15
Damage to roots and collars of coniferous woody plants

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15.1. Root and butt rot

Description: The root system is gradually killed up to and including the butt of the tree which may cause either a slow or more progressive decline with distinct tree-level symptoms. Trees with butt rot have evidence of stem or root failure (i.e. the lower stem breaks or the roots fail near the root collar). Snapped stems and broken roots have evidence of decay on the broken surface (e.g., breaking easily across the grain). Observations of characteristic symptoms in the cambial tissue or the inner wood can help diagnose the potential causal agent. These symptoms may include the type and texture of decay (see Additional Information below), visible mycelium, and staining of the wood. Fruiting bodies (basidiocarps) are diagnostic of specific diseases and can appear resupinate (growing horizontal or flat on the surface), shelf- or bracket-shaped (conks) on living or dead host plants, or mushroom-like on the ground.
Possible damaging agents: Fungi: Basidiomycota (Russulales: Figs. 15.1.1 – 15.1.4, Polyporales: Figs. 15.1.5 – 15.1.8), Hymenochaetales (Fig. 15.1.9).

Fig. 15.1.1. Tree failure on unknown species from extensive root decay caused by annosum root rot (*Heterobasidion annosum* sensu lato). USA, USDA3.

Fig. 15.1.2. Fruiting body of the root and butt rot fungus (*Heterobasidion abietinum*) on Oriental spruce (*Picea orientalis*) roots. Giresun, Eastern Black Sea region of Turkey, AL.

15.1.3. Fruiting body of annosum root rot (*Heterobasidion annosum*) on Norway spruce (*Picea abies*) roots. Bihor County, Romania, HO.

Fig. 15.1.4. Norway spruce (*Picea abies*) damaged by the white-rot fungus (*Heterobasidion parviporum*) and overthrown by wind. Bukovel, Ukraine, VK.

Fig. 15.1.5. Broken roots of windthrown trees (unknown species) with swellings caused by callus tissue around roots decayed by Schweinitzii root and butt rot (Phaeolus schweinitzii). USA, SKH.

Fig. 15.1.6. Fresh fruiting body of Schweinitzii root and butt rot (Phaeolus schweinitzii), Sękocin Stary, Poland, VK.

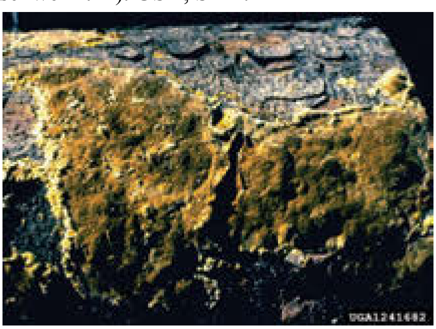

Fig. 15.1.7. Cream, yellowish or cinnamon colored ectotrophic mycelium on the outer bark of roots with laminated root rot (*Phellinus weirii* = *P. sulphurascens*). USA, USDA3.

Fig. 15.1.8. Agglutinated fungal hyphae of white rot fungus *(Phellinus noxius*). American Samoa, FB.

Fig. 15.1.9. Red to red-brown discoloration of wood from roots of sand pine (*Pinus clausa*). Decayed wood contains flecks with small elliptical white pockets (*Inonotus circinatus*). USA, ELB.

Additional information: Root and butt rots are wood-decay diseases mainly caused by Basidiomycota fungi. Entry of these organisms may occur through direct penetration of host roots or through wounds in the lower part (i.e. the butt) of the tree. Eventual tree mortality (resulting from blowdown or girdling of the root collar) depends on several factors such as the age and vigour of the host plant, the organism(s) involved and environmental factors that may affect their interaction.
Trees with root and butt rot typically exhibit crown symptoms. For conifers this might include reduced increment growth, a stress cone crop (numerous and smaller-sized cones), and chlorosis (yellowing) and thinning of foliage. Internally, diseased roots exhibit decay patterns, mycelia or staining in the wood that may extend from a few centimetres to several metres into the butt portion of the tree. Wood decayed by white rot fungi in general turns whitish because of bleaching by oxidation and loss of lignin, but color and texture can vary by the organism involved such that the decay appears stringy, spongy, laminated (separating along annual rings), or mottled, with or without formation of black zone lines. Wood decayed by brown rot fungi appears brown in color, dry, and often crumbly with horizontal and vertical fissures. For root pathogen sampling and preservation, see Chapter 4.

15.2. Root rot

Description: Most root diseases cause crown symptoms including chlorosis (yellowing) and thinning of foliage, reduced increment growth, and a distress cone crop (numerous and smaller than average size of cones). Resin exudation on roots or at the base of trees may also indicate the presence of a root disease pathogen colonizing cambial tissue. Some root pathogens may also cause extensive butt rot (decay extends up the base of the tree) and eventual tree failure whereby the lower stem breaks or the roots fail near the root collar. Decay patterns, wood staining and presence of mycelia in various forms may also be indicative of certain causal agents (see also 15.1). Fruiting bodies are often diagnostic of specific diseases. Such fruiting bodies can be annual or perennial, appear resupinate (growing horizontal or flat on the surface), shelf- or bracket-shaped (conks) on the living or dead host plant, or mushroom-like on the ground.
Possible damaging agents: Chromista: Oomycetes (water moulds: Peronosporales: Figs. 15.2.1 – 15.2.4), **Fungi**: Basidiomycota (e.g., Agaricales: *Armillaria* sp.: Figs. 15.2.5 – 15.2.12).

Fig. 15.2.1. Root necrosis under the bark of Turkish Black Pine (*Pinus nigra*), caused by Phytophthora root rot. Seydisehir-Konya Forest Nursery, Turkey, AL.

Fig. 15.2.2. Resin-soaked tap root of sand pine (*Pinus clausa*) infected with Phytophthora root rot (*Phytophthora cinnamomi*) during its first year in the field. USA, ELB.

Fig. 15.2.3. Discoloration (necrosis) on or under the bark and resin soaked tissue at the root collar of sand pine (*Pinus clausa*), caused by Phytophthora root rot (*Phytophthora cinnamomi*). Florida, USA, ELB.

Fig. 15.2.4. Decayed and discoloured root collar on Port Orford cedar infected by Phytophthora root rot (*Phytophthora lateralis*). Also evident are galleries of the redwood bark beetle (Coleoptera, Curculionidae: *Phloeosinus sequoiae Hopkins*), secondary to Phytophthora infection. California, USA, DO.

Fig. 15.2.5. Discoloration (necrosis) on or under the bark on jack pine (*Pinus banksiana*), caused by Armillaria root rot (*Armillaria mellea*). USA, USDA3.

Fig. 15.2.6. Resinosis, often a first symptom of Armillaria root rot (*Armillaria ostoyae*) infection, on Douglas fir (*Pseudotsuga menziesii*). USA, SKH.

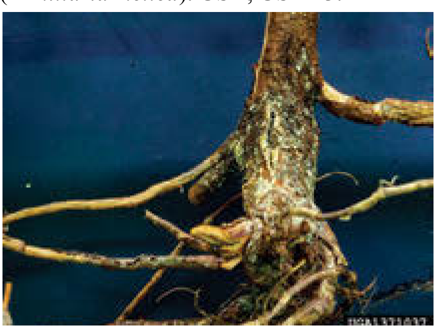

Fig. 15.2.7. Decayed and deformed roots of Norway spruce (*Picea abies)* due to Armillaria root rot (*Armillaria ostoyae*). Banská Štiavnica, Slovakia, AK.

Fig. 15.2.8. Roots of Douglas fir (*Pseudotsuga menziesii*), decayed by Armillaria root rot (*Armillaria ostoyae*). USDA3.

Fig, 15.2.9. Root collar and lower bole of ponderosa pine (*Pinus ponderosa*) with mycelial fans of Armillaria root rot (*Armillaria ostoyae*) under the bark. USDA3.

Fig. 15.2.10. Mycelial fans of *Armillaria* sp. on the lower stem of white spruce (*Picea glauca*). Wisconsin, USA, JOB.

Fig. 15.2.11. Fruiting bodies (mushrooms) of Armillaria root rot (*Armillaria* sp.). FB.

Fig. 15.2.12. Rhizomorphs of Armillaria root rot (*Armillaria* sp.) under the bark. JOB.

Additional information: Root pathogens cause problems when healthy roots of host plants come into contact with infected wood or roots underground. Root diseases primarily spread by root-to-root contact, but for some species, wind-dispersed spores, rhizomorphs or insects may play a role in transmitting the pathogen. Eventual tree mortality (resulting from blowdown or girdling of the root collar) depends on several factors such as the age and vigour of the host plant, the organism(s) involved and environmental factors that may affect the interaction of the host tree and pathogen.

Where cracks are present on roots or at the root collar, one should carefully check for discoloration and decay underneath. Armillaria can be distinguished from other root pathogens by its characteristic mycelial fans formed under the bark on infected roots, the root collar and at the base of the tree, and also by the presence of rhizomorphs. Phytophthora diagnosis can be confirmed through root and soil analysis in a laboratory. For root pathogen sampling and preservation, see Chapter 4.

15.3. Bark-feeding insect damage

Description: Dead patches of bark may indicate the presence of root-feeding insects. Examination of the roots may reveal symptoms of external feeding, especially more or less large debarked areas on the root, including frothy holes filled with boring dusts, causing girdling. Larvae may be present or not (already turned to adults).

Possible damaging agents: Insects: Larvae of Coleoptera (Buprestidae, Curculionidae: Figs. 15.3.1 – 15.3.5, Elateridae, Scarabaeidae: Figs. 15.3.6 – 15.3.9, Scolytinae), larvae and adults of mole crickets (Gryllotalpidae) and Termites (Isoptera: Fig. 15.3.10).

Fig. 15.3.1. Scots pine (*Pinus sylvestris*) root collar with a large debarked area showing resinosus due to weevil feeding (Coleoptera, Curculionidae: *Hylobius radicis*). USA, SK.

Fig. 15.3.2. Damage to roots caused by (Coleoptera, Curculionidae: *Otiorhynchus sulcatus*). Belgrade, Serbia, MG.

Fig. 15.3.3. Monterey pine (*Pinus radiata*) attacked by bark beetle (Coleoptera, Curculionidae: *Hylastes ater*) at the root collar and also infected by a black stain fungus (*Leptographium* spp.). Central Chile, WMC.

Fig. 15.3.4. Mugo pine (*Pinus mugo*) root system with breeding galleries of a weevil (Coleoptera, Curculionidae: *Hylobius pales*), the vector of Leptographium root disease (*Leptographium procerum*). USA, MAH.

Fig. 15.3.5. Slash pine (*Pinus elliottii*) roots with beetle larva feeding damage (Coleoptera, Curculionidae *Naupactus* sp.). USA, ELB.

Fig. 15.3.6. Beetle larva feeding damage (Coleoptera: Scarabaeidae) on the root system of pine (*Pinus* sp.) USA, RLA.

Fig. 15.3.7. Red pine (*Pinus resinosa*) root system eaten by May-June beetles (Coleoptera, Scarabaeidae: *Phyllophaga* sp.). Wisconsin, USA, SK.

Fig. 15.3.8. Red pine (*Pinus resinosa*) root system with feeding damage of May-June beetles (Coleoptera, Scarabaeidae: *Phyllophaga* sp.). Minnesota, USA, SK.

Fig. 15.3.9. Arborvitae liner plant (unknown species) girdled by European chafer (Coleoptera, Scarabaeidae: *Amphimallon majale*). Michigan, USA, DCa.

Fig. 15.3.10. Termite mound near the root collar of a tree (unknown species). Indonesia, MMi.

Additional information: Bark feeding insects target stressed trees, such as those weakened from disease, injuries or drought. One can extract the seedling from the ground and inspect the roots to look for debarking symptoms that are characteristic of larval feeding. If such symptoms exist, carefully inspect the soil around the seedling to find any larvae. Coleopteran beetle species chewing on roots in the larval stage often feed on foliage when adults, therefore one should also inspect the foliage of the tree. For insect sampling and preservation, see Chapter 3.

15.4. Mammal damage

Description: Bark stripped from the roots or lower stem. Roots may be severed and bark around the base of the collar eaten, or the bottom 50 cm of the stem may be ringbarked. Tunnelling by moles may cause desiccation of seedlings and transplant roots; soil heaps may bury young plants.
Possible damaging agents: Mammals: mice and rats (Fig. 15.4.1), squirrels, voles, rabbits, moles, badgers or wild boar (Fig. 15.4.2).

Fig. 15.4.1. Girdling of a small conifer tree by mice, voles or rats. Minnesota, USA, RLA.

Fig. 15.4.2. Scots pine (*Pinus sylvestris*) root systems damaged by wild boar. Dubno, Ukraine, VK.

Additional information: Rabbits can be particularly harmful when herbs and grasses are under snow cover. Rabbit damage can occur throughout the year, but tends to increase in winter and early spring. Bark stripping is most common in severe winters and late springs when snow persists. Field voles can be significant browsers of tree seedlings and, where they occur in high numbers, will often ring-bark saplings. Wood mice and squirrels eat tree seeds and bank voles may eat smaller tree seeds. For root sampling and preservation, see Chapter 4.

15.5. Root and collar-tunnelling

Description: When cut, tunnels or galleries are visible in the cambial tissue under the bark of the roots and/or collar. Severe damage may lead to wilting and, eventually, death of the tree.

Possible damaging agents: Insects: Larvae of Coleoptera (Buprestidae, Cerambycidae: Figs. 15.5.2. – 15.5.3) and Lepidoptera (Hepialidae, Sesiidae: Fig. 15.5.1).

Fig. 15.5.1. Persimmon borer (Lepidoptera, Sesiidae: *Sannina uroceriformis*) entrance holes and frass at root collar. USA, JS.

Fig. 15.5.2. Collar of a pine tree (*Pinus* sp.) damaged by weevil feeding (Coleoptera, Curculionidae: *Hylobius radicis*). USA, MMi.

Fig. 15.5.3. Wilting of pine trees (*Pinus* sp.) due to weevil damage at the root collar (Coleoptera, Curculionidae: *Hylobius radicis*). USA, MMi.

Additional information: The speed and severity of symptom development depends on the amount of damage, the species of tree and soil type. For root sampling and preservation see Chapter 4, and for insect sampling see Chapter 3.

15.6. Abiotic damage

Description: A variety of damage to roots can occur due to abiotic factors and human activities. Some of these are described below:

Possible damaging agents:

- **Windthrow** (Figs. 15.6.2, 15.6.3): strong wind or storms may uproot trees, especially those with underdeveloped or shallow root systems. All thrown trees in an area typically fall in the same direction.
- **Excessive irrigation** (flooding) (Fig. 15.6.4): leads to poor root establishment and a gradual decline in health condition of the plant, iron-induced chlorosis (yellowing), and weak or stunted growth. Can mimic drought-stress symptoms. Poor soil drainage can promote root decay and predispose the plant to infection by root disease pathogens.
- **Excessive heat** (Figs. 15.6.1, 15.6.5, 15.6.6): slow burn can be very damaging and kill the living cambium layer in the trunk and whole root collar area. In this case, when the cambium is killed, the top of the tree will soon die. High temperatures just above the soil due to solar radiation may damage young plants.
- **Planting too deeply** (Fig. 15.6.12): may cause bark deterioration at the soil line, promotes infection by decay fungi, slows the growth of trees, causes thinning of the tree canopy, early dieback, inhibits good root establishment, and can cause eventual tree mortality. Causes: re-potted nursery stock, depth of planting hole too deep, or a buried root.
- **Soil compaction** (Fig. 15.6.10): a major problem after construction. Its effect can last for years with slow gradual improvement. When the soil is compressed by heavy construction equipment, vehicles, or heavy pedestrian traffic, the soil structure is damaged which can reduce plant growth and even promote the death of mature, well-established woody plants.
- **Mechanical root damage** (Figs. 15.6.7 – 15.6.11): any digging, trenching, or roto-tilling within the root area of established trees or shrubs can cause damage to roots. Most feeder roots of trees or shrubs are within the upper centimetres of the soil. Root damage may affect the plant for several months or even years thereafter, depending on the level of stress that occurred.

Fig. 15.6.1. Loblolly pine (*Pinus taeda*) roots with heat lesions occur from high groundline temperatures. USA, ELB.

Fig. 15.6.2. Windthrow in a pole-sized red pine stand (*Pinus resinosa*). USA, JOB.

Fig. 15.6.3. Loblolly pine (*Pinus taeda*) uprooted as a result of windthrow. Alabama, USA, DS.

Fig. 15.6.4. Root systems of ponderosa pine (*Pinus ponderosa*) in flooding/high water. Utah, USA, USDA4.

Fig. 15.6.5. Longleaf pine (*Pinus palustris*) root resinosus after fire, with weevil feeding damage (Coleoptera, Curculionidae: *Hylastes* spp.). Florida, USA, GJL.

Fig. 15.6.6. Fire damage to roots and root collar of longleaf pine (*Pinus palustris*). Florida, USA, GJL.

Fig. 15.6.7. Mechanical damage to lower trunk of a pine tree (*Pinus* sp.) from a nylon bag and cord. USA, WMB.

Fig. 15.6.8. Mechanical damage to Norway spruce (*Picea abies*) roots due to logging activity. Vygoda, Ukraine, VK.

Fig. 15.6.9. Damage caused by root cutting and trenching. USA, JP.

Fig. 15.6.10. Poor planting and planning limits root growth. USA, AKo.

Fig. 15.6.11. Mound of soil heaped around a tree and a truck parked on top of the tree roots, causing potential soil compaction. USA, JH.

Fig. 15.6.12. Japanese black pine (*Pinus thunbergii*) with deformed roots from planting too deeply. USA, EB.

<u>Additional information</u>: Some of the most difficult plant problems to diagnose may not be caused by an insect pest or disease, but are rather related to management and site conditions.

15.7. Root sucking insect damage

Description: Presence of tiny apterous, fluffy insects on the roots, with color ranging from whitish to yellowish or reddish, often in large groups. White wax and/or dust powdered with grey may also indicate presence of such insects. Their presence may cause wilting and discoloration of the plant.
Possible damaging agents: Insects: Hemiptera (Pseudococcidae (root mealybugs), Phylloxeridae and Aphididae (root aphid): Figs. 15.7.1 – 15.7.4).

Fig. 15.7.1. Fraser fir (*Abies fraseri*) root system with a root aphid infestation (Hemiptera, Aphididae: *Prociphilus americanus*). USA, ERD.

Fig. 15.7.2. Declining young Fraser fir (*Abies fraseri*) with a root aphid infestation (Hemiptera, Aphididae: *Prociphilus americanus*). USA, ERD.

Fig. 15.7.3. Australian pine (*Casuarina equisetifolia*) with a colony of pineapple mealybug (Hemiptera, Pseudococcidae: *Dysmicoccus brevipes*). Gede, Kenya, WMC.

Fig. 15.7.4. Mealybug (Hemiptera, Pseudococcidae: *Rhizoecus dianthi*) on roots in the laboratory. USNCSIP.

Additional information: Root aphids are similar to aboveground aphids, but feed on the roots instead of leaves and stems. Root mealybugs are common in containers and well-drained soils. The mealybugs have a thin, uniform waxy coating and lack the terminal wax filaments typical of their foliar-feeding relatives. For root sampling and preservation see Chapter 4, and for insect sampling see Chapter 3.

15.8. Root knot

Description: Presence on the root system of galls or thickenings, ranging from 1 to 10 mm in diameter and exhibiting a large variety of shapes. They can be observed at the soil line or below the soil surface and can be caused by diverse agents, but especially nematodes (galls called "knots"), bacteria and insects. Although resembling healthy wood bark, the galls do not have annual growth rings, which can be seen when cut. Galls are commonly tiny and smooth on young plants, but on mature trees they are commonly rough. In severe infestations, heavily galled roots may rot away, leaving a poor root system with a few large galls. Severely affected plants will often wilt readily.

Possible damaging agents: **Nematoda:** Heteroderidae: *Hoplolaimus*, *Meloidogyne* spp. (Figs. 15.8.1 – 15.8.4), **Bacteria**: crown gall bacteria (e.g., *Rhizobium radiobacter*: Figs. 15.8.5 – 15.8.6), **Insects**: (Hymenoptera, Cynipidae), **Fungi**.

Fig. 15.8.1. Example of root system damage by root-knot nematode (Nematoda, Heteroderidae: *Meloidogyne* sp.). CU.

Fig. 15.8.2. Example of root system damage by root-knot nematode (Nematoda, Heteroderidae: *Meloidogyne* sp.). CU.

Fig. 15.8.3. Light micrograph of a female lance nematode (Nematoda, Hoplolaimidae: *Hoplolaimus* sp.). JDE.

Fig. 15.8.4. Juvenile nematode hatching from cyst (Nematoda, Heteroderidae: *Heterodera filipjevi*). BH.

Fig. 15.8.5. *Thuja* spp. roots with galls induced by crown bacteria (*Rhizobium radiobacter*). Belgrade, Serbia, MG.

Fig. 15.8.6. Thickening of the collar roots of Douglas fir (*Pseudotsuga menziesii*) due to crown bacteria (*Rhizobium radiobacter*). PSU.

Additional information: Cut the gall to assess the presence or absence of insect larvae and nematodes. Insect-caused galls have larvae inside, or exit holes on the surface if adult insects have emerged, but in any case galleries or cases are present. In case of absence of both organisms, bacteria have to be suspected and confirmation requires testing by specialists.

Root-knot nematodes do not produce any specific above-ground symptoms. Affected plants have an unhealthy appearance and often show symptoms of stunting, wilting or chlorosis (yellowing). Symptoms are particularly severe when plants are infected soon after planting. However, more commonly, nematode populations do not build up until late in the season and plants grow normally until they reach maturity. Nematode damage is common in nurseries where seedlings are grown outdoors in soil for 1-3 years. Root-knot nematode symptoms on plant roots can be dramatic. Infection of young plants may be lethal, while infection of mature plants causes decreased yield.

Crown gall bacteria can survive for long periods in the soil. They enter young plants through wounds and these are commonly infected in nurseries by transplanting. Bacteria can enter established trees through growth cracks or wounds caused by cultivation, mowing, weed trimmers and certain natural wounds. For insect sampling and preservation, see Chapter 3 and for pathogen sampling and preservation, see Chapter 4.

15.9. Damage caused by migratory ecto-endoparasitic nematodes

Description: Migratory ecto-endoparasitic nematodes feed on root tips or bore into roots. Symptoms of damage include sparse, stunted or misshapen roots, needle and leaf chlorosis and stunting of the shoots.
Possible damaging agents: Plant parasitic nematodes: *Helicotylenchus* spp., *Hemicycliophora* spp., *Longidorus* spp., *Paratrichodorus* spp., *Paratylenchus* spp., *Pratylenchus* spp., *Rotylenchus* spp., *Trichodorus* sp., *Xiphinema* spp. (Figs. 15.9.1 – 15.9.4).

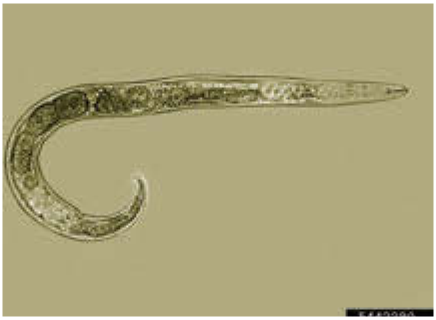

Fig. 15.9.1. Light micrograph of a pin nematode (Nematoda, Tylenchulidae: *Paratylenchus* sp.). JDE.

Fig. 15.9.2. Example of root damage by reniform nematodes (Nematoda, Hoplolaimidae: *Rotylenchus reniformis*). JDE.

Fig. 15.9.3. Light micrograph of a spiral nematode (Nematoda, Hoplolaimidae: *Helicotylenchus* sp.), USA, JDE.

Fig. 15.9.4. Example of roots damaged by dagger nematode. (Nematoda, Longidoridae: *Xiphinema* sp.), USA, JDE.

Additional information: For root sampling and preservation, see Chapter 4.