

Root rot can be tricky to identify. Some common symptoms of root rot include lower branch flagging, off-color foliage, and minimal leader growth. Root rot can be caused by 3 common pathogens:

## **ANNOSUS ROOT ROT**

- Biology
  - *Heterobasidion annosum* - fungus
  - Produces both sexual basidiospores and asexual conidiospores inside a conk-like fruiting body
  - Two distinct north American groups within the genus that are now described as separate species
    - One attacks mostly pine, juniper, and cedar
    - One attacks mostly fir, spruce, and hemlocks
    - (larch can be attacked by both groups)
  - Primary infection is by airborne sexual spores that can land on exposed wood such as cut stumps or wounds. The conidia are *not* thought to be especially important in initiating new infections
  - Secondary infection is through underground root grafting between trees
  - Primary infections by spores are the more common method of spread in a plantation setting
  - Cut stumps are only susceptible to infection by spores for about a month after cutting – after this time, the stump gets dry, less nutritious, and colonized by other competing organisms
  - *H. annosum* is NOT able to survive freely in the soil
  - Airborne spores generally travel less than 100 meters
  - The fungus generally fruits and produces spores in late summer or autumn
  - The fungus can survive in dead stumps and root systems for decades because it can feed on both living as well as dead tissues
- Some ways to Identify Annosus
  - Uniform overall shedding of needles resulting in a thin crown appearance
  - Irregular staining in sapwood in cross section caused by chemicals that are emitted by both the tree and the fungus
  - May get pitting in the wood, separation of rings
  - Mature conks or small white “buttons” protruding through bark at base of tree
  - Cutting a disc of an infested log and placing it in a Ziploc bag with a wet paper towel to encourage sporulation
    - Spores look like little golf balls on stalks under microscope
- Methods for control of Annosus
  - Removal of infested trees and roots combined with removal of one row of apparently healthy trees surrounding infested trees
  - Stump removal after cutting of healthy trees

- Trenching between infested trees and healthy trees – trenches close to 5 feet deep are recommended
- To limit damage caused by airborne spores, one can try to cut trees either in very cold weather or very hot, dry weather. Around the NW, the hot dry summer is probably more conducive to this because we do not often get freezing temperatures during winter months
- If stumps are not to be removed, immediate treatment of cut surfaces with borax or urea is recommended – this changes the pH of the cut stump surface to prevent spore germination. This is really the only chemical control, but it is effective
  - Biological control using a fungus, *Phlebiopsis gigantea*, has also proven very useful – this was available commercially in the US until 1995, when the EPA informed the forest service that they would need to register the fungus as a biological pesticide which is very expensive, so is no longer available in the US, but is currently available under the tradename Rotstop in Europe
- Adopt the widest possible spacing between trees to limit root contact
- Little chance of eradication once it is present, but can use these methods to try to limit spread

## ARMILLARIA ROOT ROT

- Biology of Armillaria
  - Fungus – many species, most common in conifers in the NW is *A. ostoyae*
  - Produces a mushroom fruiting body, with a tan cap, often called honey mushrooms
  - Fruits in the autumn around the bases of affected trees
  - Produces ONLY sexual basidiospores, no asexual stage
  - Can live freely in the soil, spreads through rhizomes
  - Rhizomes are aggregated mycelium that is melanized (filled with pigment) that allows it to withstand adverse conditions such as drying, UV radiation, harsh soil conditions, and competition with other microbes in the soil. Rhizomes can contact healthy roots and initiate infection
  - Initiation of new infections by basidiospores is NOT common and is thus not as important as spread through root grafts or through rhizomes – this is in contrast to annosus rot.
  - However, the occasional successful basidiospore may have an important role in movement of disease to a new area where it did not previously occur
  - Infection is commonly confined to an infested site, so Armillaria issues are common in tree farms that are established on old forest land

- Another possibility for spread into an uninfested site is the detachment of infested wood pieces or rhizomes and travel via water or heavy winds
  - There are about 9 closely related species in North America and they have undergone multiple changes in names/classification, so for convenience, the disease is generally referred to as being caused by Armillaria species
  - Armillaria can also survive for decades in dead root systems and stumps because it can also derive nutrition from both living and dead tissue
- Some ways to identify Armillaria
  - White mycelial fans underneath the bark of the stem or roots
  - Rhizomorphs often clinging to the root collar around the soil line, often look like feeder roots
  - Punky, pitted, chewed-up rot
  - Decimation of root system, loss of even major roots
  - Overall thinning of crown
  - Presence of clusters of honey-colored mushrooms around the base of the tree in late summer or fall – they only last a few weeks and are not present every year
- Methods of Control of Armillaria
  - Very few methods for control!
  - Once you have armillaria, it is considered essentially permanent
  - Removal of infested trees and one row of surrounding healthy trees
  - Stump removal
  - Trenching between infested and healthy trees
  - Change of species composition – unfortunately douglas-fir and true firs are among the most susceptible species. Pine and spruce tend to be a little more tolerant
  - Some site preparation treatments can be used – removal of all root material by ripping/tilling the ground and even hand removal of root scraps between rippings
  - Chemical control studies have been inconclusive and relatively unsuccessful. Some fumigation chemicals are used in high value crops and orchards where some studies have shown that direct injection of triazole fungicides like propiconazole (Alamo) into the tree can work systemically and reduce mortality
  - Armillaria grows in protected spaces such as underneath the bark of the tree or in the soil as rhizomes so chemical control is difficult and generally not recommended for trees because of the high cost for relatively little benefit

## **PHYTOPHTHORA ROOT ROT**

- Biology of Phytophthora
  - Fungal-like organism, looks like a fungus but is more closely related to algae

- Multiple spore types
    - Oospores and chlamydospores are long-lived resting spores that allow Phytophthora to withstand adverse conditions
    - Sporangia are shorter-lived sac-like spores that can either germinate directly and produce hyphae, or they can produce motile zoospores that are ejected from the sac and can swim in free water toward a host
  - Water-loving species, prefer cool wet conditions
  - Many different species that cause root rot – they vary from region to region, depending on the host material available and things like climate, temperature, and moisture
  - Live in the soil and on plant debris
- Some ways to identify Phytophthora root rot
- Symptoms mimic the other two root rots!
  - Some of the things I look for are flagging lower branches and discolored tissue underneath the bark (lesion)
  - The lesioned tissue should not have diffuse margins or be spongy – this is what I have associated more with death from anoxic conditions
  - The lesioned tissue should be dark, cinnamon brown and have a distinct margin. The tissue should be moist and firm, not a punky chewed rot like the other two
- Methods of control for Phytophthora
- Reducing water issues
    - Subsurface drainage tiles or pipes
    - Hilling of planting rows
    - If you have heavy soils - addition of sand or organic material (compost) into heavy soils to improve aeration in sites that are in planning (not very useful for already planted sites)
    - Sloping and ditching to encourage runoff
    - Backfilling of depressions/low lying spots
    - Crowning of fields in sites that are in planning
    - Chemical control by fumigation – very expensive
    - Some foliar or soil applications with materials like Subdue MAXX or Aliette can help to reduce mortality, but are not a silver bullet and their effectiveness can vary widely depending on the site, tree stress, and weather conditions
    - Planting of more tolerant species such as nordmann, Turkish, momi firs may help, but in the right conditions, these can also be affected. Unfortunately noble, fraser, and grand firs are quite susceptible. Concolor, balsam, and canaan are moderately susceptible.

PICTURES



Common symptoms of root rot (especially *Phytophthora* root rot)



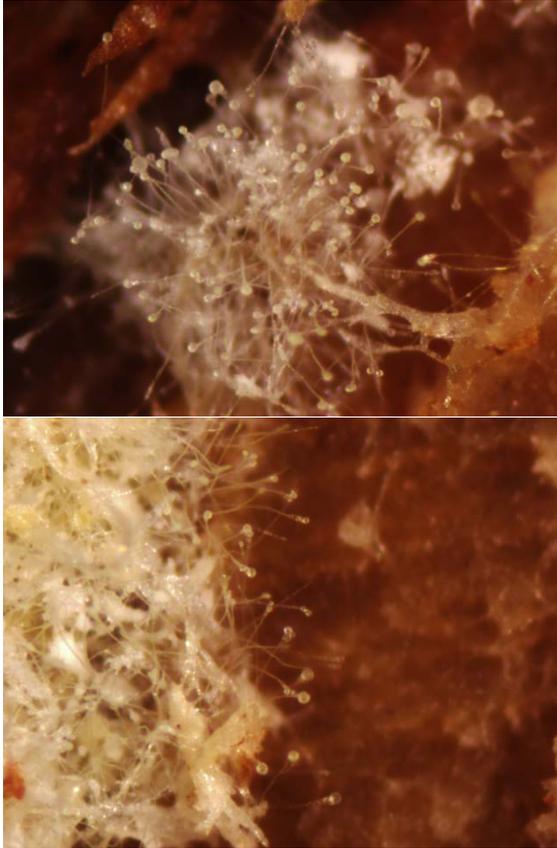
Sapwood staining from *Annosus* Root Rot



Conks of *Annosus* on base of tree (not common). Sexual spores are released from the white underside of the conk.



*Annosus* immature conk (AKA "buttons") on base of tree (more common to see)



Asexual spores of Annosus, borne on hyphae, look like golf balls on stalks. Very diagnostic of annosus.



Thin crown from Annosus Root rot



Armillaria mycelial fan underneath bark. Very diagnostic of Armillaria



Armillaria mushrooms. Found near base of trees.



Armillaria rhizomorphs around the crown and roots of the tree