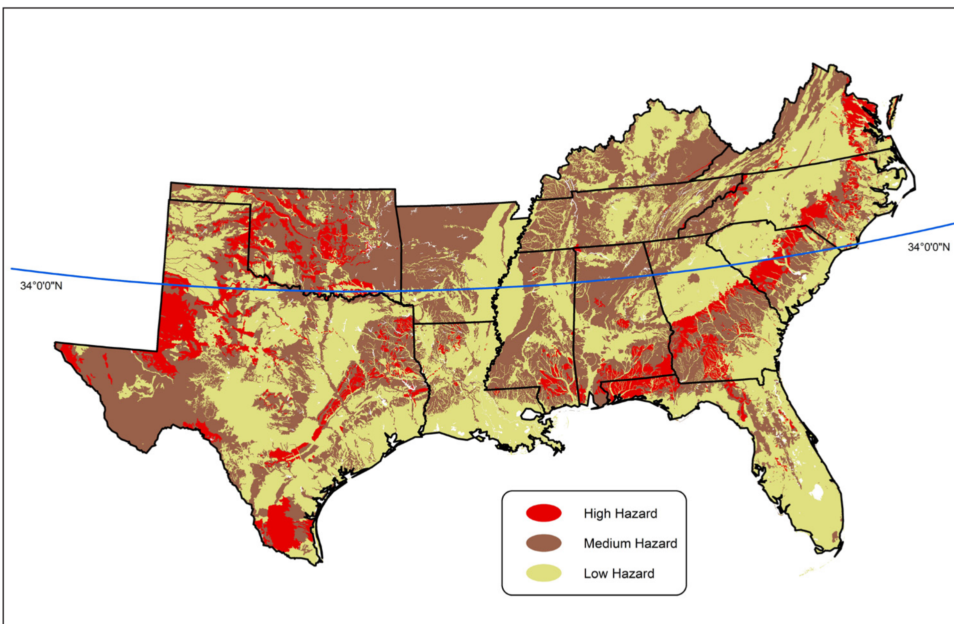

Figure 15. Southeastern U.S. Heterobasidion root disease hazard rating map based on soil type and drainage class.

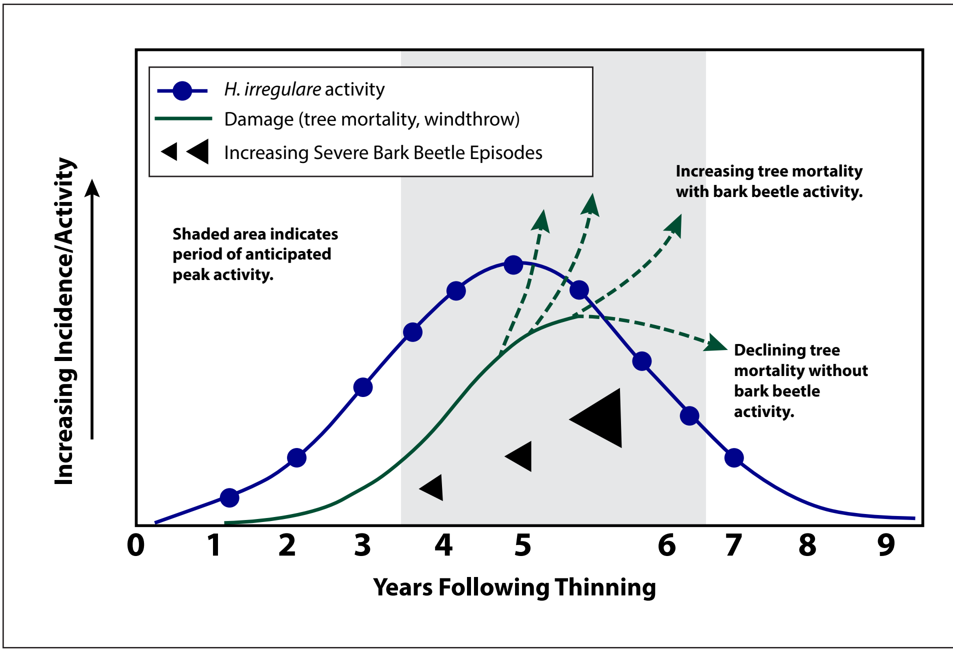

Figure 16. Model of Heterobasidion root disease development, including potential interaction with bark beetle attack in the southeastern U.S. (Diagram from Barnard 1999)

Survey and Assessment of Heterobasidion Root Disease

Surveys can be used to either detect the presence of HRD or quantify the incidence and severity of this disease. Where HRD is considered less common, the primary purpose of surveying is detection. Surveys to detect HRD should focus on stands with evidence of root disease. This will appear as pockets of progressive tree mortality detected during stand examinations or using GIS or aerial survey data. Surveying for the presence of conks is the least intensive method to confirm presence of HRD.

Surveys should be scheduled when conditions are favorable for the fungus to fruit. More intensive HRD survey methods provide greater accuracy on HRD incidence and severity. This fact was documented in a study of loblolly pine plantations in Virginia, where conks were found on only 2.5% of survey trees, while increment cores and root excavation confirmed presence of *H. irregulare* in 10.1% and 31.6% of trees, respectively. In a second study of loblolly pine plantations in Virginia, conks were found on only 9% of trees; however, bulldozing the root systems revealed that 85% of the trees were affected by HRD. Systematic and intensive sampling of stands, including root excavation and laboratory processing of symptomatic root pieces, is used for more accurate surveys. Assistance from forest health specialists or forest pathologists may be necessary to identify the pathogen.

After the presence of *H. irregulare* is confirmed, the percentage of roots affected can be used to assess the disease impact and guide the choice of best management practices. An assay method used for decades in the Southeast involves excavating roots from each of 20 1-cubic-foot soil samples systematically located throughout a stand. Roots are examined for characteristic resin soaking or stringy white rot. The percentage of roots colonized by HRD is calculated by dividing the number of symptomatic roots by the total number of roots encountered in the 20 samples.

Impact

The availability of information about the impact of HRD varies among regions in the Eastern U.S. Impacts in Southeastern pine forests have been well documented. The severity of tree mortality from HRD ranges from low (< 1%) to as high as 30%, depending on the site, environmental conditions, and spore load at the time of thinning. Radial growth loss in southern pine trees affected by HRD has been shown to range from 19 to 32% over 5-6 years. The impact of HRD can increase when trees are stressed by suppression or drought. Southern pine beetle, a major pest of the South, has also been associated with increased root colonization by *H. irregulare*. Stress induced by HRD can predispose trees to bark beetle attack (primarily southern pine beetle, Ips bark beetles, and turpentine beetles), which can then result in increased losses.

In the Midwest and Northeast, tree mortality and premature salvage of severely damaged stands have occurred, but adequate quantitative data is unavailable on growth loss, rates of pocket expansion, number and size of trees typically killed, and impact on wood supply.

Management of Heterobasidion Root Disease

The basic tools available for HRD management include prevention by protecting stump surfaces or restricting seasonal harvesting, and risk rating based on tree species and site characteristics. Applying these tools depends on many factors and differs among regions.

Highly effective stump surface treatment options include application of either a chemical or biological control agent. A borate compound currently available to prevent spores of *H. irregulare* from infecting cut stump surfaces is disodium octaborate tetrahydrate, or DOT. This compound is available as a water-soluble powder that can be applied manually with a backpack sprayer or through a mechanized attachment to a harvester. The fungus *Phlebiopsis gigantea* also has shown effectiveness as a biological control agent to prevent *H. irregulare* colonization. If a chemical protectant or biological control agent is used, compliance with regulations for pesticide usage is required.

Midwest and Northeast Specific Information

The primary management tools in the Midwest and Northeast are prevention of new stump infections by applying stump treatments or limiting thinning and harvests to the winter season. There is no absolute "safe" time period, but in areas with very cold or snowy winters, the relative risk of stump infection is reduced during the late winter period.

If no HRD occurs in the vicinity, the risk of new infestations is greatly reduced. If a stand of susceptible species is infested but the incidence of HRD is low, or it is not infested but is near stands with HRD, there is high risk of developing new disease centers when cutting occurs without protecting stumps from infection. The potential impact increases if infection occurs early in the rotation and the disease has opportunity to intensify over time through additional entries.

In stands where HRD incidence is already high, consider conversion to less susceptible tree species if appropriate for the site. Removing stumps and roots may reduce persistence of HRD on a site. However, stump and root removal will not prevent subsequent reinfestation if inoculum arrives from nearby sources.

Land managers evaluate the need to use these management tools differently based on proximity to known infestations and tolerance to risk. Individual Federal, State, and local land management organizations have developed specific guidelines or requirements that can be consulted for more specific information.

Southeast Specific Information

In the Southeast, pine stands on high-hazard sites and eastern white pine stands have a high probability of significant losses from HRD and should be managed proactively. Practices to minimize losses include: 1) planting at wider spacing to delay and reduce the number of thinnings, 2) applying stump treatments, 3) thinning during the summer at sites below 34° N latitude, and 4) planting longleaf pine or conversion to non-hosts on high-hazard sites. In pine seed orchards or on recreational areas, stump treatment or stump removal should be required regardless of the site's hazard rating.

Protective DOT or *P. gigantea* stump treatments are recommended for pine stands at risk, but not already infested by *H. irregulare*. If the percentage of roots colonized (as determined by cubic-foot soil assay) is between 10-40% in any stand, treatment of newly cut stumps with the biocontrol fungus *P. gigantea* is recommended. Unlike DOT, which only prevents surface infection, this fungus saprophytically grows into treated stumps and connected roots to compete with *H. irregulare*. Thus, *P. gigantea* can inhibit underground spread of *H. irregulare* through interconnected root systems to other stumps and adjacent trees. Another method of reducing stump infection is cutting during the summer when the mean daily temperature is above 70° F. This summer harvest option is only effective south of the 34° N latitude and can be used when thinning pine stands on high-hazard sites or for sanitation cuts of infested stands.

Harvest and regeneration of a stand is recommended when the expected losses to HRD exceed the stumpage value, or when the percentage of roots colonized by *H. irregulare* (as determined by cubic-foot soil assay) is more than 40%. Consider a less susceptible species, such as longleaf pine, for regeneration of high-hazard sites. Sites with HRD can be regenerated immediately because seedling losses to HRD on these sites are typically minor and do not greatly affect the ultimate stocking of the stand.

Assistance

Federal forest land managers can contact their local USDA Forest Service Forest Health Protection office. Others may contact their own State forest health units and universities. Various regional or State publications and Web sites, in addition to relevant literature listed below, may provide more information regarding the local status of HRD and specific required or recommended HRD management practices.

Relevant Literature

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Acknowledgments

This Forest Insect and Disease Leaflet replaces Annosus Root Rot in Eastern Conifers, which was last revised in 1984 by Kathryn Robbins. Previous versions of the leaflet were written by H.R. Powers, Jr., and J.S. Boyce, Jr., and then revised by H.R. Powers, Jr., and C.S. Hodges, Jr., in 1970.

The current version reflects a high dependence on research by a multitude of scientists across the Northern Hemisphere that has enhanced our understanding of this disease. Helpful reviews of an earlier draft of this manuscript were provided by James Jacobs, Kyoko Scanlon, Barbara Schultz, and Tyler Dreaden.

Image Credits:

Figures 1, 5, 9, 10, and 11: Glen Stanosz; Figure 2: Scott Lint, Michigan DNR; Figures 3, 4, 6, 7, 8, and 13: Michelle Cram; Figure 12: Mark Guthmiller, retired Wisconsin DNR; Figure 14: Forest Service Illustration by Juliette Watts; Figure 15: Forest Service Map by Southern Region Forest Health Protection.

Pesticides used improperly can be injurious to humans, animals, and plants. Follow the directions and heed all precautions on the labels. Some States have restrictions on the use of certain pesticides. Check your state and local regulations. Also, because pesticides are under constant review by the Federal Environmental Protection Agency, consult your county agricultural agent or State extension specialist to be sure the intended use is still registered.

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