WE NEED YOUR HELP!

We are glad to provide these materials for free. In order for us to continue receiving funding for new materials, we need to collect information on how they are used.
Thank you for taking the time to answer the following one-minute survey.

There are three ways to complete the survey:

1 Scan this code with your smartphone camera

2 Type the following link into your web browser:
https://plantheroes.org/educator-survey

3 Email your answers to:
plantheroes@publicgardens.org

1) Job title
2) Name of organization you belong to
3) What kind of educator are you?
   - Teacher
   - Summer camp counselor
   - Home schooler
   - Public garden educator
   - Informal educator
   - Other (please describe)
4) What grade level do you teach?
   - Elementary (K–5)
   - Middle School (6–8)
   - High School (9–12)
   - Other (please describe)
5) Specify what subject area you teach:
   - Science
   - Math
   - Language Arts
   - Social Studies
   - Other (please describe)
6) How many students do you teach in a school year?

PLANT HEROES

Field Guide:

Shoestring Root Rot

This fungus affects many trees and can grow to humongous proportions! It threatens forest trees all across North America.

Plant Protection Program

AMERICAN PUBLIC GARDENS ASSOCIATION

Photo: Peter O'Connor, Flickr.com

ARMILLARIA "SHOESTRING" ROOT ROT

Identification

Armillaria has three different structures you can find in affected trees. Read below to learn more!

Armillaria sometimes appears as honey-brown mushrooms at the base of infected trees. The caps of the mushrooms average 9 centimeters or nearly twice the size of this sticky note.

These mycelial fans of the fungus are a good way to identify *Armillaria*–this is the part of the fungus that absorbs nutrients from the tree.

These *rhizomorphs* are like the roots of the fungus–they grow in dead wood and through the ground. They are why we call this fungus shoestring root rot. They are flat, can grow up to several feet long, and are about 1–5 millimeters in diameter. That's around the thickness of a single piece of spaghetti. >>

Under certain conditions, the fans of *Armillaria* can glow in the dark. This is called "bioluminescence."

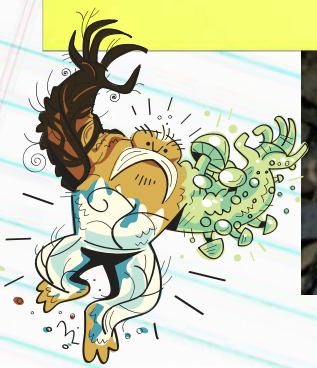


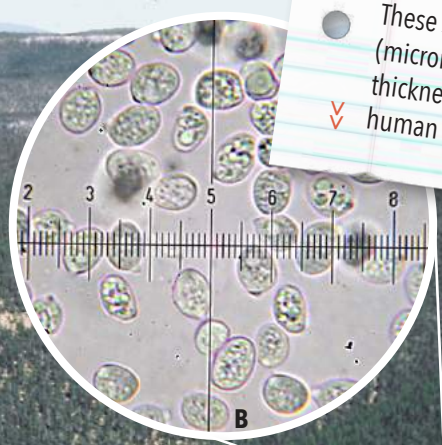
PHOTO CREDITS: A: 1400105 Linda Haugen, USDA Forest Service, Bugwood.org; B: 5367187 William Jacobi, Colorado State University, Bugwood.org; C: 502709 Joseph O'Brien, Bugwood.org; D: Martin Livezey, MushroomObserver.org,

PLANT HEROES

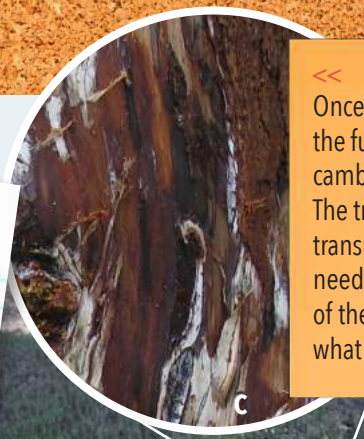
ARMILLARIA "SHOESTRING" ROOT ROT

Disease Cycle

Armillaria spreads two different ways. The first is by producing mushrooms, also sometimes known as fruiting bodies. Fruiting bodies, which appear around infected trees in late summer or autumn, produce spores (or small specks that carry the reproductive information to make new fungi). The spores can travel great distances when picked up by wind.



These spores are about 8µm (micrometers) across. The thickness of a single strand of human hair is about 100 µm!



Once a new tree is infected, the fungus attacks the cambium (living tissue). The tree can no longer transport the resources needed to the upper parts of the tree, and this process is what eventually kills the tree.

Armillaria moves through dead trees, roots, and soil by growing these rhizomorphs. The fungus can enter a new host tree by direct infection through these stringy structures. The rhyzomorphs can't spread very far, but this is how the fungus usually spreads from tree to tree.

A

UGA2250028b

PHOTO CREDITS: A: Ralph Williams, USDA Forest Service, Bugwood.org; B: Malcolm Storey, bioimages.org.uk; C: Joseph O'Brien, USDA Forest Service, Bugwood.org; D: Kathie Hodge, Cornell University, Flickr.com; E: Aleksey Gnilenkov, Flickr.com

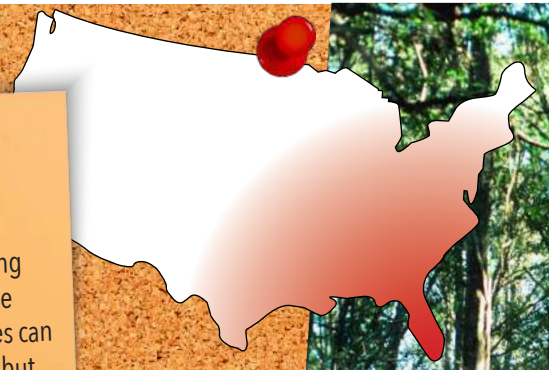
PLANT HEROES

ARMILLARIA "SHOESTRING" ROOT ROT

Host Plants

Host plants of fungus *Armillaria mellea*

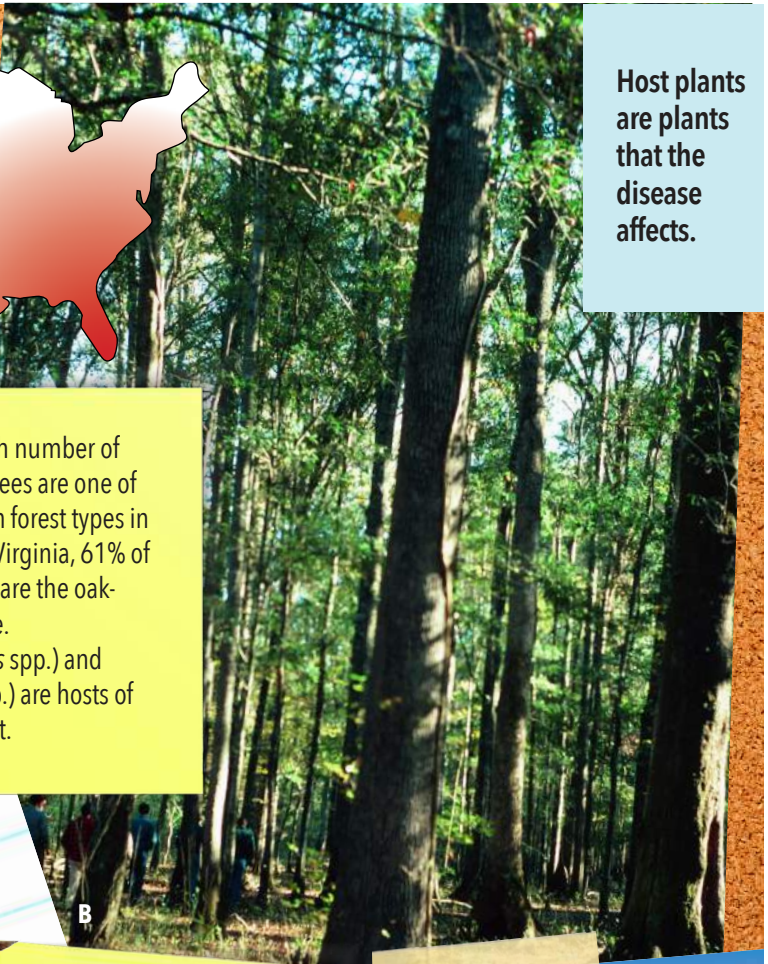
There are several species of *Armillaria* that threaten North American forests. *Armillaria mellea* is mostly found infecting deciduous trees (trees that lose their leaves in fall). This species can be found all over the country, but is doing the most damage in the southeastern U.S.



Host plants are plants that the disease affects.

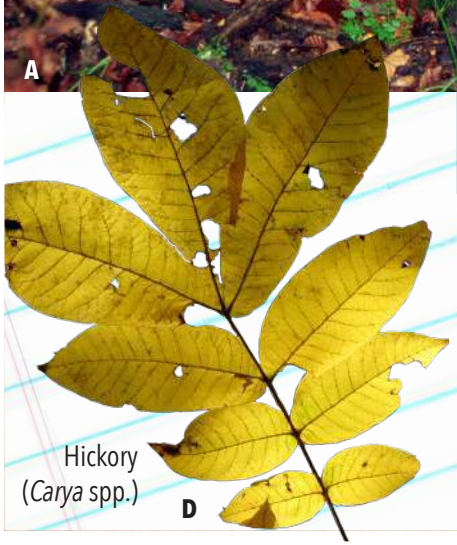
A

Forests with a high number of hickory and oak trees are one of the most common forest types in the southeast. In Virginia, 61% of hardwood forests are the oak-hickory forest type.
Both oak (*Quercus* spp.) and hickory (*Carya* spp.) are hosts of shoestring root rot.



B

Beech (*Fagus* spp.) is another very important forest tree in the eastern U.S., and is also a host of *Armillaria mellea.*



Hickory (*Carya* spp.)

D

E

Beech (*Fagus* spp.)

F

Oak (*Quercus* spp.)

Forest trees aren't the only ones threatened by *Armillaria mellea.* Recently, shoestring root rot has been found to be a threat to stone fruit (peach, pear, cherry, etc.) orchards.

>>

C

PHOTO CREDITS: A: Andrea Kunca, National Forest Centre - Slovakia, Bugwood.org; B: Paul Blostad, University of Minnesota, Bugwood.org; C: Photo by Michael Wallace, Flickr.com; D: Hickory leaf Katja Schulz, Flickr.com; E: Joe Blowe, Flickr.com; F: Joe Schumacher, Flickr.com

PLANT HEROES

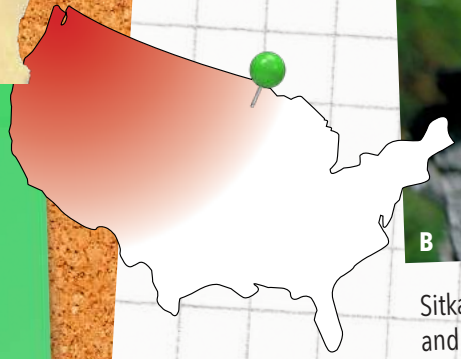
ARMILLARIA "SHOESTRING" ROOT ROT

Host Plants

Host plants of fungus *Armillaria solidipes*

Armillaria solidipes is another species of shoestring root rot. It is a major pest of conifers in the U.S. (and around the world).

The Pacific Northwest and the Rocky Mountain region are at the greatest risk for damage from *A. solidipes* because of the high numbers of conifer forests in those regions.



A

Mixed-conifer forests of Oregon and Washington are at risk of *A. solidipes* infection.

Grand fir (*Abies grandis*)

B

Sitka spruce, grand fir, and Douglas fir are all important forest trees in the Pacific Northwest, and are all hosts of *A. solidipes*. Douglas fir is a very important commercial species–the standard for construction-grade wood and a very popular Christmas tree species. It's even the state tree of Oregon!

The US Forest Service has reported finding *A. solidipes* on almost all common tree species and in all major forest types in the Rocky Mountain Region. It is also very widespread, probably occuring in all forests in the region.

D

C

^^ Sitka spruce (*Picea sitchensis*)

<< Douglas fir (*Pseudotsuga menziesii*)

PHOTO CREDITS: A, B: Dave Powell, USDA Forest Service (retired), Bugwood.org; C:Pseudotsuga menziesii Dan Mullen, Flickr.com; D: Picea sitchensis 5u5, Flickr.com

PLANT HEROES

ARMILLARIA "SHOESTRING" ROOT ROT

Damage

Malheur National Forest in eastern Oregon is home to a very large infestation of *Armillaria solidipes*. Because the rhizomorphs connect the fungus together from tree to tree, it is considered one of the largest living things on the planet–this giant has been named the "Humongous Fungus."

These dead standing and fallen trees are typical of large *Armillaria* disease centers. The fungus rots the base of the trunk and roots–this causes trees to die, become unstable, and eventually break at the base.

<<

The Humongous Fungus covers almost 2,400 acres, and it's over two miles across–that's about as wide as Manhattan in New York City! Scientists estimate that it could be up to 4,000 years old. It is by far the largest known root disease center in the world.

<<

This ponderosa pine (*Pinus ponderosa*) has been infected with shoestring root rot–notice the brown needles and the white mycelia at the base of the trunk.

PHOTO CREDITS: A, B: Nicola Twilley for Venue (v-e-n-u-e.com); C:5367186 William Jacobi, Colorado State University, Bugwood.org

PLANT HEROES

ARMILLARIA "SHOESTRING" ROOT ROT

Management

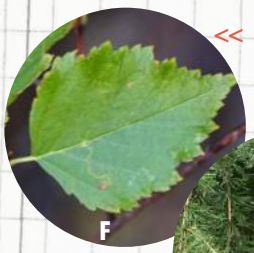
Heavy equipment destumping an infected forest area.

Firebreaks (or sections of forests without any plants) are used to stop forest fires from spreading. The same method can be applied to stopping *Armillaria* from spreading. If the break is large enough, the rhizomorphs will not be able to find new host trees, and will eventually die out.

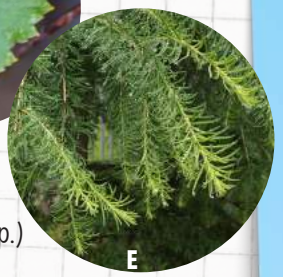
Removing infected trees from the area is the first step in managing this disease. "Destumping" is the removal of old infected stumps. Since the fungus can survive in dead wood and roots, this needs to be done before the area can be replanted.

Once the infection is stopped or slowed, new resistant trees can be planted. If the same trees are planted that were there before, any *Armillaria* persisting on the site could infect them again.

Pine (*Pinus* spp.) sapling planted in soil containing *A. solidipes*.



Birch (*Betula* spp.)



Larch (*Larix* spp.)

Birch and larch have both been found to be resistant to *Armillaria*, and do well in disturbed soil. After growing resistant trees on the site, less resistant (host) trees can be replanted, as the fungus will have died out.

PHOTO CREDITS: A: Fred Baker, Utah State University, Bugwood.org; B: Billy Humphries, Forest Resource Consultants, Inc., Bugwood.org; C: William Jacobi, Colorado State University, Bugwood.org; D: USDA Forest Service - Ogden, USDA Forest Service, Bugwood.org ; E: Kirill Ignatyev; F: Andrey Zharkikh, Flickr.com

PLANT HEROES

Join our team of Plant Heroes and learn about trees, forests, and the natural world around you!

PLANTHEROES.ORG

You can be a Plant Hero!
Are you curious about plants and animals? Do you like asking questions about nature? Do you enjoy being outdoors and having fun, climbing trees, balancing on logs, or finding a new butterfly or beetle? If so, you are already on your way to becoming a Plant Hero! We invite you to join forces with Nate, Laura, Aponi, and Frankie to protect the plants and ecosystems we all love.

How can you become a Plant Hero?
Join our team and go on a journey with Nate, Aponi, Laura, and Frankie. As a Plant Hero, you will learn to notice when plants are in trouble. You will also find out ways you can act quickly to help find solutions in your own neighborhood. Follow their adventures and learn how they help plants and ecosystems stay healthy.

On the Plant Heroes website, you will find materials to help you learn about plants, forest health, and ecosystem balance. The more you know, the more you can help protect plants and ecosystems in your own yard, neighborhood, and community!

Plant Heroes strives to spark curiosity about nature and science in all children.
Our program provides hands-on, nature-based learning materials for educators to engage children in topics of plant health, ecosystem balance, and forest health. We also spotlight the amazing work our public gardens do in protecting the plants and ecosystems we all depend on through our website and printed materials. Visit **plantheroes.org** today to learn more!

Plant Heroes is brought to you by the American Public Gardens Association, founded in 1940. Over the last eight decades, the Association has supported the work of public gardens in North America and beyond. Our mission is to champion and advance public gardens as leaders, advocates, and innovators in the conservation and appreciation of plants. Our vision is "A world where public gardens are indispensable" as they provide botanic, conservation, community, education, and economic resources to their community.

The Association is committed to increasing the knowledge of public garden professionals throughout North America through information sharing, professional development, networking, public awareness, and research, so that they have the tools to effectively serve visitors and members.

American Public Gardens Association

PublicGardens.org

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USDA