

10

Damage to roots and collars of broadleaf woody plants

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10.1. 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: Agaricales (Fig. 10.1.1), Polyporales (Figs. 10.1.2, 10.1.3, 10.1.4, 10.1.6), Hymenochaetales (Figs. 10.1.5).



Fig. 10.1.1. Imeretian oak (*Quercus imeretina*) with no obvious symptoms/damage on collar, but fruiting body of beefsteak or ox-tongue fungus (*Fistulina hepatica*). Ajameti, Republic of Georgia, IM.



Fig. 10.1.2. Unknown broadleaf tree with a fruiting body of Dryad's Saddle mushroom (*Cerioporus squamosus*). USA, CEY.



Fig. 10.1.3. Stem of birch (*Betula* sp.) with a hard, woody-textured, perennial fruiting body (basidiocarp) of a butt rot fungus (*Ganoderma applanatum*). Alaska, USA, TL.



Fig. 10.1.4. Stem of Linden (*Tilia* sp.) with fruiting bodies of a southern bracket perennial fungus (*Ganoderma australe*) at its base. Slovakia, AK.



Fig. 10.1.5. Stem of sycamore maple (*Acer pseudoplatanus*) with fruiting bodies of polypore shelf-fungi (*Oxyporus populinus*). Skole, Ukraine, VK.



Fig. 10.1.6. Base of European beech (*Fagus sylvatica*) with fruiting bodies of Maitake mushroom (*Grifola frondosa*). Lviv, Ukraine, VK.

Additional information: Root and butt rots are wood-decay diseases mainly caused by Basidiomycota fungi. Entry of these organisms 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 broadleaf trees this might include reduced increment growth, chlorosis (yellowing) and smaller-sized leaves, and dieback. 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 can appear stringy, spongy, laminated (separating along annual rings), or mottled, with or without formation of black zone lines. Wood decayed by brown rot fungi appear brown in color, dry, and often crumbly with horizontal and vertical fissures. For root pathogen sampling and preservation, see Chapter 4.

10.2. Root rot

Description: Most root diseases cause crown symptoms including chlorosis (yellowing), smaller than average sized leaves, thinning of foliage, and reduced increment growth. Exudation (bleeding) on roots or at the base of trees may occur on some tree species and can indicate the presence of a root disease pathogen. 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 10.1). 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: *Phytophthora* spp.: Figs. 10.2.1 – 10.2.5), **Fungi:** Basidiomycota (Agaricales: *Armillaria* spp.: Figs. 10.2.6 – 10.2.8).



Fig. 10.2.1. Roots and collar of European beech (*Fagus sylvatica*) with discoloration (necrosis) on and under the bark, caused by *Phytophthora* root rot (*Phytophthora cambivora*). Slovakia, AK.

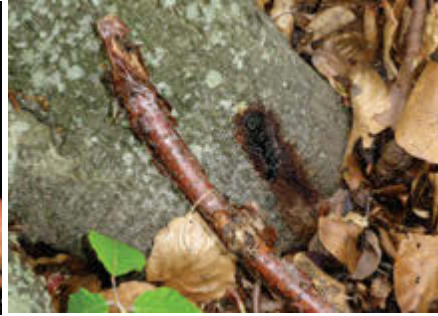


Fig. 10.2.2. European beech (*Fagus sylvatica*) root collar with a bleeding (exudates) lesion caused by *Phytophthora* root rot (*Phytophthora cambivora*). Torup, Sweden, JW.



Fig. 10.2.3. Cracks in the bark of a European beech (*Fagus sylvatica*) root showing bleeding (*Phytophthora* sp.). Austria, TC.



Fig. 10.2.4. Decayed roots of sweet chestnut (*Castanea sativa*) affected by root rot (*Phytophthora cinnamomi*). Portugal, ACM.



Fig. 10.2.5. European beech (*Fagus sylvatica*) roots and root collar area decayed from *Phytophthora* root rot (*Phytophthora cambivora*). Slovakia, AK.



Fig. 10.2.6. Girdled and decayed root system of peach (*Prunus persica*) from *Armillaria* root rot (*Armillaria tabescens*). Florida, USA, FDPI.



Fig. 10.2.7. Cracks in the bark around the root collar of European beech (*Fagus sylvatica*) caused by *Armillaria* root rot (*Armillaria* sp.). Slovakia, AK.



Fig. 10.2.8. Mycelial fans of *Armillaria* root rot (*Armillaria* sp.) under the bark. USA, RLA.



Fig. 10.2.9. European beech (*Fagus sylvatica*) tree showing fruiting bodies (mushrooms) of *Armillaria* root rot (*Armillaria mellea*). Slovakia, AK.



Fig. 10.2.10. Dead American elm (*Ulmus americana*) debarked to show rhizomorphs of *Armillaria* root rot (*Armillaria gallica*). USA, 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, 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. Often, trees subjected to other stress biotic and/or abiotic stress factors are secondarily affected by root disease. Once infected, trees are predisposed to attack by other pests and decay fungi. For root pathogen sampling and preservation, see Chapter 4.

10.3. Bark-feeding insect damage

Description: Dead, eaten root sections may indicate the presence of root-feeding insects. Examination of the roots can reveal symptoms of external feeding, especially a more or less large debarked area on the root, including frothy holes filled with boring dust, causing girdling. Larvae may or may not be present (they may have already developed into adults).

Possible damaging agents: Insects: Larvae of Coleoptera (Buprestidae, Curculionidae: Figs. 10.3.5, Elateridae: Fig. 10.3.1, Scarabaeidae: Figs. 10.3.2, 10.3.3, Scolytinae), Diptera (Tipulidae) and Lepidoptera (Noctuidae and other families); adults of Coleoptera (Curculionidae: Fig. 10.3.4); larvae and adults of mole crickets (Gryllotalpidae) and Termites (Isoptera: Fig. 10.3.6).



Fig. 10.3.1. Peanut (*Arachis hypogaea*) seedling with root feeding damage caused by click beetle larvae (Coleoptera, Elateridae: *Conoderus* sp.). USA, SLB.



Fig. 10.3.2. Dead oak seedling (*Quercus robur*) with heavy feeding damage on roots by a scarab beetle larva (grub – visible on the right) (Coleoptera, Scarabaeidae: *Holotrichia* sp.). Sentinel planting, Fuyang, China, AR.



Fig. 10.3.3. European beech (*Fagus sylvatica*) roots with bark eaten by scarab beetle grubs (Coleoptera, Scarabaeidae: *Melolontha melolontha*). Javoriv, Ukraine, VK.



Fig. 10.3.4. Root damage on *Photinia*, caused by weevil larvae and adult (Coleoptera Curculionidae: *Otiorhynchus apenninus*) in a container of plants for planting. Tivat, Montenegro, MG.



Fig. 10.3.5. Root of common hop (*Humulus lupulus*), infested with weevil larvae (Coleoptera, Curculionidae: *Otiorhynchus sulcatus*). Idaho, USA, DG.



Fig. 10.3.6. Hollowed-out pecan roots (*Carya illinoensis*) at a seedling nursery, where mortality was caused by termites (Isoptera). Oklahoma, USA, JS.

Additional information: One can extract the dying seedling from the ground and inspect the roots to look for debarking symptoms, characteristic of insect feeding. If such symptoms exist, carefully inspect the soil around to find any larvae. The 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 root insect sampling and preservation, see Chapter 3.

10.4. Mammal and bird damage

Description: Bark can be stripped on roots or lower stem. Root cutting and bark eating around the base of the collar, ringbarking the bottom 50 cm of the stem. 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. 10.4.1), squirrels (Fig. 10.4.2), voles (Fig. 10.4.4), rabbits, moles and badgers, **Birds** (Fig. 10.4.3).



Fig. 10.4.1. *Ginkgo biloba* roots debarked by mice. Skole, Ukraine, VK.



Fig. 10.4.2. Broadleaf trees stripped and debarked by squirrels (*Tamiasciurus hudsonicus*) from the root collar to the height of the surrounding vegetation. USA, MDNR.



Fig. 10.4.3. Woodpecker damage at the base of a European beech (*Fagus sylvatica*). CS.



Fig. 10.4.4. Root systems girdled by vole (*Microtus* sp.) feeding at the base of plants. USA, MAH.

Additional information: Inspect the bark carefully, especially if early spring weather was cold. Bark stripping is most common in severe winters and late spring if snow persists. Rabbits can be particularly harmful when herbaceous plants and grasses are covered by snow. Rabbit damage can occur throughout the year, but tends to increase in winter and early spring. Field voles can be significant browsers of tree seedlings and, where they occur in high numbers, will often ring-bark saplings. For root sampling and preservation, see Chapters 3 and 4.

10.5. Root and collar-tunnelling

Description: Roots and/or root collar with tunnels or galleries under the bark in the cambial tissue. These tunnels are visible when cut open and exposed.

Possible damaging agents: Insects: Larvae of Coleoptera (Buprestidae, Cerambycidae: Figs. 10.5.1 – 10.5.5, Curculionidae) and Lepidoptera (Hepialidae, Sesiidae: Fig. 10.5.6).



Fig. 10.5.1. Root and lower stem of Sassafras (*Sassafras albidum*) cut to show galleries caused by larvae of longhorn beetles (Coleoptera, Cerambycidae: *Oberea ruficollis*). USA, JS.



Fig. 10.5.2. Roots of Pecan (*Carya illinoensis*) sectioned to show galleries caused by a larva of longhorn beetle (Coleoptera, Cerambycidae: *Prionus* sp.). USA, JAP.



Fig. 10.5.3. Eastern cottonwood (*Populus deltoids* ssp. *deltoides*) root with a tunnel made by a longhorn beetle larva (Coleoptera, Cerambycidae: *Plectrodera scalator*). USA, JS.



Fig. 10.5.4. Main root of Eastern cottonwood (*Populus deltoides* ssp. *deltoides*) sliced to show a longhorn beetle larva (Coleoptera, Cerambycidae: *Plectrodera scalator*). USA, JS.



Fig. 10.5.5. Unidentified broadleaved tree with lower stem and roots sliced to show galleries and pupae of longhorn beetles (Coleoptera, Cerambycidae: *Desmocerus palliatus*). USA, JS.



Fig. 10.5.6. Unknown broadleaf tree with damage on roots and root collar due to larvae of moth borers (Lepidoptera, Sesiidae: *Sannina uroceriformis*). USA, JS.

Additional information: Diagnosing the causal agent of damage can be difficult because it may take five to seven years for symptoms to appear. The speed and severity of symptom development depends on the amount of damage, the species of tree and soil type. For root insect sampling and preservation, see Chapter 3.

10.6. Abiotic damage

Description: A variety of root damage may occur due to abiotic factors and human activities. These are detailed below:

Possible damaging agents:

- **Lower trunk damage or collar damage** (Figs. 10.6.1 – 10.6.7): some decline and dieback problems in woody plants are caused by stem or trunk damage which may be overlooked because it is very close to the ground or just under the ground surface. Examples of such damage may be caused by wind, cold, frost cracking, excessive mulch, mowers and weed trimmers.
- **Girdling roots** (Figs. 10.6.3, 10.6.12): visible, overlapping roots, progressive thinning of tree canopy, branch dieback, early tree death. Causes: root circling induced by plant containers, the width of planting holes may be too narrow or the use of root-bound nursery stock.
- **Excessive irrigation (flooding)** (Fig. 10.6.9): 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 result in root decay and predispose the plant to infection by root disease pathogens.
- **Poor soil drainage** (Fig. 10.6.12): predisposes plants to infection by root pathogens when plants are grown in wet sites.
- **Planting too deep** (Fig. 10.6.12): 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. 10.6.9): is 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. 10.6.10 – 10.6.11): 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. 10.6.1. Shallow root system of silver maple (*Acer saccharinum*) damaged by wind in a floodplain forest. USA, SK.

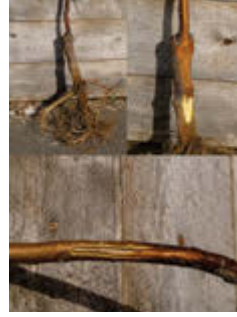


Fig. 10.6.2. Lower trunk and collar part of young apple tree (*Malus domestica*) damaged by cold injury (low temperature). USA, BW.



Fig. 10.6.3. Root systems of black willow (*Salix nigra*) in flooding/high water near Mississippi river. USA, BL.



Fig. 10.6.4. Bark cut away from a black walnut (*Juglans nigra*) root collar to show freezing damage and subsequent cankering (killed cambium) from winter injury. Minnesota, USA, LH.



Fig. 10.6.5. Ash tree (*Fraxinus* spp.) with roots exposed. Earthworm activity depletes the leaf litter on the forest floor. Canada, RL.



Fig. 10.6.6. Deformed root wads due to hard pan and windthrow from a hurricane. Conecuh NF, USA, TH.



Fig. 10.6.7. White oak (*Quercus alba*) showing root lifting, soil heaving, and windthrow. USA, DLC.



Fig. 10.6.8. Stem girdling due to roots growing around the stem, thereby suffocating the tree. USA, GMB.



Fig. 10.6.9. Soil compaction due to heavy vehicle use. USA, PBe.



Fig. 10.6.10. Red maple (*Acer rubrum*) roots, mechanically damaged by a lawnmower. RC.



Fig. 10.6.11. Root damage caused by digging and trenching during sidewalk construction. USA, AKo.



Fig. 10.6.12. A tree that was planted too deeply, potentially causing poor root development. Kentucky, USA, WF.

Additional information: The most difficult plant problems to diagnose are usually not caused by an insect pest or disease, but rather related to management and site conditions.

10.7. Root sucking insect damage

Description: Presence on the roots of tiny, apterous fluffy insects with color ranging from whitish to yellowish or reddish, often in large patches. 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 aphids: Fig. 10.7.1)).



Fig. 10.7.1. Roots of cabbage (*Brassica oleracea*) with wax bloom due to root aphids (Hemiptera Aphididae: *Pemphigus populitransversus*). USA, ANS.

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 insect sampling and preservation, see Chapter 3.

10.8. 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. They can be caused by diverse agents but especially nematodes (galls called “knots”), bacteria and insects. Although resembling healthy wood bark, the galls do not show annual growth rings when cut. Galls are commonly tiny and smooth on young plants, but on mature trees they are usually 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: *Meloidogyne* spp.: Figs. 10.8.1 – 10.8.4), **Bacteria**: crown gall bacteria (e.g., *Rhizobium radiobacter*: Figs. 10.8.5 – 10.8.7), **Insects**: (Hymenoptera, Cynipidae: Fig. 10.8.8), **Fungi**.



Fig. 10.8.1. Peach (*Prunus* spp.) root system heavily galled by root-knot nematodes (Nematoda Heteroderidae: *Meloidogyne arenaria*). USA, JDE.



Fig. 10.8.2. Root of Hedge cotoneaster (*Cotoneaster lucidus*) occupied by a female root-knot nematode (Nematoda Heteroderidae: *Meloidogyne ardenensis*). Norway, BH.



Fig. 10.8.3. Flowering dogwood (*Cornus florida*) with root galls due to root-knot nematodes (Nematoda Heteroderidae: *Meloidogyne* sp.). USA, ELB.

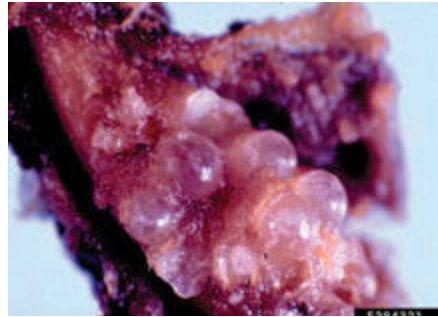


Fig. 10.8.4. Pecan (*Carya illinoensis*) roots galled by root-knot nematodes (Nematoda Heteroderidae: *Meloidogyne partityla*). USA, JWJ.



Fig. 10.8.5. Root collar of *Rosa* (*Rosa* spp.), thickened due to a crown bacterium (*Rhizobium radiobacter*). Serbia, Belgrade, MG.



Fig. 10.8.6. European black alder (*Alnus glutinososexua*) root collar and roots with presence of galls due to crown bacteria (*Rhizobium radiobacter*). Slovakia, AK.



Fig. 10.8.7. Pecan (*Carya illinoensis*) root galled by crown bacteria (*Rhizobium radiobacter*). USA, CU.



Fig. 10.8.8. Root of oak (*Quercus* sp.) with galls caused by asexual generation of a gall wasp (Hymenoptera, Cynipidae: *Biorhiza pallida*). Hungary, CG.

Additional information: Cut the gall to assess the presence or absence of insect larvae or nematodes. Insect-caused galls have larvae inside or exit holes on the surface if adult insects have emerged, but in both cases galleries or cases are present. For insect preservation, see chapter 3. In case of absence of insects or nematodes, bacteria may be the cause and tests by specialists are necessary for confirmation.

Root-knot nematodes do not produce any specific aboveground 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 in outdoor soil for 1-3 years (as opposed to plants grown in pots). 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.

10.9. Damage caused by migratory ecto-endoparasitic nematodes

Description: Migratory ecto-endoparasitic nematodes feed on tips of the roots or bore into roots. Symptoms of damage include sparse, stunted or misshapen roots, leaf chlorosis and stunting of the shoots.

Possible damaging agents: Plant parasitic nematodes: harmful for seedlings in nurseries (*Longidorus maximus*, *Trichodorus* spp., *Xyphinema* spp.), associated with trees in plantations and natural forests (*Helicotylenchus* spp., *Longidorus* spp., *Xyphinema* spp.): Figs. 10.9.1 – 10.9.2).

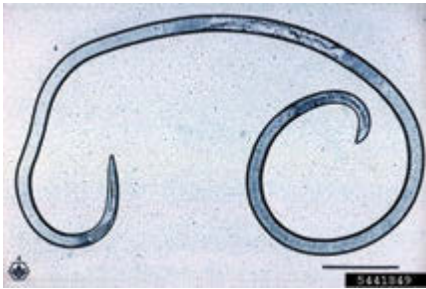


Fig. 10.9.1. Adult female of needle nematode (*Longidorus elongatus*). MP.



Fig. 10.9.2. Vine roots (*Vitis* sp.) damaged by a dagger nematode (*Xyphinema* spp.). USA, JDE.

Additional information: For root sampling and preservation, see Chapter 3.