8

Damage to stems, branches and twigs of broadleaf woody plants

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8.1. Root and stem rot

Description: External, aboveground symptoms on individual trees are variable and may include suppressed growth, reduced vigour, discoloured or smaller than average-sized foliage, premature leaf shedding, branch dieback, crown thinning, bleeding lesions on the lower stem and root collar, wilting and eventual death of trees. It is common for root and butt rots to remain unnoticed until annual or perennial (conks) fruiting bodies appear on branches or the main trunk.

Possible cause of damage: Oomycetes (water moulds: Figs. 8.1.1 – 8.1.3);

Fungi: Basidiomycota (Figs. 8.1.4 – 8.1.7) and Ascomycota (Fig. 8.1.8).

Fig. 8.1.1. Root collar of European beech (*Fagus sylvatica*) with a bleeding bark lesion caused by an Oomycete (*Phytophthora cambivora*). Bavaria, Germany, TC.

Fig. 8.1.2. Stem of grey alder (*Alnus incana*) with bark lesion caused by an Oomycete (*Phytophthora x alni*). Tyrol, Austria, TC.

Fig. 8.1.3. European chestnut (*Castanea sativa*) showing bark lesion caused by an Oomycete (*Phytophthora cinnamomi*). Montegrappa, Italy, TC.

Fig. 8.1.4. Collar of European beech (*Fagus sylvatica*) with fungal fruiting bodies (*Polyporus squamosus*). Switzerland, WSL.

Fig. 8.1.5. Stem of common ash (*Fraxinus excelsior*) with brown cubical stem rot caused by a fungus (*Laetiporus sulphureus*). Lviv, Ukraine, VK.

Fig. 8.1.6. Armillaria root rot (*Armillaria* sp.) on oak (*Quercus robur* "Fastigiata"). Akershus county, Norway, VT.

Fig. 8.1.7. White mycelial fans and necrotic tissue caused by Armillaria root rot (*Armillaria* sp.) on cherry (*Prunus avium*). Hordaland county, Norway, VT.

Fig. 8.1.8. A shows European beech (*Fagus sylvatica*) attacked by the fungus brittle cinder (*Kretzschmaria deusta*). B and C show the perfect and imperfect stages of the fungus, respectively. Larvik, Norway, VT.

Additional information: Root and butt rot fungi are particularly difficult to detect and manage. Most of them occur as parasites on living trees and as

saprophytes on dead organic matter. They infect the host tree through wounds in the lower part of the trunk or root, or penetrate healthy roots directly. In some cases, they kill the cambium at the root collar, whereas in other cases they decay the heart - or sapwood of the roots (root rot) or at the stem base (butt rot). Eventually, the rot may expand to the stem of the tree (stem rot). See also 10.1.

Symptoms may not become visible until a late stage of the infection (i.e. when most of the root system is already affected). Similarly, fruiting bodies of the fungus infecting the tree may develop several years after infection. Removing these fruiting bodies will not heal the tree, since the fungus is living internally in the wood. The process of decay may take many years, with some older trees containing several different columns of decay. Frequently, trees infected by root and butt rot pathogens are uprooted or broken by, for example, wind or snow. For pathogen collection and preservation, see Chapter 4.

8.2. Vascular diseases

Description: Pathogens causing vascular diseases invade the active xylem, causing a failure of the water transport to the foliage. Early symptoms appear as yellowing and wilting (flagging) of leaves on individual branches. As the branches die, leaves often turn brown, curl up, and eventually drop off. A brown or green staining is seen in the outer layer of the wood. This is due to the presence of fungal mycelium in the vessels and to a discoloration of the vessel walls. In cross section, the staining may appear as a circle or have an irregular shape.

Possible damaging agents: Fungi: Ascomycota (Hypocreales, Ophiostomales) (Figs. 8.2.1 – 8.2.4).

Fig. 8.2.1. Sapwood of a maple tree (*Acer* sp.) with necrosis under the bark, symptoms of verticillium wilt (*Verticillium* sp.). USA, WJ.

Fig. 8.2.2. Brown discoloration in the wood of a sycamore (*Acer pseudoplatanus*), caused by a wilt fungus (*Verticillium* sp.). Traun, Upper Austria, Austria, TC.

Fig. 8.2.3. Lower trunk portion of red maple (*Acer rubrum*) with outer tissue cut away to reveal discoloured xylem tissue due to verticillium wilt (*Verticillium* sp.). Note: no discoloration or necrosis on the bark and no fruiting bodies. Kentucky, USA, PB.

Fig. 8.2.4. Brown discoloration in the wood of a pedunculated oak (*Quercus robur*), caused by a wilt fungus (*Ophiostoma roboris*). Sambir, Ukraine, VK.

Additional information: Spores of fungi causing wilt diseases are frequently vectored by beetles and deposited in galleries and tree wounds. To detect staining in the wood, the bark has to be removed and the sapwood inspected. For pathogen collection and preservation, see Chapter 4.

8.3. Frass and dust on the bark and/or at the tree base

Description: Signs of insect feeding and boring on bark or into wood. The colour of dust and frass varies, depending on the location of feeding damage. Visible damage may include wilted and discoloured leaves, crown thinning, the occurrence of insect tunnels under the bark, exit holes in the bark and patches of bark removed by woodpeckers.

Possible damaging agents: **Insects:** Adults and larvae of Coleoptera (Curculionidae, Scolytinae, bark and ambrosia beetles; Cerambycidae, longhorn beetles: Figs. 8.3.1 – 8.3.4), larvae of Hymenoptera (Siricidae wood wasps) and Lepidoptera (Cossidae: Figs. 8.3.5 – 8.3.6, Sesiidae).

Fig. 8.3.1. *Fraxinus chinensis* stem basis with red sawdust as a sign of internal damage by larvae of long-horned beetle (Coleoptera, Cerambycidae: *Anoplophora chinensis*). Sentinel nursery, Fuyang, China, AR.

Fig. 8.3.2. Yellow frass at base of a black locust tree (*Robinia pseudoacacia*) as a symptom of attack by long-horned beetle larvae (Coleoptera, Cerambycidae: *Megacyllene robiniae*). USA, JS.

Fig. 8.3.3. Fibrous frass at the base of an eastern cottonwood tree (*Populus deltoides* ssp. *deltoides*) due to internal damage by long-horned beetle larvae (Coleoptera, Cerambycidae: *Plectrodera scalator*). USA, JS.

Fig. 8.3.4. Stem of unknown species with larval frass of long-horned beetle (Coleoptera, Cerambycidae: *Anoplophora glabripennis*). Ithaca (in laboratory), USA, GC.

Fig. 8.3.5. Stem base of unknown species showing sawdust mixed with frass of xylophagous moth larvae (Lepidoptera, Cossidae: *Cossus cossus*). Kecskemét, Hungary, GC.

Fig. 8.3.6. Trunk of elm (*Ulmus* sp.) showing lateral feeding and brownish frass expelled from a gallery tunnelled underneath bark by xylophagous moth larvae (Lepidoptera, Cossidae: *Prionoxystus robiniae*). USA, JS.

Additional information: To determine the causal agent of the damage look above the base of the tree to find holes in the bark and remove the bark to uncover the gallery and collect insects (adults, larvae). For insect collection and preservation, see Chapter 3.

8.4. Abiotic damage

Description: A large variety of damage to stems, branches and twigs occurs due to abiotic factors; these are detailed below (Figs. 8.4.1 – 8.4.6).

Possible damaging agents:

Frost: Stem and trunk damage: growth loss and a general weakening of the tree.

- Winter frost may cause stem and trunk damage. This damage may occur in the form of cankers, cracks, and scabby bark. Generally, damage occurs on the sun-exposed side of the tree. Cracks may be closed over by contiguous living bark, or may form cankers that bridge the wound with burls and ridges (frost ribs). On trunks, bulging frost cracks run vertically and start at wounds or branch stubs. The cambium can be cut between dead and live stem zones and examined for dark brown discoloration.
- Frost can cause tree mortality if the tree is girdled with cankers. Reduced growth from terminal bud damage and top damage can also occur.

Snow: Bent main stems, branch stripping or breakage, stem breakage, or uprooting.

- Snow damage symptoms include temporarily or permanently bent main stems, depending on duration and movement of the snow pack and branch stripping or breakage, stem breakage, or uprooting. Symptoms are seen in small groups or on scattered individual trees in affected stands. Older trees can suffer from top breakage.

Ice: Abrasion of the main stem.

- Windblown ice crystals corrode portions of the main stem above the snowline. Affected areas of stem have a smooth appearance.

Hail: Stripped branches, stem lesions, scars and bruises, ragged crowns.

- Hail damage symptoms can be seen over a broader area and consist of stripped branches, stem lesions, scars and bruises on the upper surface of branches or tattered, ragged crowns with missing foliage and buds. Damage symptoms are aligned in one direction. Buds, foliage, and branches litter the ground.

Wind: Broken branches, breaking off or uprooting of the tree, reduced growth.

- Strong winds can cause branches to break off or uproot the entire tree. Uprooted trees lie parallel, often with a large mass of roots and soil attached. Damage can be in small areas or widely distributed. Susceptible trees are often diseased, along the margin of a damaged area, have shallow roots because of a high water table or shallow soils, or are stressed by other factors, such as poor drainage.

Wounds: Bark removal, gouges, cracks, cankers in the bark, blackened carbon.

Summer and winter sun-scald: Wounds, cankers.

- Summer sun-scald is heat injury to the exposed bark during the summer months. The bark will die and a canker forms around the damaged area. The wound or cankered area is an excellent location for decay fungi and other harmful fungi to enter the tree and cause further damage or permanent defects.

- Winter sun-scald is injury from rapid changes in bark temperature during cold sunny winter days. Exposed darker bark becomes much warmer on the sunny side of the tree than the air temperature during the afternoon, but cools very rapidly after sunset. These temperature changes can result in bark injury that can also result in canker formation.

Fire: Fire wounds are identified by charred and blackened bark. Fire injury to foliage can be from direct burning or from radiant heat. Mortality is common, especially if stems are affected.

Mechanical damage: Mechanical wounds, typically caused by logging activities, are commonly found as gouges on the lower trunk.

Fig. 8.4.1. Scars and wounds on the upper surface of ginkgo tree (*Ginkgo biloba*) twigs or tattered lesions caused by hail. Skole, Ukraine, VK.

Fig. 8.4.2. Bending of young birch (*Betula pendula*) and oak (*Quercus* sp.) trees as a result of snow damage. Katowice, Poland, MN.

Fig. 8.4.3. Icing and burdening of young oaks (*Quercus* spp.) by snow, causing a permanent tree bending, Katowice, Poland, MN.

Fig. 8.4.4. Green ash (*Fraxinus pennsylvanica*) showing sun-scald damage to the trunk. USA, WJ.

Fig. 8.4.5. Eucalyptus (*Eucalyptus* sp.) with cankers caused by frost and winter injury (general). USA, RLA. **Fig. 8.4.6.** White oak (*Quercus alba*) damaged years ago by lightning. USA, RC.

8.5. Cankers

Description: Cankers on trees consist of localized dead (necrotic) sections of bark on stems, branches or twigs. Cankers may appear swollen or sunken, and vary in shape and size. The bark appears discoloured compared to healthy bark, and is often cracked at the margin. Exudations may occur on the canker surface and can be particularly pronounced at its margins. Once a canker has girdled the affected tree part, the stem, branch or twig distal to the canker dies. If the trunk is affected, the entire tree eventually dies. The ability of the tree to heal around wounded tissue depends to some extent on the vigour of the tree.

Most plant pathogens are unable to penetrate healthy bark directly, but can successfully invade wounded bark tissue. Cankers caused by fungi on stems, branches and twigs may be annual (lasting for one year), perennial (lasting for multiple years usually evident by concentric rings of callus), or diffuse (where necrosis spread is so rapid that the host does not have the opportunity to build barriers, e.g., wound periderm and callus, to stop it). Multiple cankers can be present on a single tree.

Possible damaging agents: **Fungi:** Ascomycota (Figs. 8.5.1 – 8.5.6) and **Bacteria** (Figs. 8.5.7–8.5.8).

Fig. 8.5.1. Malformed stems (A, B) and necrosis under the bark (C) of European beech (*Fagus sylvatica*) due to attack by a canker fungus (*Neonectria ditissima*). The fungus has red fruiting bodies (D). Larvik, Norway, VT.

Fig. 8.5.2. Black poplar (*Populus nigra*) showing stem discoloration caused by a fungus (*Cryptodiaporthe populea*). Tikeri, Georgia, IM.

Fig. 8.5.3. European chestnut (*Castanea sativa*) showing stem necrosis caused by a canker fungus (*Cryphonectria parasitica*) and contrasting healthy bark on side branch. Ollon, Switzerland, WSL.

Fig. 8.5.4. Pubescent oak stem (*Quercus pubescens*) with brown discoloration on bark surface due to the charcoal disease fungus (*Biscogniauxia mediterranea*). Rovinjsko Selo, Croatia, TC.

Fig. 8.5.5. Twig of Oriental beech (*Fagus orientalis*) with fruiting bodies of the beech tarcrust fungus (*Biscogniauxia nummularia*) and underlying tissue necrotic. Ambrolauri, Georgia, VK.

Fig. 8.5.6. Stem of sycamore maple (*Acer pseudoplatanus*) showing split bark and underlying tissue necrosis as a result of the canker fungus (*Eutypella parasitica*). Altmünster, Austria, TC.

Fig. 8.5.7. Crown dieback and stem bleeding (with underlying tissue necrosis) on horse chestnut (*Aesculus hippocastanum*), caused by the bacterium *Pseudomonas syringae* pv. *aesculi*. Rogaland county, Norway, VT.

Fig. 8.5.8. Common ash (*Fraxinus excelsior*) with bark canker caused by the bacterium *Pseudomonas syringae* ssp. *savastanoi* pv. *fraxini*. Urfahr, Austria, TC.

Additional information: For fungal collection and preservation, see Chapter 4.

8.6. Holes and/or bleeding on the bark

Description: Emergence or exit holes of insects, of different shape (Figs. 8.6.1, 8.6.2, 8.6.7) and size, are visible on the bark of branches, twigs and stems. Galleries can be observed in and/or underneath the bark (Figs. 8.6.6, 8.6.8), on the phloem and/or the wood surface. Gallery patterns vary with the diameter and insect species. Accumulation of sawdust around entrance holes (Fig. 8.6.5), and sap flow on the bark (Figs. 8.6.3, 8.6.4) at penetration sites may occur. Note: similar symptoms are caused by *Phytophthora* spp.

Possible damaging agents: **Insects:** Adults of several families of Coleoptera (Curculionidae, Scolytinae (bark and ambrosia beetles: Figs. 8.6.1 – 8.6.6); Buprestidae (jewel beetles: Figs. 8.6.7 – 8.6.8); Cerambycidae (longhorn beetles: Figs. 8.6.2 – 8.6.3)) and Hymenoptera (Siricidae and Sesiidae (wood wasps)).

Fig. 8.6.1. Trunk with circular exit holes of unidentified bark beetles or long-horned beetles (Coleoptera, Scolytinae or Cerambycidae). Baja, Hungary, GC.

Fig. 8.6.2. Birch (*Betula* sp.) with circular exit holes made by long-horned beetle adults (Coleoptera, Cerambycidae: *Monochamus urrusovi*). Bulgan Province, Mongolia, YNB.

Fig. 8.6.3. Young quaking aspen (*Populus tremuloides*) stem with a bleeding wound caused by the tunnelling activity of a long-horned beetle larva (Coleoptera, Cerambycidae: *Saperda calcarata*). USA, SK.

Fig. 8.6.4. Stem of beech (*Fagus* sp.) with sapflow and fungal infection at the emergence holes of adult bark beetles (Coleoptera, Scolytinae: *Taphrorychus bicolor*). Magyarpolány, Hungary, GC.

Fig. 8.6.5. Frass tubes sticking out of the holes on the trunk of a sugar maple (*Acer saccharum*), produced by adult granulate ambrosia beetles (Coleoptera, Scolytinae: *Xylosandrus crassiusculus*). USA, LL.

Fig. 8.6.6. The fully developed gallery with adult of a bark beetle (Coleoptera, Scolytinae: *Scolytus scolytus*) underneath bark of dying elm (*Ulmus laevis*). Kraków, Poland, MKA.

Fig. 8.6.7. Trunk of ash (*Fraxinus* sp.) with a D-shaped exit hole of a jewel beetle (Coleoptera, Buprestidae: *Agrilus planipennis*). USA, PDCNR.

Fig. 8.6.8. Oak (*Quercus* sp.) branch with a larval tunnel, made by a jewel beetle (Coleoptera, Buprestidae: *Agrilus angustulus*), visible under the thin bark. Gyula, Hungary, GC.

Additional information: Note the shape and dimensions of the exit hole. To determine the damaging agent, remove the bark around the hole and collect insects from the gallery (adult, larva) in spring or summer time. For insect collection and preservation, see Chapter 3 and for pathogens see Chapter 4.

8.7. Twig and/or branch girdling or pruning

Description: Accumulation of twigs and branches with brown, premature leaves on the ground. A complete circle around a twig or small branch is cut through the bark and into the wood and a thin column of the centre wood is present (Fig. 8.7.1). Circular holes made by larvae in the bark are visible and frass or excrement are present on twigs and branches (Fig. 8.7.3). The cut ends of twigs attacked by a twig girdler resemble the damage caused by beavers (Fig. 8.7.4), whereas in the case of a twig pruner infestation a hollowed out space, filled with frass, and larval galleries underneath the bark, tunnelled along the twig or branch can be observed (Figs. 8.7.2, 8.7.5).

Possible damaging agents: Insects: Larvae and adults of longhorn beetles (Coleoptera, Cerambycidae: Figs. 8.7.1 – 8.7.5).

Fig. 8.7.1. Fresh girdle on twig of hickory (*Carya* sp.) made by an adult of a twig girdler (Coleoptera, Cerambycidae: *Oncideres cingulata*). USA, LLH.

Fig. 8.7.2. Longitudinal and cross-sections of an oak twig (*Quercus* sp.), revealing a larva of a twig pruner (Coleoptera, Cerambycidae: *Anelaphus villosus*). USA, JS.

Fig. 8.7.3. Girdled twig of hickory (*Carya* sp.) showing holes and frass expelled by a fully grown larva of a twig girdler (Coleoptera, Cerambycidae: *Oncideres cingulata*). USA, LLH.

Fig. 8.7.4. Typical end of twigs of hickory (*Carya* sp.) girdled by adults of a twig girdler (Coleoptera, Cerambycidae: *Oncideres cingulata*). USA, GJL.

Fig. 8.7.5. Branch of unknown species with smooth girdle made by a branch pruner (Coleoptera, Cerambycidae: *Psyrassa unicolor*). USA, JS.

Additional information: Look for accumulations of twigs under the shade of trees in August and September. To determine the damaging agent, gather some twigs and branches, remove the bark and collect larva. Note that in some cases insect collection and identification is possible in late summer, when overwintering larvae can be found in twigs and branches that have fallen due to girdling by adults. For insect collection and preservation, see Chapter 3.

8.8. Scars on the bark

Description: Maturation feeding of insects or cuts in the bark to oviposit by insects. Bark on twigs, branches and stems have small splits. Sometimes, bristles or hairs stick out from the cut or eggs deposited in slits by insects are visible. Narrow and short feeding tunnels in the branches and twig bark may be seen and the bark surface might be covered in a thin layer of silver ‘spider’ web.

Possible damaging agents: **Insects:** Adults of several families of Coleoptera (Buprestidae (jewel beetles: Figs. 8.8.2, 8.8.5), Cerambycidae (longhorn beetles: Figs. 8.8.1, 8.8.7), Curculionidae and Scolytinae (bark beetles: Figs. 8.8.6., 8.8.8)); Hemiptera (Cicadidae: Fig. 8.8.4), Diptera (Agromyzidae), and Hymenoptera (Cimbicidae (sawflies: Fig. 8.8.3)); larvae of Lepidoptera (Yponomeutidae).

Fig. 8.8.1. Stem of *Zelkova schneideriana* with bark gnawings and the responsible adult long-horn beetle (Coleoptera, Cerambycidae: *Batocera horsfieldii*). Sentinel nursery, Fuyang, China, AR.

Fig. 8.8.2. Poplar stem (*Populus* sp.) with symptoms of attack by jewel beetle adults (Coleoptera, Buprestidae: *Agrilus populneus*). Kecskemét, Hungary, GC.

Fig. 8.8.3. Branch of unknown species with ring-shaped scars due to adult feeding and oviposition of a sawfly (Hymenoptera, Cimbicidae: *Cimbex femorata*). Hungary, ERD.

Fig. 8.8.4. Oak twig (*Quercus* sp.) with egg laying scars of an adult cicada (Hemiptera, Cicadidae: *Magicicada septendecim*). USA, ERD.

Fig. 8.8.5. Beech (*Fagus sylvatica*) trunk with bark covered by a cap-shaped hill at the oviposition site of an adult jewel beetle (Coleoptera, Buprestidae: *Agrilus viridis*). Hungary, FL.

Fig. 8.8.6. Maturation feeding injury on an American elm (*Ulmus americana*) twig caused by an adult bark beetle (Coleoptera, Scolytinae: *Scolytus multistriatus*). USA, JOB.

Fig. 8.8.7. Stem of young poplar (*Populus* sp.) showing oviposition scars of an adult long-horn beetle (Coleoptera, Cerambycidae: *Saperda populnea*). Mátrafüred, Hungary, GC.

Fig. 8.8.8. Maturation feeding injury on elm (*Ulmus* sp.) of a bark beetle (Coleoptera, Scolytinae: *Scolytus scolytus*). Szeghalom, Hungary, GC.

Additional information: To determine the causal agent of the damage, carefully remove the bark around the scar and collect the insects. Note that finding agents is only possible during a short period of time, depending on the insect species, usually in spring and summer time. For insect collection and preservation, see Chapter 3.

8.9. Punctures on the bark and/or scale insect presence

Description: Small, often hardly visible feeding punctures on the bark and/or insects with piercing-sucking mouthparts on plant stems and twigs are observed. Colour, shape, texture and other features vary with the insect species. Sticky excrement, sooty mould and honeydew-seeking ants are often visible on the tree. Multiple life stages of scale insects (female adults, nymphs) on one twig or branches may occur.

Possible damaging agents: Insects: Larvae and adults of many families of Hemiptera (Aphididae (aphids: Fig. 8.9.1), Coccidae (Figs. 8.9.2 – 8.9.6), Diaspididae and other scale families); Coreidae and other true bug families, Fulgoridae, Cicadidae.

Fig. 8.9.1. Twig of common ash (*Fraxinus excelsior*) infested by different life stages of leaf-nest aphids (Hemiptera, Aphididae: *Prociphilus fraxini*). Lviv, Ukraine, VK.

Fig. 8.9.2. Twig of common ash (*Fraxinus excelsior*) infested by a scale (Hemiptera, Coccidae: *Eulecanium tiliae*). Lviv, Ukraine, VK.

Fig. 8.9.3. Twig of goat willow (*Salix caprea*) infested by adult female and crawling neonates (reddish spots) of scale (Hemiptera, Coccoidea: *Chionaspis salicis*). Skole, Ukraine, VK.

Fig. 8.9.4. Twig of spindle tree (*Euonymus* sp.) covered by scales (Hemiptera, Coccoidea: *Unaspis euonymi*). Kecskemét, Hungary, GC.

Fig. 8.9.5. Twig of oak (*Quercus* sp.) infested by adult scales (Hemiptera, Coccidae: *Parthenolecanium rufulum*). Slovakia, MZ.

Fig. 8.9.6. Sweetbay (*Magnolia virginiana*) stem infested by scales (Hemiptera, Coccidae: *Parthenolecanium rufulum*). Kentucky, USA, WF.

Additional information: Inspect plants to determine whether female scales, nymphs, honeydew, sooty mould or ants and other pests are present. It is advisable to perform plant inspection in a winter period, when trees are devoid of leaves and scale insects can be more easily seen. Collect some of the affected plant part or several specimens if possible. If a specimen cannot be collected, take a photo of the insect and damage to the plant. For insect collection and preservation, see Chapter 3.

8.10. Twig and stem swelling

Description: Swelling or overgrowth of plant tissue may occur on twigs, branches and lower parts of the stem. Under the bark, in phloem and wood, straight or winding feeding tunnels running in different directions can be observed. In case of fungal or bacterial damage, the abnormal growth is spindle-shaped to globose and has a rough surface, either vertically or horizontally ridged and covered with small knobs. On large trees, galls may reach a diameter of two to three times that of the tree at the point of occurrence and at times encircle the stem.

Possible damaging agents: **Insects:** Larvae of several families of Coleoptera (Buprestidae, Cerambycidae: Figs. 8.10.5 – 8.10.6; Curculionidae and Scolytinae: Fig. 8.10.4); Diptera (Cecidomyiidae midges, Agromyzidae flies); Hymenoptera (Cynipidae gall wasps: Fig. 8.10.7, Eurytomidae) and Lepidoptera (Gelechiidae, Sesiidae, Tortricidae); nymphs (larvae) and adults of Hemiptera (Aphididae: Figs. 8.10.1 – 8.10.4, 8.10.8); **Fungi:** Ascomycota (Fig. 8.10.9); Basidiomycota (Fig. 8.10.10); **Bacteria** (Figs. 8.10.1, 8.10.11, 8.10.12).

Fig. 8.10.1. Branch and stem swellings on oak (*Quercus* sp.) caused by bacteria carried by an aphid (Hemiptera, Aphididae: *Lachnus roboris*). Mátrafüred, Hungary, GC.

Fig. 8.10.2. Branch of oak (*Quercus* sp.) covered by adults and eggs of an aphid (Hemiptera, Aphididae: *Lachnus roboris*), causal agents of the swelling seen on the lower right. Mátrafüred, Hungary, GC.

Fig. 8.10.3. Twigs of Turkey oak (*Quercus cerris*) swollen by the infestation of a gall wasp (Hymenoptera, Cynipidae: *Pseudoneuroterus macropterus*). Devecser, Hungary, GC.

Fig. 8.10.4. Twig of a young poplar (*Populus* sp.) sliced to show the galleries and frass caused by weevil larvae (Coleoptera, Curculionidae *Cryptorhynchus lapathi*). Hungary, GC.

Fig. 8.10.5. Poplar twig (*Populus* sp.) with typical swelling, due to a long-horn beetle larva, and adult emergence hole in its centre (Coleoptera, Cerambycidae: *Saperda populnea*). Hungary, GC.

Fig. 8.10.6. Twig of aspen (*Populus tremula*) sliced to show the larva corresponding to Fig. 8.10.5. Mátrafüred, Hungary, GC.

Fig. 8.10.7. Twig of Imeretian oak (*Quercus imeretina*) showing mature artichoke shaped galls due to a gall wasp (Hymenoptera, Cynipidae: *Andricus fecundatrix*). Ajameti, Georgia, IM.

Fig. 8.10.8. Twig of laurel poplar (*Populus laurifolia*) with aphid galls (Hemiptera, Pemphigidae: *Pemphigus borealis*). Khentii Province, Mongolia, YNB.

Fig. 8.10.9. Mountain ash (*Sorbus aucuparia*) with swellings caused by a canker fungus (*Neonectria ditissima*). Akershus county, Norway, VT.

Fig. 8.10.10. Swelling on hawthorn (*Crataegus* sp.) caused by a rust fungus (*Gymnosporangium clavariiforme*). Vestfold county, Norway, VT.

Fig. 8.10.11. Pedunculate oak (*Quercus robur*) twig swelling caused by a bacterium (*Pseudomonas savastanoi* pv. *fraxini*). Medobory, Ukraine, VK.

Fig. 8.10.12. Abnormal swelling on a poplar (*Populus* sp.) stem caused by a bacterial infection (*Xanthomonas populi*). France, MM.

Additional information: To determine the causal agent of the damage, first analyse the physical appearance of the galls, i.e. size, shape, textures and colour, and note the position of the galls on the tree. These features are characteristic for galling insect species. If possible, collect samples and carefully open galls to locate the causal agent (larva). Parasites and predators could also be found inside the gall. For insect collection and preservation, see Chapter 3 and for pathogens see Chapter 4.

8.11. Witches' brooms

Description: Dense concentration of young shoots on the branches of trees. These shoots are frequently thicker and shorter than normal ones. This changes the structure and appearance of the tree. Brooms can take different shapes, e.g., spherical, conical, weeping, columnar, and be present individually or repeatedly on the same tree (Fig. 8.11.1). Brooms may grow for the entire life of the host tree and reach considerable sizes. Sometimes growth deformation like stem fasciations can also be observed.

Possible damaging agents: **Insects:** Adults of several families of Hemiptera (Aphididae: Fig. 8.11.2, Cicadellidae (leafhoppers): Figs. 8.11.3 – 8.11.4, Delphacidae (planthoppers), Psyllidae (jumping plant lice)), **Fungi:** Ascomycota (Figs. 8.11.5 – 8.11.7), **Hemiparasitic plants** (mistletoe: Fig. 8.11.8); **Nematodes, Viruses, Bacteria, Phytoplasmas** (Figs. 8.11.9 – 8.11.10).

Fig. 8.11.1. Branches of hackberry (*Celtis occidentalis*) with multiple witches' brooms. USA, WC.

Fig. 8.11.2. Bell's honeysuckle (*Lonicera x bella*) with witches' broom caused by an aphid (Hemiptera Aphididae: *Hyadaphis tatarica*). USA, WC.

Fig. 8.11.3. A vector of witches' broom phytoplasma to be looked for: an adult leafhopper (Hemiptera, Cicadellidae: *Hishimonus phycitis*). France, JLD.

Fig. 8.11.4. Stem of white ash (*Fraxinus americana*) with witches' broom caused by a phytoplasma vectored by leafhoppers (Hemiptera, Cicadellidae). USA, JOB.

Fig. 8.11.5. Stem of an oriental hornbeam tree (*Carpinus orientalis*) with witches' broom caused by a fungus (*Taphrina carpini*). Lviv, Ukraine, VK.

Fig. 8.11.6. Witches' brooms on birch (*Betula pubescens*) caused by a fungus (*Taphrina betulina*). Rogaland county, Norway, VT.

Fig. 8.11.7. Close up image of a witches' broom on birch (*Betula pubescens*) caused by a fungus (*Taphrina betulina*). Akershus county, Norway, VT.

Fig. 8.11.8. Norway maple (*Acer platanoides*) tree colonised by mistletoe (Plantae, Santalaceae: *Viscum album*). Tenopil, Ukraine, IM.

Additional information: For insect and fungal collection and preservation, see Chapters 3 and 4, respectively.

8.12. Epicormic shoots/fasciation

Description: Epicormic shoots are sprouts growing from dormant buds on woody plant parts that developed in a previous growth period. Fasciation indicates flattened, elongated, “compressed-looking” shoots and flower heads. Fasciated stems are due to an abnormal activity in the growing tip of the plant. Often an abnormal number of flowers are produced on affected stems. Normal branches may arise from fasciated stems.

Possible damaging agents: **Fungi:** Ascomycota, **Bacteria** (Figs. 8.12.1 – 8.12.6).

Fig. 8.12.1. Stem of European chestnut (*Castanea sativa*) with epicormic shoots induced by a fungus (Ascomycota Diaporthales: *Cryphonectria parasitica*). Vinzel, Switzerland, WSL.

Fig. 8.12.2. Trunk of Imeretian oak (*Quercus imeretina*) with epicormic shoots. Ajameti, Georgia, IM.

Fig. 8.12.3. Twig of goat willow (*Salix caprea*) showing fasciation caused by an unknown microorganism. Turka, Ukraine, VK.

Fig. 8.12.4. American elm (*Ulmus americana*) showing epicormal sprouting (unknown damaging agent). USA, CC.

Fig. 8.12.5. Black walnut (*Juglans nigra*) with epicormic branches on the stem (unknown damaging agent). USA, EB.

Fig. 8.12.6. Ash (*Fraxinus* spp.) showing epicormic branches and shoots on the stem (unknown damaging agent). USA, JSH.

Additional information: Epicormic buds and shoots occur in many woody broadleaved species, unlike most conifers. For species identification, direct observation or consultation with local specialists or game managers is needed.

8.13. Bark necrosis

Description: Necrotic bark lesions are usually characterised by bark discoloration. Perennial lesions may form on individual branches and scaffold limbs. Fungi infect the crotch and trunk, spreading rapidly through the bark and sapwood. Bark necrosis can be of different shapes, e.g., elongated or circumferential.

Possible damaging agents: Fungi: Ascomycota (Figs. 8.13.1 – 8.13.4).

Fig. 8.13.1. Bark of a twig of pedunculated oak (*Quercus robur*) with fruiting bodies of a fungus (*Colpoma quercinum*). Underlying tissue is necrotic. Lviv, Ukraine, VK.

Fig. 8.13.2. Stem of black poplar (*Populus nigra*) with elongated bark necrosis caused by a canker fungus (*Cryptodiaportha populea*). Tikeri, Georgia, IM.

Fig. 8.13.3. Common ash (*Fraxinus excelsior*) stem showing progressive bark discoloration (lower arrow) and necrosis (upper arrow) caused by the ash dieback fungus (*Hymenoscyphus fraxineus*), Sweden, MC.

Fig. 8.13.4. Bark necrosis on common ash (*Fraxinus excelsior*) centred around a side branch caused by the ash dieback fungus (*Hymenoscyphus fraxineus*). Akershus county, Norway, VT.

Fig. 8.13.5. Bark necrosis on Norway maple (*Acer platanoides*) caused by a canker fungus (*Neonectria ditissima*). Akershus county, Norway, VT.

Additional information: For fungal collection and preservation, see Chapter 4.

8.14. Mammal and bird damage

Description:

- A. Stripping the bark from stems, branches or twigs by feeding of some mammals (e.g., cervids, rodents, hares). Damage caused by cervids may occur on standing trees (typically from several centimetres or so above the ground to 2.5 m height) (Figs. 8.14.2, 8.14.3) or on fallen trees (Fig. 8.14.4), exposing underlying wood. The damage appearance can vary, i.e. extensive and deep into the wood during the spring and summer, a small area removed, with fragments of phloem left, or the outer layer of the bark forming a ribbed surface on the stem in winter. On the damaged surface, teeth marks may be visible in the wood, their size depending on the species (rodents, hares) (Figs. 8.14.1, 8.14.5, 8.14.10).
- B. Smooth bark on stems or branches as a result of male cervids rubbing their antlers to remove the velvet covering. During fraying, branches can be broken. The damaged surface is smooth, without bark fragments and agent teeth marks (Fig. 8.14.6). If the bark is removed all the way around the stem (girdling), the tree will die in the future.
- C. Apical shoots of young trees chewed (Fig. 8.14.9), including leaves and buds, by cervids (browsing leaves a torn edge) or hares (cutting leaves a sharp edge).

Missing buds on young trees or differently sized, irregular holes in the stem are visible. In the spring, horizontal rows or rings of holes pecked next to each other in the tree stem (Fig. 8.14.7) or in the autumn outgrowth around the holes may be observed (Fig. 8.14.8). Shattered and perforated bark, shattered pieces of wood and sawdust can be detected at the base of the tree. This type of tree damage is caused by some birds (woodpeckers, fowls, pheasants).

Possible damaging agents: **Mammals** (cervids, rodents, hares), **Birds** (woodpeckers - often; fowls, pheasants - rarely) (Figs. 8.14.1 – 8.14.10).

Fig. 8.14.1. Aspen (*Populus tremula*) tree killed by unidentified rodents (Mammalia, Rodentia) during winter feeding on the bark. Southern Siberia, Russia. AVS.

Fig. 8.14.2. Stripping of bark from the stem of goat willow (*Salix caprea*) caused by elk (Mammalia Artiodactyla Cervidae: *Alces alces*) feeding in summer season. St. Petersburg, Russia, NVS.

Fig. 8.14.3. Bark removed (whittled down) from lime tree (*Tilia* sp.) stems by red deer (Mammalia Artiodactyla Cervidae: *Cervus elaphus*). Czech Republic, PK.

Fig. 8.14.4. Fallen stem of aspen (*Populus tremula*) fed upon by elk (Mammalia Artiodactyla Cervidae: *Alces alces*). Saint Petersburg, Russia, NVS.

Fig. 8.14.5. Lower stem of birch (*Betula* sp.) with visible tooth marks, indicating beaver feeding (Mammalia Rodentia Castoridae: *Castor fiber*). Saint Petersburg, Russia, NVS.

Fig. 8.14.6. Damage to aspen (*Populus* sp.) stems from antler rubbing by male mule deer (Mammalia Artiodactyla Cervidae: *Odocoileus hemionus*). USA, WC.

Fig. 8.14.7. Maple stem (*Acer* sp.) with holes created by a bird sapsucker (Aves Piciformes Picidae: *Sphyrapicus varius*). Delaware, Ohio, USA, RLA.

Fig. 8.14.8. Aspen (*Populus tremula*) with overgrowth on the bark at the place of ringing by a bird sapsucker (Aves Piciformes Picidae: *Sphyrapicus varius*). USA, JT.

Fig. 8.14.9. Chewed apical shoot of young common ash (*Fraxinus excelsior*) by red deer (Mammalia Artiodactyla Cervidae: *Cervus elaphus*). Graubünden, Switzerland, SKU.

Fig. 8.14.10. Young sugar maple trees (*Acer saccharum*) fed upon by unidentified rodents (Mammalia: Rodentia) during the winter. LaCrosse County, Wisconsin, USA, SK.

Additional information: To determine the causal agent of the damage, document the damage with photos. A short description of the tree injury should include the part of the tree in which the damage occurs (stem, branch or twig) and on which section of the stem. It is also recommended to check for the presence and size of teeth marks and other signs of animal life (excrements, fur) or other accompanying symptoms of illness (changes in foliage, bleeding on the stump, etc.).