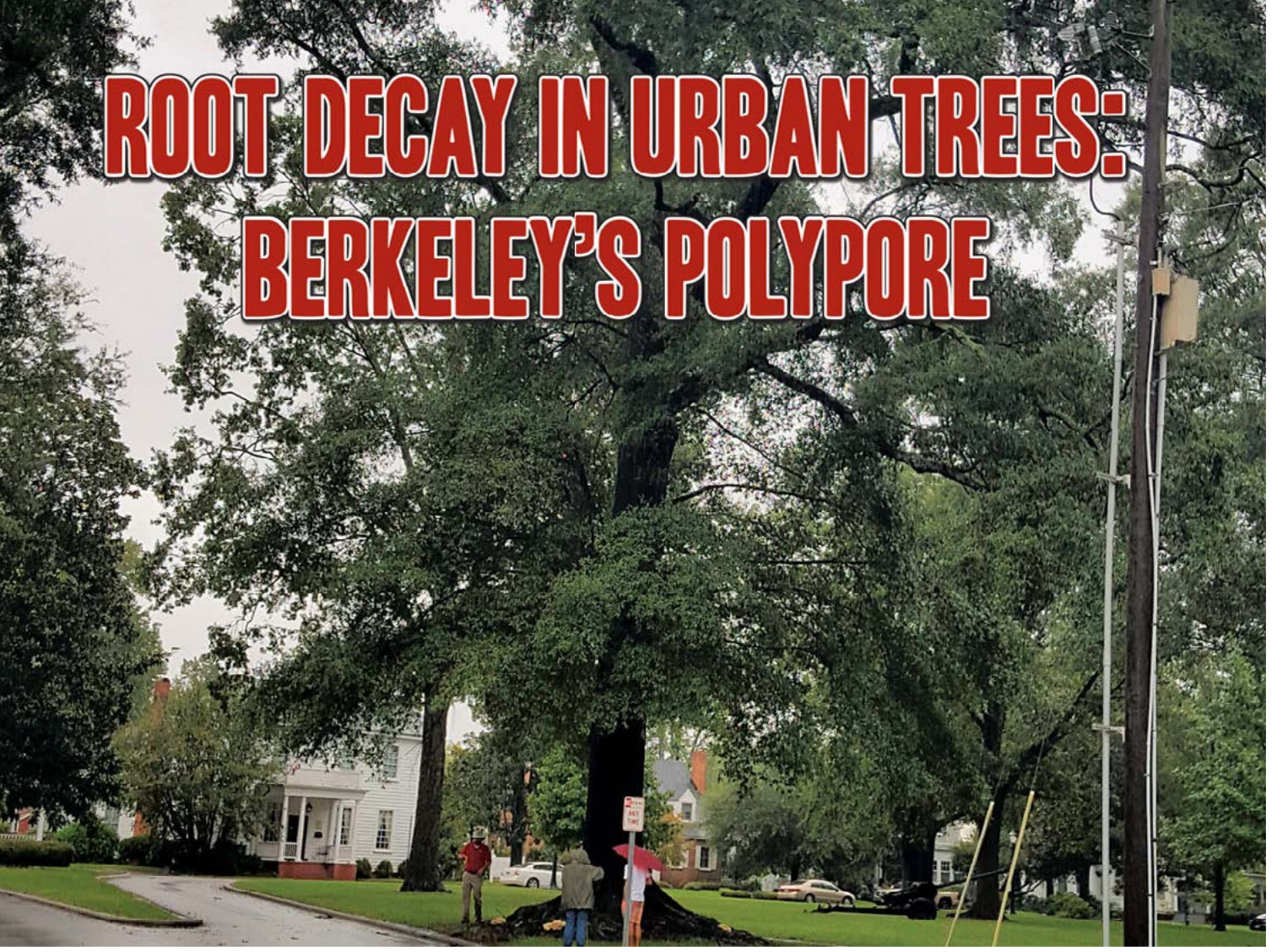
ROOT DECAY IN URBAN TREES: BERKELEY'S POLYPORE



Photograph 5: The apparently healthy crown of the tree with numerous mushrooms of **B. berkeleyi** *fruiting on woody roots as shown in Photograph 2. All images courtesy of the author.*

By Christopher J. Luley

It is September and your client has a two-foot-diameter, 30-pound mushroom growing from the base of their oak (Photograph 1 and 1a). They are wondering what it is doing to the tree *and* why you can't identify this gigantic and obtrusive fungus in their backyard. It can only be one pathogen, Berkeley's polypore (*Bondarzewia berkeleyi*, previously named *Polyporus berkeleyi*).

Photograph 1: A large specimen of **Bondarzewia berkeleyi** *at the base of a laurel oak.* **B. berkeleyi** *always fruits at the base of the tree or from woody roots.*

Identification

Berkeley's polypore is probably the largest of all the decay fungi that fruit on urban trees. It is most common east of the Rockies. A different *Bondarzewia* species is reported from western conifers. Besides its large size (often two feet or more in diameter), it is relatively easy to identify

Decay Fungi Series

This is the first article in a series from Christopher J. Luley that will run in *TCI Magazine* this year on decay fungi species found in urban trees.

Photograph 1a: Berkeley's polypore is the largest of the annual decay fungi that may be found around urban oaks. Individual specimens have been reported up to 40 pounds and 2 or more feet in diameter.

Photograph 2: Numerous mushrooms of* B. berkeleyi *growing from the roots of an oak in September.

given the following characteristics:

- Mushrooms attached to exposed or buried roots or the base of trees. Also fruiting from old stumps. Primarily found on oaks but also reported from chestnut and cherry in the east (Photograph 2).
- Overlapping rosettes of one to five or more, 6- to 25-cm (3-10 inch) wide lobes with a single, mostly central stem or stipe (Photograph 3).
- Top cream or tan to gray or white, with faint to more apparent zonation (Photograph 3); cap may be finely hairy or not.
- Angular pores that are easily visible with the naked eye and that run down the length of the individual lobes (Photograph 4, next page).
- Drying cream or tan or darker and not bruising black when touched or turning black when deteriorating (Photograph 4a, next page).

Berkeley's polypore might be confused with a couple of other common annual fungal species that decay urban trees such as *Grifola frondosa*, *Laetiporus cincinnatus* and *Meripilus sumstinei*. However, none of these fungi are as large or have the group of characteristics of *B. berkeleyi* outlined above. *G. frondosa* has brown or tan fronds that are much smaller; *L. cincinnatus* has much smaller pores that can hardly be seen with the naked eye and is yellow to reddish on top; and *M. sumstinei* bruises and fades black and has much smaller fronds and pores.

Photograph 3:* B. berkeleyi *showing the large fronds typical of this fungus and lighter color of some specimens.

Importance

There is not a lot of information on *B. berkeleyi* and its impact on urban trees. I have observed numerous mushrooms of this fungus on the roots and base of individual trees with crowns in normal condition (Photograph 5, facing page). The literature reports that the pathogen causes a white stringy rot as it decays the wood and initially leaves rays intact. Internal cavities or hollows are reported as the decay progresses. The wood of recently cut trees is reported to have the odor of anise that can be detected from 20 to 30 feet away.

Decay of the fungus is in the roots and lower trunk or butt and usually does not progress higher than four feet up the trunk from ground level. As the decay progresses, oaks infected with *B. berkeleyi* may become "butt swelled" or have the symptom known as bottle butt. Trees with long-standing infections are reported to have extensive decay and internal cavities, suggesting that trees may progressively pose an elevated risk of failure with time.

Managing infected trees

Trees with Berkeleyi's polypore should at a minimum be sounded for decay with a mallet. Advanced testing with resistance

Photograph 4: Large pores of* B. berkeleyi *on a drying specimen. The pores of this fungus are easily seen with the naked eye.

drilling or tomography (sound waves) may be warranted where decay is progressing in buttress roots or butts. However, *B. berkeleyi* can also develop on smaller-diameter woody roots (Photograph 2). This poses a difficult situation for arborists because there is no good means to test trees for decay or make decisions on the likelihood of failure when decay is developing in smaller-diameter woody roots. Pull testing or monitoring tree movement in winds with electronic sensors may hold some potential for evaluating this type of root decay, although these are seldom practiced in North America.

Crown reduction is one alternative to removing trees with decay in the roots and base. This is a general recommendation that should be approached cautiously unless some assessment of decay has been made. Crown condition cannot be used as a means to assess internal decay. Removing live crown during reduction has the potential to reduce the tree's growth and its ability to contain infections.

B. berkeleyi is reported as edible when young, but may become bitter as it ages. As with any mushroom on the ground or on trees, positive identification is essential before consumption.

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***Photograph 4a: A drying specimen of* B. berkeleyi. *Note that the fungus is turning darker color but not black, as occurs with* M. sumstinei.**

TreeRot.com, a website dedicated to decay fungi of urban trees. This article was based on a portion of his presentation, "Root Rot, Really?" made at TCI EXPO 2015 in Pittsburgh. To listen to an audio recording of that entire presentation, go to this article in the online version of this issue and click here.

Root Decay in Urban Trees – Part 2

Ganoderma sessile (aka Ganoderma lucidum) – An Important Root Disease and Butt Decay by Any Name

This is the second article in a series from Christopher J. Luley on decay fungi species found in urban trees that will run in TCI Magazine *this year. The first part, "Berkeley's Polypore," ran in the March 2017 issue.*

By Christopher Luley, Ph.D, and Andrew Loyd

You may not recognize the name, just don't forget the face (Photograph 1). The name has changed, but the widespread occurrence east of the Rocky Mountains and damage caused by this pathogen remains the same. *Ganoderma sessile* (formerly one of many species labeled under the name '*Ganoderma lucidum'*) is a common root and butt decay pathogen in urban trees. It's one of the "Big Three" that we recommend arborists become familiar with because it has a wide host range, it is relatively easy to identify in the field and it can be important to a tree's biological health and mechanical stability (Photograph 2).

Photograph 1, left. The name of the widely known and important root and butt rot fungus* Ganoderma lucidum *has changed. The fungus is now named* Ganoderma sessile. *Fruiting on the base of this Norway maple developed in early September in New York. All images courtesy of the authors.

Photograph 2.* Ganoderma sessile *on a red oak. The fungus is relatively easy to identify in the field given the varnished red color of the top of an annual conk, absence of a stem, and growth on hardwood tree species. Fresh conks also usually have a white margin. Note the brown spores on the root below the fruiting.

Identification

Mycologists recently went back to the older name of *G. sessile,* which was described in 1902 from collections made in New York, for the fungus in North America that previously has been widely labeled under the name '*Ganoderma lucidum'. G. lucidum* is the correct name for a similar fungus found in Europe and probably parts of Asia. The genus *Ganoderma* contains species commonly referred to as "reishi" (Japanese) or "lingzhi" (Chinese) that are highly prized and have been used medicinally in Asia for centuries.

Arborists need to be aware that the similar-appearing "laccate" (those with a red to mahogany varnished-appearing top) *Ganoderma* species are not all one species. However, in most cases, the species fruiting from the base or roots of

Photograph 3. Developing conks of* G. sessile *from the same Norway maple as in Photograph 1. Note these conks lack the varnished red color when very young.

living hardwoods in urban environments in the Eastern U.S. is the widespread *Ganoderma sessile.* We highly recommend you see the Extension publication on this group of fungi by Loyd and others (http://edis.ifas.ufl.edu/pp333) for identification of similar-appearing *Ganoderma* species on other hosts such as palms and pines.

The common *G. sessile* on hardwoods has the following visual characteristics:

- Annual conk that is tough and leathery and lacking a stem or stipe (more rarely, some conks have short stem or stipe)
- Single or clusters of round to half-moon-shaped conks attached to woody roots or the base of deciduous trees (Photograph 2).
  - Similar conks fruiting from woody roots of oaks or other hardwoods with a stem are probably *G. curtsii* (see below).
- Individual conks are usually 4 to 10 inches across and 1 to 2 inches thick.
- The top of the conk has a thin crust that is red or mahogany to ocherous (varying from light yellow to brown) in color and varnished-appearing when fresh. Fresh conks may also have a white margin (Photograph 2).
- Developing conks are initially light colored and may lack the varnished red (Photograph 3).
- Interior of the conk is initially cream colored but becomes darker brown with age and has conspicuous concentric zones (Photograph 4).
- Pore surface is initially white, and darkens to brown with age and handling (Photograph 4). Pores are small and are barely visible to the naked eye.
- Brown basidiospores may be seen on the surface of the conk or on wood below conks as a "coat" of dust (Photographs 2 and 5).

Photograph 4. White pore surface, brown zonate interior and varnished top of* G. sessile*. The interior or context is lighter cream colored when the conk is young.

Photograph 5. Annual conks of* G. sessile *around a declining hickory. Note the dark, previous year's conks close to the soil line and the brown spores on the top of the conks on the far right.

Conks of *G. sessile* begin to develop in the warmer months of the year, which in southern latitudes could be as soon as early spring, while in northern latitudes it is more commonly observed fruiting in the latter portion of the summer. Although the fruiting bodies are annually produced, conks from previous years can often be found together with fresh conks on some trees (Photograph 5). The lacquered or varnished appearance fades greatly on old conks, but the dark red or mahogany color can often still be detected. Conks may appear in multiple, consecutive years with new fruiting mixed in with older, faded conks.

A very similar-appearing decay fungus named *Ganoderma curtsii* typically has an off-centered stem or stipe that generally distinguishes it from *G. sessile* (Photograph 6). *G. curtsii* has been associated with decay, decline and death of landscape oaks and other hardwood species, but will

Photograph 6.* Ganoderma curtsii *is a similar-appearing species that has a stem or stipe and is commonly found fruiting from the woody roots of oaks. Other species that appear similar to* G. sessile *may be found on palms, pines and dead hemlocks.

Photograph 7. Ganoderma sessile *fruiting at the base of a crabapple. The fungus has a very wide host range and is common on maples, oaks, beech, honeylocust, hickory and many other hardwoods.*

not be discussed further here.

Biology and importance

Infection by *G. sessile* probably occurs mostly by spores that infect wounds on the lower trunk or woody roots. The pathogen has a wide host range that includes many deciduous species including oaks, maples, beech, hickory, honeylocust, sweetgum, poplars and even crabapple (Photograph 7). Stressed trees appear to be more susceptible to infection and subsequent damage from *G. sessile*.

The fungus has the ability to both kill and decay woody roots and decay the wood in the base or butt of infected trees. It is not unusual to find urban maples, honeylocust and other tree species with *G. sessile* fruiting that are exhibiting decline symptoms, such as a thinning crown and crown dieback (Photographs 8A-C). However, in some cases, some tree species such as infected oaks may have normal crowns with varying amounts of decay and remain stable biologically and mechanically for longer periods of time (Photograph 9).

Decay from *G. sessile* develops in both the roots and base of infected trees, and therefore, consideration

Photograph 8A. A declining Norway maple infected with Ganoderma sessile. *Note dead branches at various locations in the crown (see Photograph 1 for fruiting at the base and on the roots of this tree).*

Photograph 8B. A pignut hickory infected with Ganoderma sessile. *Note the low-density crown and small dead branches (see Photograph 5 for fruiting at the base of the tree).*

Photograph 8C. A dying honeylocust infected with Ganoderma sessile. *Honeylocust is reported to sometimes die relatively rapidly when infected by the pathogen.*

Photograph 9. A swamp white oak with a large and healthy crown. The oak is infected with Ganoderma sessile. *Oaks may have few crown symptoms as decay develops in the base and roots.*

Photograph 10A. Ganoderma sessile *is a well-adapted saprophyte and can fruit for an extended period of time on stumps after infected trees are removed.*

needs to be given to tree stability and the extent of decay in both these parts of the tree even if conks are just present on the lower trunk. I have observed trees fail with *G. sessile*, but the appearance of fruiting bodies of this fungus does not necessarily mean that a tree should be removed.

Managing infected trees

In many cases, trees infected with *G. sessile* are removed because the trees are in poor condition and the decline in biological health creates other issues such as unattractive trees or elevated risk from dead or dying branches. Trees with advancing decline symptoms and infection by *G. sessile* will almost never recover, and the presence of *G. sessile* will only exacerbate decline symptoms, leading to hazardous trees. In these cases, expectations and management should be approached accordingly.

The risk of failure from roots or the trunk base from *G. sessile* decay must also be considered, but not all infected trees have to be removed immediately. In some cases, trees could have limited amounts of decay in the base and buttress roots even though *G. sessile* is observed fruiting near these locations. Decay assessments of the trunk base and exposed buttress roots should be performed at least by common decay testing methods such as sounding with a hard plastic mallet and/or probing when fruiting bodies of *G. sessile* and/or other decay fungi are observed fruiting in

Photograph 10B. **G. sessile** ***fruiting from a buried root after a tree was removed and young tree was planted.*** **G. sessile** ***can be transmitted by root contact, but there is no evidence young or vigorous trees are infected or damaged via root contact.***

these locations.

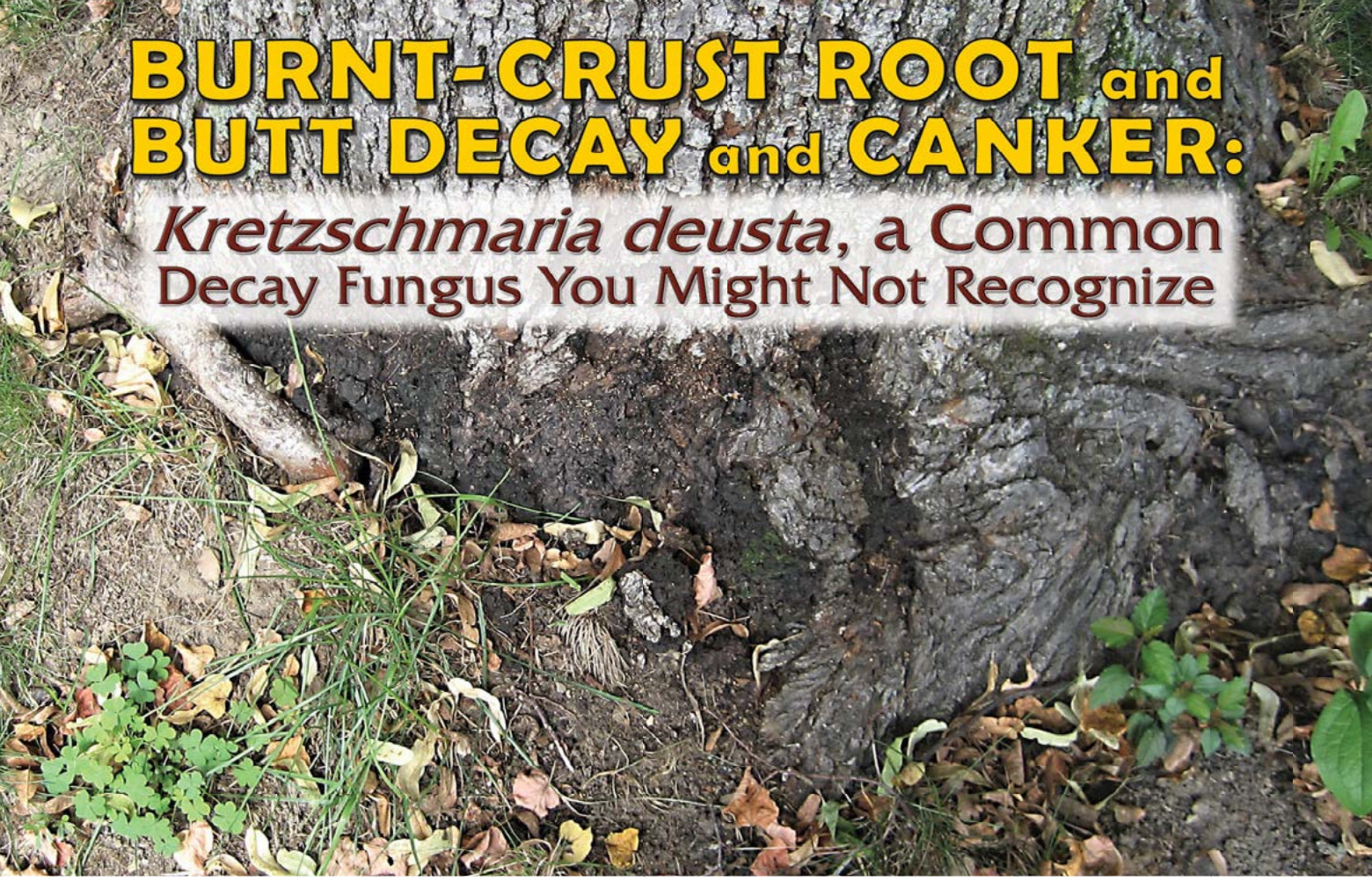
Advanced testing methods for root and decay in the base may be warranted in some cases for trees with long-standing infections, or with cavities, or concern about decay in roots, or where elevated risk is present because of high-occupancy or high-value targets. Decay testing of an infected root system is more difficult to perform and evaluate, and some trees will require soil excavation to adequately test for root decay.

G. sessile is a very good saprophyte (lives on dead or decaying wood), and can also be commonly observed fruiting on stumps or from buried roots of trees that were previously removed (Photograph 10A & 10B). Stump grinding, as well as grinding as many of the larger diameter roots as possible, is recommended to reduce or eliminate fruiting after tree removal. Spread of *G. sessile* by root contact is known, but it appears that infection of young vigorous trees via root contact is not a significant means of spread (Photograph 10B).

Christopher J. Luley, Ph.D., is president and pathologist at Urban Forest Diagnostics LLC in Naples, New York, author of the manual Wood Decay Fungi of Living Urban Trees*, and developer of TreeRot.com, a website dedicated to decay fungi of urban trees.*

Andrew Loyd received his master's degree from North Carolina State University. His M.S. research focused on the aquatic niche Phytophthora species in North Carolina watersheds, and the potential risks involved with using source water that is infested with Phytophthora to irrigate ornamental nursery plants. Loyd is employed by the F.A. Bartlett Tree Experts Company and is pursuing his Ph.D. in the Forest Pathology Lab at the University of Florida. His research is working on the clarification of Ganoderma species diversity and function in the Southeastern U.S.

BURNT-CRUST ROOT and BUTT DECAY and CANKER: *Kretzschmaria deusta*, a Common Decay Fungus You Might Not Recognize



Photograph 1. **Kretzschmaria deusta** ***fruiting on a littleleaf linden. Arborists may not know that this fungus is an important wood decay and canker pathogen or may overlook its presence because of its low profile. Unless otherwise noted, all images courtesy of the author.***

By Christopher Luley, Ph.D.

Kretzschmaria deusta is not exactly a household name. But it is the scientific name of one of the most common and important root and butt decay pathogens in urban trees. The so-called burnt-crust fungus may not be recognized by arborists because it is not a conk, mushroom or bracket like most other decay fungi (Photograph 1). It also is easily overlooked because of its variable appearance and reduced size (Photograph 2).

The fungus, which has a wide host range, can aggressively attack weakened trees. It also can kill living tissues in the bark and sapwood in trunks and roots, and

Photograph 2. A sugar maple infected with **Kretzschmaria deusta**. ***Note the black crusty material in the butt and roots in the center of the image (yellow arrow) and the multiple rolls of wound wood that have been killed by the fungus (green arrow).***

Decay Fungi Series

This is the third article in a series from Christopher J. Luley on decay fungi species found in urban trees that will run in *TCI Magazine* this year. The first part, "Berkeley's Polypore," ran in March. Part 2, "*Ganoderma sessile* (aka *Ganoderma lucidum*) – An Important Root Disease and Butt Decay by Any Name," ran in April.

then decay the wood. Trees infected with *K. deusta* may eventually fail as the decay weakens roots and the wood in the base of the tree (Photograph 3).

In the spirit of changing names, this fungus is a leader, going previously by *Hypoxylon deustum*, *Ustulina deusta* and *U. vulgaris*, among others! It belongs to the large group of fungi in the ascomycete group – or those fungi that fruit as small cup- or flask-shaped structures, and that usually require a microscope to properly identify. *K. deusta* gets its common name "burnt crust" for the black, tar-like material (technically named stroma, the fungal tissue that contain the sexual reproductive structures of the fungus) that develops on infected trees (Photograph 4).

Photograph 4. Stroma or fungal material of the pathogen on a hickory (despite the oak leaf in the image). The sexual spore stage is imbedded in this material, which is dry and crumbly when it is removed from the tree.

Identif cation

Field identification of *K. deusta* has to be considered tentative because confirmation requires a microscope to observe fruiting structures and spores. However, the fungus commonly is found fruiting on the butt or roots, on the margins or face of dead wood in living trees, or sometimes on bark of infected tissues. The fungus is widely distributed in North America.

Two spore stages of the fungus are produced, and this can confuse identification. The "imperfect" or asexual spore stage is often seen in the spring when the stroma is initially developing. This stage forms a white to gray layer on top of the developing black stromatic tissue (Photograph 5). The thickness of the black, crusty fungal tissue associated with the perfect stage increases during the growing season (Photograph 4). The black crust persists and can be found at most times of the year, while the lighter-colored imperfect stage is seldom seen later in the season. The black stroma degrades during the dormant season, but even during the growing season it also easily crumbles into pieces when you try to remove it from infected tissues.

Photograph 3.* Kretzschmaria deusta*-infected tree that failed. It is the same tree depicted in Photograph 2. The tree was also infected with* Armillaria sp. *that also likely contributed to the failure.

Biology and importance

K. deusta is like most decay fungi and infects wounds via spores released from fruiting structures, although there is also evidence that root-to-root spread can occur. The fungus is somewhat unique in that it can kill living sapwood in the base of the tree and roots, and can cause cankers by killing the bark and cambium (Photograph 6, next page).

K. deusta is most aggressive on weakened trees, but trees with seemingly healthy crowns also can be attacked. The decay can progress relatively rapidly on trees weakened by other factors. In the Northeast, it is often seen infecting tissues killed by bleeding canker infections on European beech. Crown symptoms usually only develop on trees that have most of their roots or trunks infected. Arborists should be aware that some trees may be extensively decayed and show very few crown symptoms.

K. deusta has a wide host range but is most common on sugar and other maples, European linden, European beech, hicko-

Photograph 5. The white to gray imperfect or asexual stage of* Kretzschmaria deusta *on a European beech. Note that the tree is also showing symptoms of Phytophthora bleeding canker.

Photograph 6. **Kretzschmaria deusta** ***is also a canker pathogen in that it can kill bark and cambium in addition to decaying wood. Note discolored sapwood beneath after the fruiting and bark was removed. See Photograph 1 for the appearance of the bark before it was removed.***

ry, hackberry, sycamore and elm. It is less common on oaks, but this is a reported host in the literature. Hackberry infected with the fungus should almost always be removed as soon as possible, as this tree species has shown little resistance to rapid killing and decay of roots, particularly in southern states.

The decay caused by *K. deusta* is somewhat unique in that the fungus creates holes in cell walls by degrading cellulose. This degradation reduces the tensile strength of wood and leaves the wood brittle. Seriously infected trees often snap off at roots or near ground level without the formation of significant hollows (Pho-

Photograph 7. A European beech that snapped off at ground level due to at least partial infection by **Kretzschmaria deusta** ***Photograph by Trevor Hall, Bartlett Tree Experts.***

Photograph 8. A sugar maple cross section infected with Kretzschmaria deusta. *Note the black "zone lines" (yellow arrow) or fungal material in the decayed wood and the absence of hollows forming in the decayed area. The tree also had carpenter ants nesting in the decayed wood.*

tograph 7). Bulges or other symptoms of adaptive growth are also usually absent in infected trees. Decayed wood when cut usually has a large number of "zone lines," or distinct black lines of fungal material that zigzag throughout the decayed wood (Photograph 8).

Managing infected trees

Arborists need to take note and assess *K. deusta*-infected trees carefully for a number of reasons, including:

- Sounding with a mallet is seldom very useful to quantify decay because hollows are usually not formed in decaying wood. Sounding may detect areas where bark is loose from infection.
- Trees may have advanced decay but may not exhibit crown symptoms (Photograph 9).
- Advanced decay-detecting tools such as tomography and resistance drilling are not likely to fully identify decayed wood in the early stages of development.
- Interpretation of resistance-drilling charts in trees infected with *K. deusta* can be very challenging because of the way soft rot develops in wood.
- Trees weakened by urban stress can be decayed relatively rapidly by the fungus.

Care should be taken in removing trees with K. deusta, *because infected hinge wood may not hold as desired.*

Crown reduction should be approached with care because reducing crown area and associated energy-production capacity may reduce the ability of the tree to resist decay spread.

Care should be taken in removing trees with *K. deusta,* because infected hinge wood may not hold as desired (Photograph 10).

There are no fungicides registered for management of *K. deusta*. My attempts to slow spread with phosphoric acid-containing fungicides on European beech-

Photograph 9. A purple leaf European beech infected with Kretzschmaria deusta *that is showing no crown symptoms despite an advancing infection, as depicted in Photograph 5.*

Photograph 10. Hinge wood on this large sugar maple did not hold as desired, because the wood had been decayed by Kretzschmaria deusta. *Photograph provided by Nathan Wright, National Grid.*

es infected with Phytophthora bleeding canker have not produced an observable reduction in subsequent disease spread.

Christopher J. Luley is president and pathologist at Urban Forest Diagnostics LLC in Naples, New York, author of the manual Wood Decay Fungi of Living Urban Trees, *and developer of TreeRot.com, a website dedicated to decay fungi of urban trees.*

Wood Decay and the Cleanup Crew

By Kevin T. Smith, Ph.D, and Jessie A. Glaeser, Ph.D.

Arborists are encouraged to recognize the wood-decay process as an important factor in tree health and public safety. Technical experts who develop training materials to recognize wood-decay processes in living trees are frequently forest pathologists. Much of the history of forest pathology was to support production of sound, high-quality timber. That heritage is passed on in terms used by arborists today that are derived from timber production, such as "defect" and "degrade." These terms are used for genuinely adverse conditions such as cracks and seams. Unfortunately, the terms are also sometimes applied to positive features that contribute to tree recovery and stability, such as response growth and woundwood formation.

Mushrooms and other fungal fruiting bodies are signs of infection. However, such infections are not necessarily the enemy of healthy and safe landscapes.

Wood decay in nature

Trees and fungi developed together and have coexisted for a long time. For forest ecosystems, wood produced as part of tree growth is a primary storage material for carbon and biological energy. Fungi break down wood structure to release the stored carbon and energy to build their own structures and to fuel their biology. Many other organisms, from bacteria to bears, take good advantage of the wood-decay process and use this flow of carbon and energy to provide for their own nutrition and habitat. Wood-decay fungi and other organisms large and small transform the breakdown products into soil organic matter, which supports the growth of the next generation of trees.

The primary components of wood, such as cellulose and lignin, are polymers (chains) of sugar and amino acid derivatives, respectively. Although the simple components are readily digested by many microorganisms, the polymers resist breakdown by most fungi. Of those fungi that decay wood, most of them participate in only a portion of the pathway that runs from being alive and healthy to being punky but recognizable as wood, through to soil humus. In a tricky piece of chemical engineering, some decay fungi have developed chemical systems that unravel and open up the polymer structure without enzymes. Once the structure is opened, digestive enzymes are able to enter and do their work.

Figure 1: The common bricktop mushroom (Hypholoma lateritium) on a stump. Bricktop mushrooms can be readily distinguished from the shoestring fungus by gill color, which is purple-gray in the former and orange to cinnamon in the latter. All images by K.T. Smith and K.R. Dudzik, USDA Forest Service.

The problem with indicators

Arborists need to be aware that the mere presence of decayed wood or a cavity does not mean that a tree is likely to die in the foreseeable future or to structurally fail. Other indicators such as included bark, cracking or lifting of the root plate, prolonged flooding, or construction injury (Mattheck 2015) are frequently more associated with tree mortality or structural failure. The presence of an active decay fungus does not necessarily mean the tree is severely compromised but does present an opportunity to refine the assessment of tree condition.

Textbooks classify decay fungi as "pathogens" that cause disease and "saprobes" or "saprotrophs" that break down organic matter. In the history of plant pathology, even well into the 20th century, some experts questioned whether wood decay in living trees, particularly decay of heartwood that lacked living cells, could be considered as disease. Conversely, opportunistic fungi that colonized already killed sapwood but did not spread beyond the initial compartmentalization boundaries were considered as pathogens. Of

Decay Fungi Series

This is the fourth article in a series on decay fungi species found in urban trees that will run in *TCI Magazine* this year. The first three parts, all from Christopher J. Luley, included:

March: Part 1: "Berkeley's Polypore"

April: Part 2: "*Ganoderma sessile* (aka *Ganoderma lucidum*) – An Important Root Disease and Butt Decay by Any Name"

May: Part 3: "Burnt-Crust Root and Butt Decay and Canker: *Kretzschmaria deusta*, a Common Decay Fungus You Might Not Recognize"

course, the fungi didn't bother to read the arguments, they simply pursued their survival strategies.

The wood-decay fungi are not always so easy to classify as being pathogens or saprobes. Determining the species can also be difficult, even with good samples of fruiting bodies: mushrooms, conks, brackets or crusts. Reliable identification from photographs is even more difficult in that a single image or two will likely not contain all of the macroscopic characters indicative of a given genus or species, especially when the fruiting body is very young or past its prime. Differences that are striking and obvious to the professional mycologist or the dedicated enthusiast with a microscope may be subtle and missed by the arborist.

Also, key field characteristics such as texture or smell (and even taste!) are not conveyed in a photograph. Still, some species or groups are distinctive enough to be identified by photos supplemented with a little additional information on habitat and non-visual features. That's part of the basis for photo guides that are useful to identify the top handful of decay fungi that most frequently threaten or coexist with urban and community trees (e.g., Luley 2005 and 2017; Glaeser and Smith 2010). Indeed, there are a few decay fungi that should be learned by arborists. Chris Luley's guide (2005) lists several fungal genera, the presence of which should cause concern and likely action, including *Ganoderma, Armillaria* and *Ustulina* (the last referred to as *Kretzschmaria* by some specialists). These are comparatively few and may vary by region.

Dr. Alex Shigo used the term "cleanup crew" to refer to saprobic fungi in living trees that decay wood killed by physical injury, flooding or some other damaging event. As the wood-decay fungi that are not usually associated with serious disease or tree risk greatly outnumber those that heighten risk of structural failure, this article is presenting just a few examples that are especially common in the northeastern and northern midwest of the U.S. and that also occur in other parts of the country. More important than the precise species of fungi in the cleanup crew is to realize that they are active and out in the landscape and commonly encountered by arborists, landowners and managers.

Figure 2: Dead man's fingers (*Xylaria polymorpha*) on buttress root.* Xylaria polymorpha *is a weakly pathogenic fungus that produces clumps of fungal tissues or stroma at the base of a dead face of a living tree or from shallow-buried woody roots. Infection by this fungus should not be an immediate call for removal but should prompt additional attention and efforts to reduce stress.

Stump cleanup

Stumps provide a special habitat that does not occur in the natural forest, but which is readily exploited by some decay fungi, including the potentially serious *Ganoderma, Armillaria* and *Heterobasidion* pathogens. The remaining root system provides intimate contact with damp soil, and the cut surface provides a large surface area. Consequently, the colonized stump provides a range of environmental characteristics of aeration and moisture as well as access to infection from the soil surface.

Saprobic and potentially beneficial fungi also colonize and decay stumps as part of the cleanup crew. The common bricktop mushroom (*Hypholoma lateritium*) and velvet foot or winter mushroom (*Flammulina velutipes*) are superficially similar to the pathogenic shoestring mushroom (several species of *Armillaria*) in that they all occur in clumps on decaying stumps or woody roots of living trees. All three are the classic mushroom shape with gills attached or running slightly down the central stipe or stem. However, the bricktop mushrooms can be readily distinguished from the shoestring fungus by gill color, which is purple-gray in the former and orange to cinnamon in the latter. The spore color of the bricktop is purple-brown, while off-white to cream in the shoestring fungus. Spore color of the velvet foot is also whitish, but the lower portion of the stipe is dark and velvety, unlike that of the shoestring mushroom. Of course, presence of the black "shoestring" foraging structures also indicate the shoestring fungus. The bricktop may have an additional role in moving essential fertilizer elements from the mineral soil into the tree rooting zone.

Natural pruning of branches

As a tree crown increases in size, interior and lower branches become shaded and are no longer useful to the tree. The crowns of neighboring trees meet and compete for sunlight, and the shaded branches die and may become a liability to the tree.

Some major forest pathogens that are infrequent in the urban environment do enter mature stems through branch stubs such as the paint fungus (*Echinodontium tinctorum*) and red-ring rot fungus (*Porodaedalia pini*). Others infect dead, attached branches without much spread in the living portions of the tree and are part of the clean-up crew.

Branch shedding is a necessary part of tree development as forest stands close and become shaded. Even open-grown trees shed branches of all sizes following storm injury, heavy defoliation from insects and fungi, and root damage from human construction and other activity.

Attached, decaying branches provide unique habitat for a variety of plants, animals and organisms and are actively conserved by some landowners and managers, more often in Europe than in the U.S. The decline in vigor, death and decay of branches proceeds at different rates depending on species and the environment. After the branch breaks away at or near the branch collar, the tree has the potential to close over the wound and restore continuity of the vascular cambium, the tissue beneath the bark that produces cells that mature into wood and inner bark.

Most often found on dead, attached branches, the milky tooth (*Irpex lacteus*) facilitates the physical breakage of branches or stem tops killed from storm injury or some other cause. Decay and breakage of the branch facilitates closure and restoration of the vascular cambium at the position of the shed branch.

When the milky-tooth is found on wood in ground contact, it is usually due to breakage after colonization and establishment in the tree crown. This fungus is an indicator that the supporting branch is dead, but is likely not the cause of branch death.

Figure 3: Milky tooth (*Irpex lacteus*) on a shed branch. Most often found on dead, attached branches, the* Irpex lacteus *facilitates the physical breakage of branches or stem tops killed from storm injury or some other cause. Decay and breakage of the branch facilitates closure and restoration of the vascular cambium at the position of the shed branch.

*Figure 4: Black jelly drops (*Bulgaria inquinans*) on downed wood. The cup fungi have many members of the cleanup crew that, although common, are not noticed until they are seen in large numbers such as with the black jelly drop.*

Downed wood and root cleanup

The cup fungi have many members of the cleanup crew that, although common, are not noticed until they are seen in large numbers such as with the black jelly drop (*Bulgaria inquinans*). Perhaps due to the odd shape and firm yet jelly-like consistency, homeowners sometimes find these alarming. Present on dead portions of standing trees or within a few years of ground contact, *Bulgaria* usually appears and disappears within a single growing season.

Dead-mans fingers (*Xylaria polymorpha*) is a weakly pathogenic fungus that produces clumps of fungal tissues or stroma at the base of a dead face of a living tree or from shallow-buried woody roots. (Figure 2, page 57) Trees with reduced ability to compartmentalize due to, say, low energy reserves from defoliation are especially vulnerable to the spread of this fungus. Infection by this fungus should not be an immediate call for removal but should prompt additional attention and efforts to reduce stress.

The challenge for decision-making

The challenge for the arborist is that, with increased awareness of the role of wood-decay fungi in structural failure, the guidelines for practice will overreach prudence and the practitioner will overreact and condemn a tree with any amount of decay or presence of fruiting bodies, slating it for removal. We have learned from experts in engineering that even large volumes of decaying wood or even open cavities do not necessarily confer a great degree of risk. The extent of wood decay is important, but not the only important factor to assess tree condition. The challenge for the practitioner is to accurately assess not how much wood has been lost to decay, but to assess 1) the quality and quantity of the wood that remains and 2) the strength of the response growth of the tree to compensate for injury, infection and decay.

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The authors thank Chris Luley, Ph.D., for his constructive comments, which improved the quality of this article.

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This article was based in part on Smith's presentation, "Compartmentalization Concepts & Consequences," at TCI EXPO 2016 in Baltimore, Maryland. To listen to an audio recording of that entire presentation, go to this article in the digital version of this issue online, at www.tcia.org under the Publications tab, and click here.

Figure 5: Winter mushroom on stump. Velvet foot or winter mushroom (*Flammulina velutipes*) is superficially similar to the pathogenic shoestring mushroom (several species of* Armillaria*) in that they both occur in clumps on decaying stumps or woody roots of living trees. Both are the classic mushroom shape with gills attached or running slightly down the central stipe or stem.

Root Rot Part 5:
Don't mess with *Inonotus dryadeus*

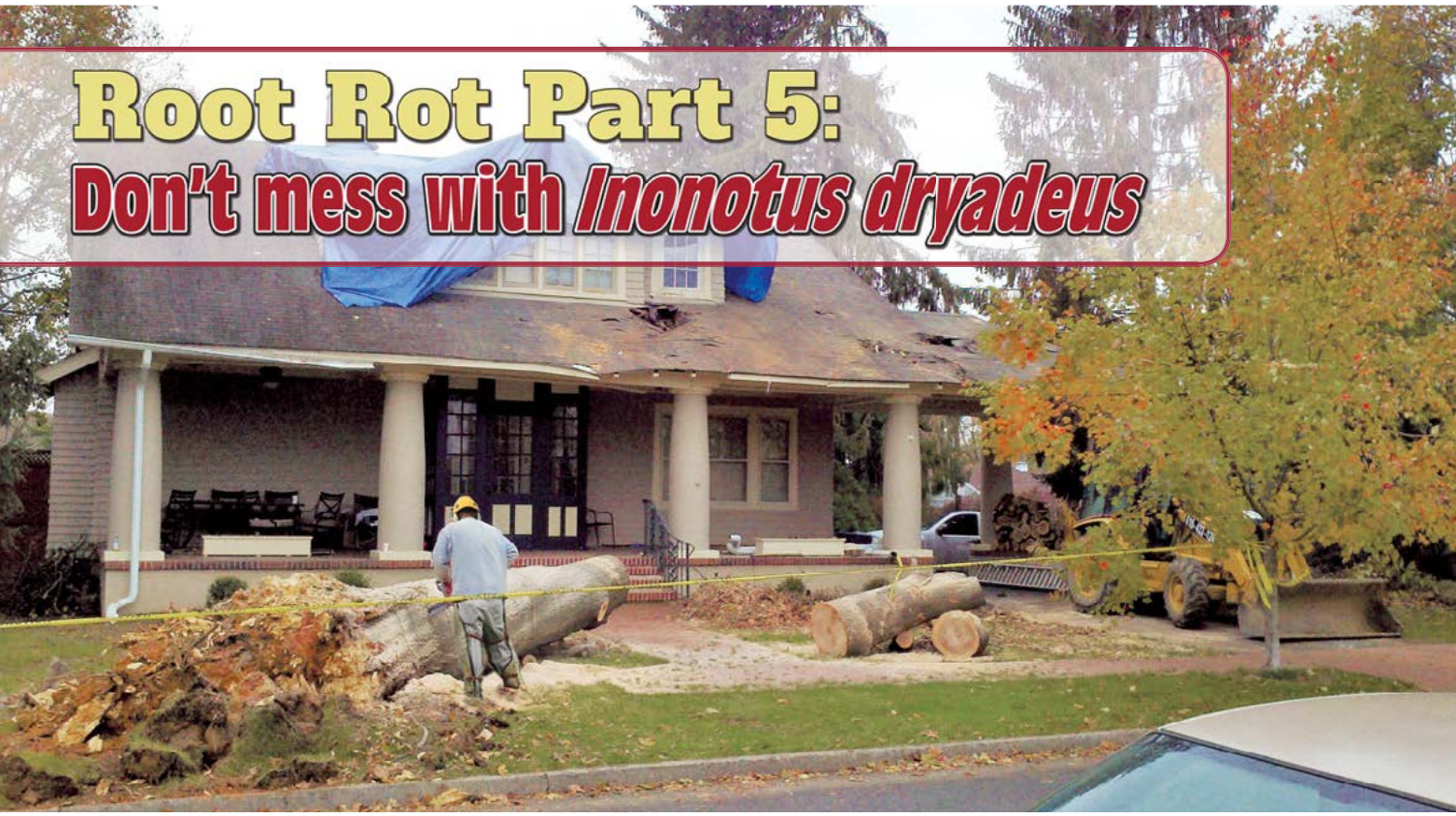

Photo 2. **Inonotus dryadeus** ***decays the structural roots, which can lead to failure of the entire tree. The decay is primarily in the roots and seldom progresses much above the soil line. Photo by Russ Carlson.***

By Christopher Luley, Ph.D.

The warted polypore (aka weeping conk or weeping polypore) *Inonotus dryadeus* is one of the more insidious and difficult to manage root-decay pathogens of urban trees.

The fungus is common on oaks (less common on other hardwoods) throughout the United States (Photo 1) and is reported on conifers in the Northwest. It is particularly common on oaks in southern states east of the Rocky Mountains. The fungus acts primarily as a structural root decay leading to windthrow or failure of the entire tree at the soil line or from decayed buttress roots (Photo 2). Arborists dealing with the fungus need to be aware that in-

Photo 1. **Inonotus dryadeus** ***fruiting on the roots of an oak, the most common host of the decay fungus. Unless otherwise noted, photos courtesy of the author.***

Decay Fungi Series

This is the fifh article in a series on decay fungi species found in urban trees that will run in *TCI Magazine* this year. Previous articles, all from Christopher J. Luley, unless otherwise noted, included:

March, Part 1: "Berkeley's Polypore"

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June, Part 4: "Wood Decay and the Cleanup Crew," by Kevin T. Smith, Ph.D., and Jessie A. Glaeser, Ph.D.

Photo 3. The top of Inonotus dryadeus *is light cream- to yellow-colored when fresh. Amber-colored drops of liquid may form on the top of fresh conks, helping in field identification. The drops eventually dry and may leave depressed areas on the surface, hence the name warted polypore.*

fected trees may have relatively healthy-appearing crowns, thus cloaking the amount of decay in the root system.

Identification

Inonotus dryadeus is relatively easy to identify in the field when conks are young because it often produces fresh drops of amber to clear liquid on the top of the conk (Photo 3). As the drops dry, they sometimes leave a depressed area, hence the name warted conk or polypore.

Photo 6. The pore surface or underside of the conk is light colored when young and pores are small, so they are difficult to see with the naked eye.

Photo 4. Inonotus dryadeus *conks may be large and often irregular shaped, but always form on larger roots at or near the soil line.*

Photo 5. Conks are cream or yellow colored when young and darken brown with age. The very dark conk on the top of the group is from previous years' fruiting. Inset - 5A. The interior of the conk is yellow-brown when young and becomes darker brown with age. Note the lighter-colored pore surface (underside of conk) and weeping.

The fungus can produce large (sometimes 10 to 15 or more inches in diameter), irregular-shaped, annual conks that form on larger-diameter roots or right at the soil level on the main trunk (Photos 1 and 4). The conks may join together, forming larger masses of conks on the soil surface or on roots near the base of the tree. Smaller, individual conks may also develop on some trees (Photos 4 and 8).

The top of the conk is a cream to yellow color that is velvety textured when fresh but then roughens and darkens to gray or brown with age (Photo 5). The interior of the fruiting is 2 to 4 inches thick and is yellow-brown to reddish-brown and then brown depending on its age (Photo 5A, inset). The pore surface is light colored or cream or yellow when fresh, and also darkens brown with age (Photo 6).

New conks typically develop in later summer into the fall and usually persist into the following year where they may often be seen intermixed with fresh conks (Photo 5). Older conks are rough textured and black to brown in color throughout.

Biology and importance

Decay from *I. dryadeus* typically begins in the root system and moves toward the trunk where it seldom progresses much above the soil line into the trunk (Photos 1 and 2). The roots are structurally weakened by the decay, but the pathogen also can kill areas of bark and cambium. Decay is of the white-rot type.

Photo 7. Trees with a large number of conks around the base usually have extensive decay and are removal candidates. This is the same tree as in Photo 2 that later failed. The dark-colored conks are from previous years' fruiting. Photo by Russ Carlson.

Spread of the fungus from tree to tree appears to be primarily by spores, and there is no evidence that root-to-root contact is an important means of infection. Diseased trees often occur singly, further supporting an absence of root-to-root or soil mode of spread. The fungus may remain as a saprophyte in roots and at the base of stumps, where it continues to fruit and release spores after the tree has been removed.

Managing infected trees

Managing *I. dryadeus*-infected trees can be tricky. Trees with a large number of conks are very likely to have extensive decay and require removal (Photo 7). However, decay can be spread out in the root system when there are only a few conks or on trees that have no fruiting (Photos 8 and 8A). Trees with a few conks or conks on more than one side of a tree should be considered for advanced decay testing. This testing may require root-crown excavation to expose roots and testing roots for decay with advanced decay-testing tools. Decay progresses from the underside of the root, so visual inspection of roots alone is usually not adequate (Photo 9).

As trees become over-mature or the condition of the crown deteriorates, the likelihood of impact from *I. dryadeus* is greater. Known infected trees with poor-condition crowns are likely candidates for removal. The crowns of some infected trees may show decline symptoms as the fungus progressively attacks the roots. However, relying on crown condition alone when assessing an *I. dryadeus* infection is unwise as some trees with extensive root decay may still have full crowns that mask the degree of infection of large-diameter

Photo 8. A willow oak with a single, fresh conk at its base. Trees with fewer conks can still have extensive decay in the root system. See the apparently healthy-looking crown of this same tree in Photo 8A.

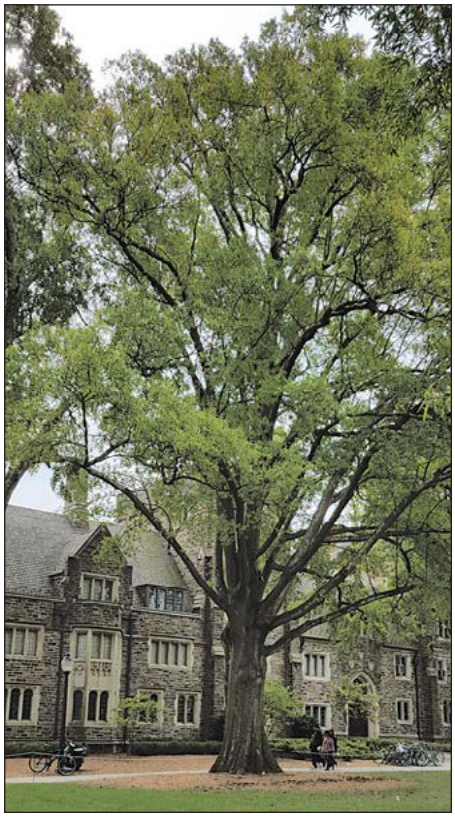

Photo 8A. Trees with one or a few conks should be considered for advanced testing of roots for decay. The crown of the tree cannot be relied upon as an indicator of decay extent in root systems (same tree as in Photo 8).

roots.

Further, sounding the trunk with a mallet or testing the butt of infected trees is unlikely to help determine the amount of decay because decay reaches the trunk only in later stages of disease develop-

Photo 9. Old conks on a southern red oak; see Photo 10 for image of healthy-appearing crown. In most cases, visual inspection of roots is not useful in determining the presence or extent of decay because decay progresses from the bottom of the root up. Advanced-decay tools and soil excavation may be needed to determine the extent of decay in the root system.

ment and seldom progresses much above the soil line. Therefore, arborists should use caution when assessing trees with *I. dryadeus* by alerting clients that careful consideration of management options, including using advanced assessment techniques, is warranted.

Christopher J. Luley is president and pathologist at Urban Forest Diagnostics LLC in Naples, New York, author of the manual Wood Decay Fungi of Living Urban Trees*, and developer of TreeRot.com, a website dedicated to decay fungi of urban trees.*

Kevin T. Smith, Ph.D., supervisory plant physiologist with the USDA Forest Service, Northern Research Station (NRS), in Durham, New Hampshire, provided technical editing for this article.

Photo 10. A southern red oak infected with* Inonotus dryadeus. *Crown condition may not predict the extent of decay in the root system.

Armillaria Tabescens:

Mushroom Root Rot Caused by the Ringless Armillaria

Photo 1: Most arborists have heard of Armillaria mellea, *or the honey mushroom, that is the cause of shoestring root rot, shown.* A. mellea *and closely related species have a central stem with a ring around the stem (arrow).* A. mellea *and allies often form rhizomorphs (see inset) that are seldom seen with* A. tabescens*-infected trees. All images courtesy of the author.*

Decay Fungi Series

This is the sixth article in a series on decay fungi species found in urban trees that will run in *TCI Magazine* this year. Previous articles, all from Christopher J. Luley, unless otherwise noted, included:

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June, Part 4: "Wood Decay and the Cleanup Crew," by Kevin T. Smith, Ph.D., and Jessie A. Glaeser, Ph.D.

July, Part 5: "Don't Mess with *Inonotus dryadeus*"

By Christopher Luley, Ph.D.

Most arborists have heard of Armillaria root rot (caused by *Armillaria mellea,* Photo 1, and other closely related species) or know its other common names, such as shoestring root rot or oak root rot. Many, many articles have been written about Armillaria root rot! But mushroom root rot caused by *Armillaria tabescens* is less well known even though it is an important and common cause of root disease in landscape trees. The disease was formerly known as Clitocybe root rot, reflecting an older taxonomic name of the fungus. Root disease caused by the fungus *A. tabescens* is different enough in appearance and impact that arborists should be aware of the difference and

Photo 2: A declining silver maple infected with Armillaria tabescens. *Silver maple and oaks are common landscape hosts of the fungus, but many other tree species may be attacked.*

Photo 3: Light-brown groups of mushrooms that form tight clusters are typical of A. tabescens.

Photo 5: Armillaria species all have white or cream-colored spore prints. Note the white spore print that was produced where two A. tabescens *caps overlapped. Photo 5i, inset: White spore print of* A. tabescens *that was produced by placing a mushroom cap on a colored piece of paper.*

importance of the "ringless" Armillaria.

Mushroom root rot is mostly found east of the Rockies, and is most important in more southern states, although it definitely affects landscape trees in the northern states such as New York and Michigan. It is widely distributed and important in Florida. It has an exceedingly wide host range, and is most common on deciduous trees and shrubs, but it also affects pines in southern states. Silver maple and oaks are very common landscape hosts (Photo 2), and the fungus is an important pathogen of fruit trees. The fungus has been reported in more than 210 plant species in 137 different genera.

Identification

Fortunately, *A. tabescens* is one of the easiest *Armillaria* species to identify in the field. The fungus has all the common features but *lacks* a ring around the stem, hence the common name of the fungus of "ringless Armillaria." Identifying features include:

- Light-brown to honey-colored to yellowish caps on gilled mushrooms (Photo 3) in cespitose clusters (groups of mushrooms with their stems closely packed together but not attached or fused at the base, Photo 4).
- Individual mushroom caps 2 to 3.5 inches across and with a *central stem* and light-colored gills.
- Light-brown to cream-colored gills that produce a white spore print (to make a spore print, remove several mushroom caps and place on colored paper until spores drop – usually 1-2 days. Putting a cover over the cap helps the process, Photo 5i). Spore print color may also appear on overlapping caps (Photo 5).
- Mushrooms appearing in autumn in lawns or at the base around landscape trees, often at a distance from the main trunk but always attached to roots (Photo 6-8). In the southernmost states, fruiting may occur at other times of year depending on rainfall amounts.

Photo 4: Cespitose cluster (tight clusters of mushrooms that are not fused at the base) of A. tabescens *mushrooms. Note the absence of a ring around the stem, hence the common name of the fungus of "ringless Armillaria."*

Photo 6: A cluster of A. tabescens *mushrooms attached directly to the roots at the base of a Norway maple.*

• Mycelial fans (Photo 9) may form on infected roots or at the root collar, but rhizomorphs (Photo 1i) common with other *Armillaria* species are very rare.

Clusters of *A. tabescens* mushrooms form quickly after summer rains and often degrade relatively quickly during high autumn temperatures. The lack of the ring around the stem is one easy-to-see feature that distinguishes it from *A. mellea* and related *Armillaria* species. The jack-o-lantern fungus is similar appearing but has orange caps and often has a lateral (not attached in the center of the mushroom cap) stem.

Photo 7: A degraded cluster of* A. tabescens *that had developed close to the trunk of a silver maple in August in New York.

Biology and importance

Mushroom root rot is somewhat different than most root-decay fungi in the way it attacks trees. Like most root pathogens, weakened or stressed plants are more likely to be damaged. However, *A. tabescens* more aggressively kills woody roots than other decay fungi. It progressively works toward the main trunk until it reaches the root collar, where it can kill bark and cambium at the soil line. As roots are attacked, affected trees decline in biological health. The symptoms are typical of decline diseases, including slow growth, off-color leaves, small leaf size, sparsely foliated crowns, defoliation and small-branch death. Larger branches die as the disease progresses.

In some cases, affected trees may die altogether in a short period of time, or larger trees may wilt as they are progressively attacked. On pines and other conifers, foliage often yellows, and individual branches may die before the rest of the tree declines in health.

If the fungus reaches the main trunk, cankers or depressed dead areas may form on the lower trunk and larger-diameter roots. Mycelial fans also can develop in

Photo 8: Clusters of* A. tabescens *at a distance from the trunk of a declining silver maple in August in New York. The mushrooms are attached to roots and can develop at some distance from the tree.

Photo 9: Mycelial fans of Armillaria that develop under the bark as the fungus kills the bark and cambium. Mycelial fans are diagnostic for Armillaria if they are found beneath the bark on recently killed tissues.

affected sapwood and can only be seen if bark is removed. Decay in woody roots is of the white-rot type and follows killing of the bark and cambium of roots.

Root decay, where woody roots are rotted by the fungus, also occurs, and root failure is a possibility on mushroom root-rot-affected trees. Most trees are likely removed because of the deterioration in health before they fail from the root-decay attack.

Spread of *A. tabescens* can occur via root contact and likely by spores released from mushrooms. Roots do not require wounding for infection to occur. Spread via rhizomorphs in the soil, as occurs with *A. mellea,* is not important for *A. tabescens*.

Managing infected trees

Declining trees with mushroom root rot are probably difficult to save. Some phosphoric acid-containing fungicides have Armillaria on the label, but efficacy is unknown. Exposing partially infected roots to air to let them dry is reported as effective in arresting localized infections, but practical application in the landscape would be difficult. Tree stability is apparently less of an issue with *A. tabescens*, but trees with fruiting bodies should always be evaluated for potential impacts if a root failure could occur.

An important consideration is the planting of new trees in or near the location where *A. tabescens*-infected trees have been removed as attack of recently planted replacement trees has been reported. Grinding out and removing stumps and large diameter roots is a good idea where *A. tabescens* was present and other landscape plants are growing or may be installed.

Christopher J. Luley is president and pathologist at Urban Forest Diagnostics LLC in Naples, New York, author of the manual "Wood Decay Fungi of Living Urban Trees," and developer of TreeRot.com, a website dedicated to decay fungi of urban trees.

Kevin T. Smith, Ph.D., supervisory plant physiologist with the USDA Forest Service, Northern Research Station (NRS), in Durham, New Hampshire, provided technical editing for this article.

Grifola (Polyporus) frondosa - Should I Worry About the "Hen of the Woods"?

Photo 1: Grifola frondosa *fruiting around the base of a mature white oak. The fungus is a well-known edible with anti-cancer and other medicinal properties. All photos courtesy of the author.*

Decay Fungi Series

This is the seventh article in a series on decay fungi species found in urban trees that will run in *TCI Magazine* this year. Previous articles, all from Christopher J. Luley, unless otherwise noted, included:

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July, Part 5: "Don't Mess with *Inonotus dryadeus*"

October, Part 6: "*Armillaria tabescens*: Mushroom Root Rot Caused by the Ringless Armillaria."

By Christopher Luley, Ph.D.

Arborists with a mycological bent often know *Grifola frondosa* because it is common around oaks in the late summer and fall, is good to eat and has a well-known anti-cancer medical profile. It is often referred to under the name "Maitake." The fungus is found mostly east of the Rocky Mountains, getting its common name of "hen of the woods" from the clustered appearance of the fronds that may resemble the back end of a hen chicken. But should arborists worry about *G. frondosa* fruiting near or on a client's oak year after year (Photo 1)?

Photo 2: Grifola frondosa *may fruit at a distance from the trunk but is attached to woody roots.*

Identification

G. frondosa is relatively easy to identify in the field. It is an annual fungus that develops in autumn in the Northeast. It fruits attached to the base of mature oaks, maples and other hardwoods, but can also be found attached to woody roots at a dis-

Photo 2A: Supersonic-air-tool excavation of the soil around a Grifola frondosa *fruiting body (covered in soil here from the excavation). Although it was growing at a distance from the trunk, the excavation showed it was attached to a woody root via a column of fungal growth, shown in the picture.*

Photograph 3. The caps of G. frondosa *vary in color from brown to shades of gray. This specimen showing gray-brown color.*

tance from the trunk (Photos 2 and 2A). There are several features that help identify *G. frondosa* in the field, including:

- Fruiting bodies that vary in size from 8 inches to 2 feet across at the base of the tree or on soil several feet from the trunk, but never higher up the trunk of the tree.
- Overlapping clusters of fronds that are each 1-3 inches across
- Fronds that are brown (Photo 3) or sometimes light to darker gray (Photos 4 and 4A)
- Interior or context that is white (Photo 5)
- Pore layer that is white when fresh with pore openings that are visible in some places to the naked eye (Photo 6)
- Pores that usually run down the stem (Photo 6)
- Drying brown, but not turning black or mushy on drying (Photo 7)

G. frondosa could be confused with

Photo 4: Darker gray-colored specimen. The fungus gets its common name from the similar appearance to the back end of a hen chicken, hence "hen of the woods."

Meripilus sumstinei (Photo 7A) or *Bondarzewia berkelyei* (See March 2017 issue of *Tree Care Industry*), but the combination of the above characteristics typically can be used in the field to separate the different species. *G. frondosa* consistently fruits around infected trees, and arborists may find it appearing on an annual basis around the same tree.

Biology and importance

G. frondosa is very common around mature oaks, and the white rot decay may be

Photo 4A: A lighter gray-colored specimen. Fruiting bodies may be attached directly to roots or the base of the tree at ground level, but are not found higher up on the trunk.

Photo 5: The fungus has stems and context that are white when fresh.

Photo 6: G. frondosa *has a white pore surface and the pores run down the stem of individual fronds. The pores are large enough that they can be seen with the naked eye on mature fruiting bodies.*

Photo 7: The fungus typically dries a brown color as it ages. This is in comparison to the similar-looking Meripilus sumstinei *that turns black and soft with age (see Photo 7A).*

Photo 7A: The similar-appearing Meripilus sumstinei *bruises black, and turns black and mushy as it ages.*

Photo 8: A red oak that is infected with Grifola frondosa. *The tree crown is showing no symptoms of the infection, and other than fruiting bodies, there are no other indicators of the infection in the roots.*

present in both roots and on the base or butt of the tree. However, advanced testing of the base and buttress roots of trees with *G. frondosa* may show only minimal amounts of decay. Little is known about the ability of *G. frondosa* to actually kill roots. Trees with *G. frondosa* may have normal crowns (Photo 8), suggesting that the fungus is not aggressively killing roots. Other than fruiting bodies, trees may have no other symptoms of decay such as external cavities. However, *G. frondosa* also may be present on trees infected with other decay fungi as evidenced by both fruiting on the tree at the same time.

Managing infected trees

Trees with *G. frondosa* fruiting near or on them can often remain in the landscape for many years. At a minimum, they should be inspected by sounding or with a mallet or probing where appropriate. Arborists should also be aware that testing the base or larger-diameter roots with resistance drilling or tomography may not identify significant amounts of decay. Additional advanced testing may require exposing roots with a supersonic air tool and evaluating the extent of decay in larger-diameter woody roots.

In most cases, this extent of testing is probably not warranted on trees infected with *G. frondosa*. However, this does not mean that advanced decay cannot be present on individual trees, although this appears to be relatively rare. Arborists should also be aware that other decay fungi can be present in infected trees that may pose other risks of decay and failure.

Christopher J. Luley is president and pathologist at Urban Forest Diagnostics LLC in Naples, New York, author of the manual Wood Decay Fungi of Living Urban Trees*, and developer of TreeRot.com, a website dedicated to decay fungi of urban trees.*

Ganoderma applanatum – The Artist's Conk

Photo 11: Numerous conks of Ganoderma applanatum *on a declining sugar maple. More typically, the fungus produces single or several conks on the lower trunk.*

By Christopher Luley, Ph.D.

Thus far, this series has focused on pathogens that cause root rot in trees, but we will soon switch our focus to move up the tree into the trunk. Aiding that transition is this month's subject, Ganoderma applanatum*, which falls into the category of root and trunk or butt rots, possibly more leaning toward the butt than root.*

Everyone has seen *Ganoderma applanatum* – just maybe in a boutique rather than on a tree. *G. applanatum* is a decay fungus that is also known as the artist's conk. It is a common backdrop or canvas for artists, who use its pore surface, on its underside, for sketching or painting scenes of nature or other images (Photo 1). However, the fungus is common and an important decay pathogen on urban trees. It is widely distributed in all 50 states and has an equally wide host range that includes many hardwoods, such as oaks, beeches and maples, as well as some conifers.

G. applanatum is also one of the few fungi frequently associated with advanced decay sufficient to call for advanced assessment or removal (Photo 2). The artist's conk also has been widely used and

Photo 1: Ganoderma applanatum *is often used as a backdrop for artwork such as painting or sketching that scratch the pore surface. Unless otherwise noted, photos courtesy of the author.*

Photo 2: Ganoderma applanatum *-decayed white oak. The tree had small conks but extensive decay when it was finally removed. Trees with* G. applanatum *often have advanced decay.*

studied because of its putative medicinal benefits profile.

Identification

G. applanatum produces a perennial conk, and larger specimens can reliably be identified in the field. There are several other similar-appearing perennial *Ganoderma* species, but they are very rare in urban landscapes in most areas of the United States. *G. applanatum* conks are also common on stumps or logs after trees fail or are removed. It is one of the largest and longest-lived perennial conks, growing to more than 2 feet in diameter (Photo 3) and reaching ages of up to 40 years or more! However, the typical life span of a conk (note: the infection in the tree continues even if the conk no longer is sporulating) is usually shorter, i.e., less than 10 years. Conks usually appear low on the trunk or near the ground (Photo 4). They can generally be aged by their size and number of concentric rings on the top of the conk.

Photo 3: Ganoderma applanatum *conks are relatively easy to identify in the field and with time can become very large. It is one of the largest perennial conks, is widely distributed in the United States and has a very wide host range.*

Photo 4: Ganoderma applanatum *conks are usually on the lower trunk. The fungus also can decay larger buttress roots.*

Decay Fungi Series

This is the eighth article in a series on decay fungi species found in urban trees that have run in *TCI Magazine* this year. Previous articles, all from Christopher J. Luley, unless otherwise noted, included:

March, Part 1: "Berkeley's Polypore"

April, Part 2: "*Ganoderma sessile* (aka *Ganoderma lucidum*) – An Important Root Disease and Butt Decay by Any Name"

May, Part 3: "Burnt-Crust Root and Butt Decay and Canker: *Kretzschmaria deusta*, a Common Decay Fungus You Might Not Recognize"

June, Part 4: "Wood Decay and the Cleanup Crew," by Kevin T. Smith, Ph.D., and Jessie A. Glaeser, Ph.D.

July, Part 5: "Don't Mess with *Inonotus dryadeus*"

October, Part 6: "*Armillaria tabescens*: Mushroom Root Rot Caused by the Ringless Armillaria"

November, Part 7: *Grifola (Polyporus) frondosa* – Should I Worry About the "Hen of the Woods"?

Photo 5:* Ganoderma applanatum *conks are very hard, perennial and can produce spores for 10 years or more. Photo credit: Gary Raffel, Dynamic Tree Systems.

Other identifying features include:

• Very hard, shelf-like or fan-shaped to nearly flat or, more rarely, hoof-shaped conk, 2 to 24 inches or more in diameter attached directly to a tree, almost always without a stalk or stem (Photo 5);

Photo 6: The tops of* Ganoderma applanatum *conks are brown to gray and are concentrically furrowed with age. They usually have a white margin when a new pore layer is being produced.

Photo 6A: The top surface may be covered with a layer of rusty-colored or brown spore deposits, giving it a light brown color that can be wiped away.

• Conks that are producing a new pore layer often have a white or light-colored margin;

• Top surface of the conk is brown to gray colored with rough, somewhat concentric furrows on the top surface (Photo 6);

• The top surface may be covered with a layer of rusty-colored or brown spore deposits, giving it a light brown color that can be wiped away (Photo 6A);

• Interior or context is brown and 1 to 2 inches thick (Photo 7);

• Pore layer that is white when fresh, with pore openings that are too small to be visible to the naked eye. The pore surface scratches brown when fresh (Photo 8).

Conks of *G. applanatum* can be more difficult to identify when they are small or are just developing. Larger specimens are extremely woody and hard and can be very difficult to remove from a tree.

Biology and importance

G. applanatum is one of the more important decay fungi because when it appears, trees typically have advanced decay (Photos 2 and 9). The fungus is a white rot that removes lignin and cellulose together, resulting in a straw-colored appearance to decayed wood (Photo 2) that is weakened greatly even in the initial stages of decay. The decayed wood may also have thin black zone lines comprised of fungal material. *G. applanatum* appears to be able to colonize and decay sapwood, thus effectively reducing the shell of sound wood that trees require for stability (Photo 10).

Photo 7: The context or middle of the conk is brown, and the previous pore layers can be seen when the conks are cut apart.

The fungus is a little unusual in that decay may be found in buttress roots as well in the lower trunk. The root decay is reported usually to be limited to larger-diameter buttress roots. Infected trees may show few symptoms of crown decline right up to the point of failure. However, the conks are also common on declining trees and may be numerous on trees at the end stages of decline (Photo 11, page 42)

Photo 8: Pore surface of* Ganoderma applanatum*. The pores are very small but etch brown when fresh, allowing the permanent etchings for artistic purposes.

Photo 9: Decay caused by the artist's conk is usually extensive by the time the fruiting appears on trees. The fungus removes lignin and cellulose at the same time, and can decay sapwood and progressively weaken the structural stability of the tree. Photo credit: Gary Raffel, Dynamic Tree Systems.

or when trees eventually fail.

Infection occurs through windborne spores or insects moving spores to wounds.

Managing infected trees

Trees with *G. applanatum* should be evaluated closely and should be considered for removal based on the appearance of conks. At a minimum, trees with *G. applanatum* should be sounded with a mallet and considered for advanced testing if they are to be retained in the landscape.

Trees with large conks indicating long-standing fruiting and infection are candidates for removal because of the known potential of the fungus to progressively decay sapwood. Arborists should also consider the potential for buttress-root failure when the conks are near the ground and should not be deceived by the healthy appearance of tree crowns on infected trees.

Christopher J. Luley is president and pathologist at Urban Forest Diagnostics LLC in Naples, New York, author of the manual Wood Decay Fungi of Living Urban Trees *and developer of TreeRot.com, a website dedicated to decay fungi of urban trees.*

Photo 10: Extensive decay on a European beech infected with* Ganoderma applanatum. *Note conks on the face of the stump.

PHAEOLUS SCHWEINITZII:
HOLY COW – IT'S THE COWPIE FUNGUS!

Decay Fungi Series

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March, Part 1: "Berkeley's Polypore"

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November, Part 7: *Grifola (Polyporus) frondosa* – Should I Worry About the "Hen of the Woods"?

December, Part 8: "*Ganoderma applanatum* – The Artist's Conk"

Photo 1: Conk of P. schweinitzii *at the base of a larch. The fungus is common in urban areas on a wide range of conifer species.*

By Christopher Luley, Ph.D.

It would be odd to see a cowpie in a deep urban setting, unless it was a conk of *Phaeolus schweinitzii,* which is also known as the cowpie or velvet-top fungus. This common root and butt decay fungus may fruit on the trunk or on the ground around conifers in urban areas (Photo 1, facing page).

It gets its name from the conks that form on the ground having a similar appearance to cow droppings (Photo 2). *P. schweinitzii* has a wide host range on evergreen trees, infecting pines, spruces, firs, larch and others. This is an interesting pathogen that can kill and decay roots of all ages, including those of seedlings, and decay the roots and lower trunk to the point of failure. *P. schweinitzii* is probably the most common decay fungus that fruits on conifers in urban areas and can be found in most locations in the country where conifers grow. The fungus is relatively easy to identify in the field, and conks are valued for dye-making purposes, as they impart a range of earthy tones to yarn or fabrics.

Identification

P. schweinitzii conks can develop on the lower trunk or on the ground at distances of more than 6 feet from the base of an infected tree. The conks are annual and typically develop from June into the fall. Identifying features include:

- Round to kidney-shaped, overlapping rosettes or clusters of conks with velvety or woolly tops. Individual caps are 2 to 10 inches wide while clusters can be up to 2 feet across (Photo 3).
- Conks on the ground usually have a short stem, while those attached to the trunk are without stems.
- Top or caps are colored ochre (a pale brownish-yellow color) to reddish, rusty brown, often with a lighter-yellow margin when young (Photo 3). Caps are lightly zonate with colors and zonation fading and darkening with age (Photo 4).
- Interior or context is ½ to 2 inches thick and yellow to ochre, similar to the color of the top (Photo 5).
- Pore layer has irregularly shaped pores that can be seen with the naked eye on at least some parts of the pore

Photo 5: The interior or context of a* Phaeolus schweinitzii *conk is similar in color to the top and is usually 1 to 2 inches thick. All images courtesy of the author.

Photo 2: The fungus often fruits on the ground at distances away from the trunk. It gets one of its common names from its similar appearance to a cowpie.

Photo 3: Overlapping clusters may develop on the trunk and are pale yellow to rusty brown, often with a lighter-yellow margin when young.

Photo 4: Conks on the ground are usually round to oblong. Note the velvety appearance of the top.

Photo 6. Closeup of pore layer showing darker-color bruising when pressed. Note the pores are visible with the naked eye and the openings are irregular in shape.

surface. The pore surface bruises a darker color when pressed (Photo 6).

- Conks turn dark brown, and then black with age and when they persist on the ground, and may appear similar to a cowpie (Photo 2).

Biology and importance

As mentioned, *P. schweinitzii* can infect and kill roots of all ages including small rootlets on young trees. The fungus also appears to colonize roots damaged or killed by other pathogens such as *Armillaria*. Root infection by the fungus may result in reduced growth and other decline symptoms, but infected trees may show few crown symptoms (Photo 7, same tree as in Photo 3).

Decay develops in the lower trunk and usually originates from root colonization such that trunk decay may be present without external cavities or other indicators. The decay is typically restricted to the lower 15 feet of the trunk. Site factors that result in poor growth or tree stress are often cited as increasing the potential for infection and damage by *P. schweinitzii.*

Decayed wood is first streaked reddish brown, while in its later stages it is a red-brown cubical rot where the wood breaks into rectangular or irregular-shaped cubes (Photo 8). The decay removes cellulose and leaves the darker-colored lignin, resulting in wood that is brittle and trees that are susceptible to snapping off as the decay advances. Close observation of decayed wood may show an inconspicuous sheet of mycelial fans between wood fractures, and wood to have a strong odor of turpentine. Root death and decay and trunk decay are well known to eventually result in root or trunk failures.

Managing infected trees

Conifers infected with *P. schweinitzii* require close inspection because of the potential for root and trunk failure. Sounding with a mallet or hammer or other advanced assessment methods would identify most trees with advanced trunk decay. However, care needs to be taken when sounding conifers, as it can be more difficult to interpret results on trees with lower-density wood.

The potential for extensive root decay has to be considered where fruiting occurs, and root evaluations using advanced assessment methods may be necessary depending on individual cir-

cumstances. The literature and observations are also very clear that trees infected with *P. schweinitzii* may not show obvious crown symptoms despite advancing root or trunk decay.

Christopher J. Luley is president and pathologist at Urban Forest Diagnostics LLC in Naples, New York, author of the manual Wood Decay Fungi of Living Urban Trees*, and developer of TreeRot.com, a website dedicated to decay fungi of urban trees.*

Kevin T. Smith, Ph.D., supervisory plant physiologist for the U.S. Forest Service in Durham, New Hampshire, contributed to this article.

Photo 7. At left, a white pine infected with* P. schweinitzii *(same tree as Photo 3). Sounding with a mallet indicated extensive trunk decay despite the mostly normal-appearing crown. Advanced testing of roots and trunk may be needed, as infected trees may fail from roots or the trunk.

Photo 8. The fungus causes a brown-red cubical rot similar to the brown rot depicted here. The decayed wood may have an odor of turpentine when trees are cut.