# Damage to leaves of broadleaf woody plants. Chapter 6

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# 6
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## 6.1. Skeletonisation

**Description:** Soft leaf tissue eaten, leaving leaf veins intact. Sometimes the lower or upper epidermis remains untouched (if feeding is on the upper side of the leaf in the first case and is on the lower side of the leaf in the second).
**Possible damaging agents: Insects:** Larvae and adults of some Coleoptera (Fig. 6.1.1). Larvae of some Hymenoptera (Figs. 6.1.2 – 6.1.4) and Lepidoptera (Fig. 6.1.5).

**Fig. 6.1.1.** Leaf of pussy willow (*Salix caprea*) skeletonised by larvae of a leaf beetle (Coleoptera, Chrysomelidae: *Phratora* sp.). Novosibirsk, Russia, NK.

**Fig. 6.1.2.** Leaf of pedunculate oak (*Quercus robur*) partially skeletonised on lower side by sawfly larvae (Hymenoptera, Tenthredinidae). Sentinel tree plantations, Fuyang, China, AR.

**Fig. 6.1.3.** Leaf of Schneider's Zelkova (*Zelkova schneideriana*) skeletonised on lower side by sawfly larvae (Hymenoptera, Tenthredinidae). Sentinel tree plantation, Fuyang, China, AR.

**Fig. 6.1.4.** Leaf of Schneider's Zelkova (*Zelkova schneideriana*) skeletonised by sawfly larvae (Hymenoptera) in a sentinel planting. Fuyang, China, AR.

**Fig. 6.1.5.** Leaf of bird cherry (*Prunus padus*) skeletonised by black-veined white (Lepidoptera, Pieridae: *Aporia crataegi*). Black lake village, The Republic of Khakassia, Russia, NK.

**Fig. 6.1.6.** Leaf of pedunculate oak (*Quercus robur*) skeletonised by unknown insects in a sentinel planting, Fuyang, China, AR.

**Additional information:** For insect collection and preservation, see Chapter 3.

## 6.2. Perforation and shot holes

**Description:** Holes in the leaf lamina between the leaf veins. Size of holes is variable.

**Possible damaging agents: Insects:** Direct feeding perforation by larvae and adults of Coleoptera (e.g., Chrysomelidae and Curculionidae: Figs. 6.2.1 – 6.2.3), shot holes left by larvae of leaf miners at the end of their development (Lepidoptera: Incurvariidae, Gracillariidae; Coleoptera: Curculionidae) (Figs. 6.2.4, 6.2.5), **Fungi:** shot-holes disease due to pathogens (e.g., Coryneum Blight-Shothole: Fig. 6.2.6).

**Fig. 6.2.1.** Leaf of guelder-rose (*Viburnum opulus*) perforated by larvae of a beetle (Coleoptera, Chrysomelidae: *Pyrrhalta viburni*). Novosibirsk, Russia, NK.

**Fig. 6.2.2.** Leaf of ash (*Fraxinus* spp.) with typical shot hole of chewing adult weevils and window peeling larvae (Coleoptera, Curculionidae: *Steronychus fraxini*). Magyargencs, Hungary, GC.

**Fig. 6.2.1.** Leaf of guelder-rose (*Viburnum opulus*) perforated by larvae of a beetle (Coleoptera, Chrysomelidae: *Pyrrhalta viburni*). Novosibirsk, Russia, NK.

**Fig. 6.2.4.** Silver birch (*Betula pendula*) leaf with holes from cut-out mines by moth larvae (Lepidoptera, Incurvariidae: *Incurvaria pectinea*). Novosibirsk, Russia, NK.

**Fig. 6.2.5.** Leaf of *Betula microphylla* with a round hole resulting from a mine of a weevil larva (Coleoptera, Curculionidae: *Orchestes rusci*). Novosibirsk, Russia, NK.

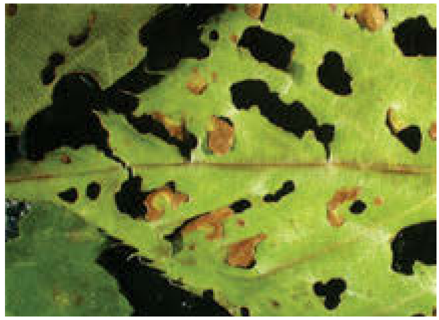

**Fig. 6.2.6.** Sour cherry (*Prunus cerasus*) leaf with shot holes due to fungal attack (*Thyrostroma carpophilum* = *Stigmina carpophila*). Brunn am Gebirge, Austria, TC.

**Additional information:** Perforation is often due to young, open-living larvae of Coleoptera; older larvae can provide other types of damage, e.g., rough eating (see section 6.4). In case of leaf miners, several mines (later several holes) are often present on one leaf. The larva makes an excision of almost the same size as the mine; then, sandwiched in this excision, the larva drops out leaving a hole on the leaf. Spots are oval to round and expand into brown spots with light centres. Centres of infected spots often necrose and drop out during warm weather, giving the leaves a characteristic shot-hole appearance. In case of pathogens, lesions can initially be dark brown, reddish, or purplish spots and may be surrounded by a light green to yellowish halo. For insect collection and preservation see Chapter 3 and for pathogens see Chapter 4.

## 6.3. Cut-outs

**Description:** Leaf margin showing cuts due to insects: tissue of lamina eaten at the edge or cut-out for building nests. Cuts can be any shape; e.g., irregular, square, oval or circular.
**Possible damaging agents: Insects:** Usually adult insects of some Coleoptera (Curculionidae: Figs. 6.3.1, 6.3.2), Hymenoptera (Megachilidae: Fig. 6.3.3, Argidae, Tenthredinidae), Lepidoptera (Fig. 6.3.4).

**Fig. 6.3.1.** Leaf of *Eucalyptus* sp. with irregular cut-outs done by adults of an invasive weevil (Coleoptera, Curculionidae: *Gonipterus* sp.). Corsica, France, AR.

**Fig. 6.3.2.** Leaf of common lilac (*Syringa vulgaris*) with square cut-outs left by adult weevils (Coleoptera, Curculionidae: *Otiorhynchus sulcatus*). Novosibirsk, Russia, NK.

**Fig. 6.3.3.** Leaf of green ash (*Fraxinus pensylvanica*) with oval and round cut-outs left by solitary bees (Hymenoptera, Megachilidae: *Megachile centancularis*). Krasnoyarsk, Russia, NK.

**Fig. 6.3.4.** Leaf margin of Chinese holly (*Ilex cornuta*) cut-outs by moth larva (Lepidoptera) in a sentinel planting. Fuyang, China, AR.

**Additional information:** Before checking leaves, especially with square damage (often left by weevils (Curculionidae)), place a Japanese umbrella or an ordinary umbrella under the branches to catch insects. For insect collection and preservation see Chapter 3.

## 6.4. Rough eating

**Description:** Eating away soft tissue of the leaf lamina including veins. The main leaf vein and some hard parts of other veins may be left untouched.
**Possible damaging agents: Insects:** Larvae of many Lepidoptera (Fig. 6.4.1), Coleoptera (Figs. 6.4.2, 6.4.3), larvae and adults of some Hymenoptera (Fig. 6.4.4).

**Fig. 6.4.1.** Leaf of *Acer tatatricum* roughly eaten by the moth larvae (Lepidoptera, Ypsolophidae: *Ypsolopha chazariella*). Novosibirsk, Russia, NK.

**Fig. 6.4.2.** Leaf of guelder-rose (*Viburnum opulus*) severely defoliated by mature beetle larvae (Coleoptera, Chrysomelidae: *Pyrrhalta viburni*). Novosibirsk, Russia, NK.

**Fig. 6.4.3.** Leaf of Chinese ash (*Fraxinus chinensis*) roughly eaten by an unknown insect. Sentinel plantation, Fuyang, China, AR.

**Fig. 6.4.4.** Leaf of willow (*Salix* sp.) roughly eaten by sawfly larvae (Hymenoptera, Tenthredinidae: *Nematus* sp.). Kerlavic, France, SA.

**Additional information:** Before checking leaves, especially with square damage (often due to weevils: Curculionidae), place a Japanese umbrella or an ordinary umbrella under the branches to catch insects. For insect collection and preservation see Chapter 3.

## 6.5. Leaf rolling

**Description:** Leaves can be strapped (pulled over) or cut in a certain way and then glued. This deformation of the leaf lamina creates a shelter where the insect continues to feed by cutting and folding/rolling.

**Possible damaging agents: Insects:** Some Coleoptera (especially Attelabidae) (Figs. 6.5.1 – 6.5.3) and some Lepidoptera (Figs. 6.5.4 – 6.5.6).

**Fig. 6.5.1.** Leaf of silver birch (*Betula pendula*) rolled by a weevil (Coleoptera, Attelabidae: *Deporaus betulae*). Novosibirsk, Russia, NK.

**Fig. 6.5.2.** Leaf of Chinese ash (*Fraxinus chinensis*) rolled by an unidentified weevil (Coleoptera, Attelabidae). Sentinel tree plantation, Fuyang, China, AR.

**Fig. 6.5.3.** Leaf of Turkey oak (*Quercus cerris*) with leaf rolls (Coleoptera, Attelabidae: *Attelabus nitens*). Mátrafüred, Hungary, GC.

**Fig. 6.5.4.** Leaf of basket willow (*Salix viminalis*) rolled by a lepidoptera larva (Lepidoptera, Gracillariidae: *Caloptilia stigmatella*). Novosibirsk, Russia, NK.

**Fig. 6.5.5.** Unfolded leaf of European beech (*Fagus sylvatica*) containing an unidentified moth larva (Lepidoptera, Tortricidae). Sentinel tree plantation, Fuyang, China, AR.

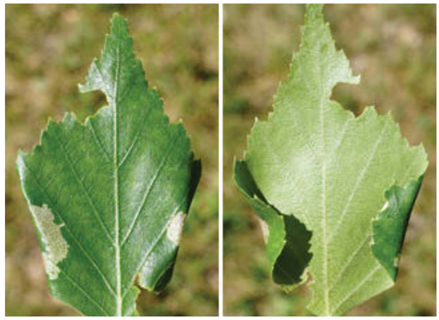

**Fig. 6.5.6.** Leaf margin of silver birch (*Betula pendula*) pulled down by a moth larva (Lepidoptera, Gracillariidae: *Parornix betulae*), upper view and lower side. Novosibirsk, Russia, NK.

**Additional information:** Check the leaves on the upper and lower side to find folded leaf margins. Often under such folds, feeding larvae of insects can be found. Record the shape of shelter and presence or absence of silk. For insect collection and preservation see Chapter 3.

## 6.6. Leaf curling

**Description:** Leaf deformation caused by an abnormal growth of the leaf tissues. The deformed parts may also constitute a shelter for the damaging organisms. Infected leaves display a variety of colours ranging from light green and yellow to shades of red and purple. Fungal infection causes the meristematic cells at leaf margins to proliferate quickly and randomly, which results in leaves becoming wrinkled, puckered, and/or curled to various degrees.

**Possible damaging agents: Insects:** Hemiptera, especially aphids (Aphididae: Fig. 6.6.1), psyllids (Psyllidae: Fig. 6.6.2), larvae of some Lepidoptera, Diptera (especially Cecidomyiidae: Fig. 6.6.3), thrips, mites (Acari, especially Eriophyidae: Fig. 6.6.4), **Fungi:** Ascomycota, Taphrinaceae (Figs. 6.6.5, 6.6.6), **Phytoplasmas**, **Bacteria**, **Roll viruses**.

**Fig. 6.6.1.** Siberian crab apple (*Malus baccata*) leaves deformed by aphids (Hemiptera: Aphididae). Novosibirsk, Russia, NK.

**Fig. 6.6.2.** Leaf of European ash (*Fraxinus excelsior*) deformed by psyllids (Hemiptera, Psyllidae: *Psyllopsis fraxini*). Lviv, Ukraine, VK.

**Fig. 6.6.3.** Maple (*Acer* spp.) leaves distorted by gall midges (Diptera, Cecidomyiidae: *Dasineura irregularis*). Mátrafüred, Hungary, GC.

**Fig. 6.6.4.** Silver poplar (*Populus alba*) leaves deformed by mites (Acari, Eriophyidae: *Aceria dispar*). Gödöllő, Hungary, GC.

**Fig. 6.6.5.** Leaf of black alder (*Alnus* glutinosa) curled due to a fungus (*Taphrina tosquinetii*). Rava-Ruska, Ukraine, VK.

**Fig. 6.6.6.** Pink curled leaves of peach tree (*Prunus persica*) induced by a fungus (*Taphrina deformans*). Wolkersdorf, Austria, TC.

**Additional information:** In spring, reddish areas on developing leaves can represent fungal damage. These areas become thickened and puckered, causing leaves to curl and distort. As the disease progresses, the thickened areas turn yellowish grey and become covered with velvety spores. Affected leaves turn yellow or brown and fall prematurely. For insect collection and preservation see Chapter 3, and for pathogens, see Chapter 4.

## 6.7. Leaf galling

**Description:** Outgrowth of plant tissue; can affect the leaf lamina, vein or petiole. The shape, size and colour can vary greatly and are dependent on the particular organism causing the damage.

**Possible damaging agents: Insects:** different Hymenoptera (especially Cynipidae, Eulophidae and Thenthredinidae: Figs. 6.7.1, 6.7.2), Diptera (Cecidomyiidae: Figs. 6.7.3, 6.7.4), and Hemiptera (Aphididae: Figs. 6.7.5 – 6.7.7), **Mites** (Acari, especially Eriophyidae: Fig. 6.7.8).

**Fig. 6.7.1.** Leaf of pedunculate oak (*Quercus robur*) damaged by gall wasp (Hymenoptera, Cynipidae: *Cynips quercusfolii*). Lviv, Ukraine, VK.

**Fig. 6.7.2.** Oak (*Quercus* sp.) leaves deformed by gall wasp (Hymenoptera, Cynipidae: *Cerroneuroterus vonkuenburgi*). Taichung, Taiwan, GC.

**Fig. 6.7.3.** Leaf of honey locust (*Gleditsia triacanthos*) with midge galls (Diptera, Cecidomyiidae: *Dasineura gleditsiae*). Egervár, Hungary, GC.

**Fig. 6.7.4.** European beech (*Fagus sylvatica*) damaged by gall midges (Diptera, Cecidomyiidae: *Mikiola fagi*). Skole, Ukraine, VK.

**Fig. 6.7.5.** Black poplar (*Populus nigra*) deformed by gall aphid (Hemiptera, Aphididae: *Pemphigus spyrothecae*). Lviv, Ukraine, VK.

**Fig. 6.7.6.** Elm (*Ulmus* spp.) leaf with aphid gall (Hemiptera, Aphididae: *Eriosoma lanuginosum*). Lviv, Ukraine, VK.

**Fig. 6.7.7.** Chinese zelkova (*Zelkova schneideriana*) leaves with aphid galls (Hemiptera, Aphididae: unidentified species). Sentinel planting, Fuyang, China, AR.

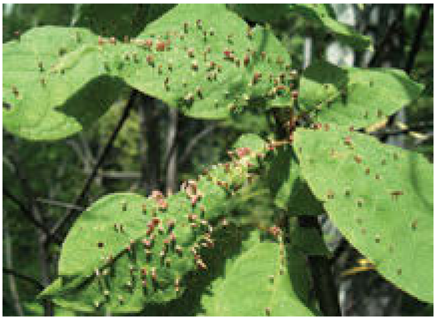

**Fig. 6.7.8.** Bird cherry (*Prunus padus*) leaves with mite galls (Acari, Eriophyidae: *Eriophyes padi*). Krasnoyarsk, Russia, NK.

**Additional information:** Galls can appear on leaves throughout the season. Look for irregular growth, distortions or colourful swellings. Check the upper and lower sides of leaves and the petiole, in order to find anomalous formations that can be of different shapes like round, oval, papilla- and felt-like. For insect collection and preservation see Chapter 3. Similar structures could be produced by rust fungi, as described in Chapter 4.

## 6.8. Webbing

**Description:** Fine webbing covers the leaves. Tiny organisms can be seen moving on the web. Infested leaves lose their colour and drop prematurely, often in a very short period of time.

**Possible damaging agents: Insects, Mites**, especially spider mites (Acari: Tetranychidae: Figs. 6.8.1 – 6.8.4).

**Fig. 6.8.1.** White oak (*Quercus alba*) leaves with fine webbing covering the leaf surfaces caused by spider mites (Acari: unidentified species). USA, JS.

**Fig. 6.8.2.** Honey locust (*Gleditsia triacanthos*) with bronzing foliage symptoms due to spider mite damage (Acari, Tetranychidae: *Platytetranychus multidigituli*). Colorado, USA, WC.

**Fig. 6.8.3.** Spindletree (*Euonymus* spp.) leaf with white webbing by rust mites (Acari, Eriophyidae: *Cecidophyes psilonotus*). Hungary, GC.

**Fig. 6.8.4.** Plant injury (unknown species) showing web by spider mites (Acari: unidentified species). USA, CU.

**Additional information:** Presence of mites can be ascertained by shaking the leaves with such webbings over a white piece of paper. For mite preservation, see Chapter 3.

## 6.9. Presence of froth or spittle

**Description:** Cover of frothed-up plant sap, resembling saliva, produced by froghopper nymphs sucking sap from phloem.

**Possible damaging agents: Insects:** Froghoppers (Hemiptera: Cercopidae: Figs. 6.9.1 – 6.9.2) and spittlebugs (Hemiptera: Clastopteridae, Aphrophoridae: Figs. 6.9.3, 6.9.4).

**Fig. 6.9.1.** Goat willow (*Salix caprea*) petioles and twigs covered by foam of a froghopper (Hemiptera, Cercopidae: *Aphrophora salicina*). Morshyn, Ukraine, VK.

**Fig. 6.9.2.** Willow (*Salix* sp.) petioles and twigs covered in foam of a froghopper (Hemiptera, Cercopidae: *Aphrophora salicina*). Mátrafüred, Hungary, GC.

**Fig. 6.9.3.** Dogwood (*Cornus* sp.) petioles covered by foam of dogwood spittlebug (Hemiptera, Clastopteridae: *Clastoptera proteus*). USA, BW.

**Fig. 6.9.4.** Willow (*Salix* sp.) leaves covered by foam with nymphs of willow spittlebug (Hemiptera, Aphrophoridae: *Aphrophora salicina*). Slovakia, MZ.

**Additional information:** Adult froghoppers jump from plant to plant. The froth serves a number of purposes. It hides the nymph from predators and parasitoids, insulates them against heat and cold, thus providing thermal and moisture control. Without the froth the insect would quickly dry up. The nymphs pierce plants and suck sap causing very little damage, much of the filtered fluids go into the production of the froth, which has an acrid taste, deterring predators.

## 6.10. Presence of wax

**Description:** Leaves waxy and sticky at contact on one side or both sides.
**Possible damaging agents: Insects:** Wax may result from secretion from Hemiptera: Coccoidea (scales: Fig. 6.10.1), Aphididae (aphids: Figs. 6.10.2, 6.10.4 – 6.10.6), Flatidae (planthoppers: Fig. 6.10.3) and whiteflies (Aleyrodidae).

**Fig. 6.10.1.** Leaf of Chinese holly (*Ilex cornuta*) with scale insects on central vein (Hemiptera: Coccidae). Sentinel planting, Fuyang, China, AR.

**Fig. 6.10.2.** Foliage and shoot of Chinese holly (*Ilex cornuta*) attacked by aphids (Hemiptera: Aphididae). Sentinel planting, Fuyang, China, AR.

**Fig. 6.10.3.** Larval skins and wax cover of planthoppers on *Rubus* sp. leaves (Hemiptera, Flatidae: *Metcalfa pruinosa*). Gödöllő, Hungary, GC.

**Fig. 6.10.4.** Larval skins and wax cover of woolly aphids (Hemiptera, Aphididae: *Phyllaphis fagi*) on European beech (*Fagus sylvatica*) leaves. Lviv, Ukraine, VK.

**Fig. 6.10.5.** Aphids (Hemiptera, Aphididae: *Aphis pomi*) and their wax cover on the leaves of an apple tree (*Malus* sp.). KDA.

**Fig. 6.10.6.** Gall aphids (Hemiptera, Aphididae: *Pemphigus populitransversus*) and wax on cabbage roots. USA, ANS.

**Additional information:** If wax is present, inspect leaves and twigs for presence of larvae and/or adults. Unlike aphids and whiteflies, the remains of an exoskeleton shed during moulting may be attached to scale insects, which protects insects from predators and allows feeding (sucking sap from phloem). There are two groups of scales: (1) armoured scales secrete a protective cover over their bodies; the majority overwinter as eggs beneath the female cover; (2) soft scales are usually larger and protect themselves with waxy secretions. The majority overwinter as immature, fertilized females. For collection and preservation of insects, see Chapter 3.

## 6.11. Rust diseases

**<u>Description</u>:** Bright yellow, orange or red spots or patches on the leaf with powdery spores. Spores are produced in small blisters on the upper leaf surface or may emerge from tiny cups or tubes (pustules) on the lower surface of the leaf. Pustules can be orange, yellow, brown, black or white. Some have a rusty brown colour, giving the disease its common name.
**<u>Possible damaging agents</u>: Fungi:** Basidiomycota (Pucciniales, Uredinales: Figs. 6.11.1 – 6.11.8).

**Fig. 6.11.1.** Leaves of boxwood (*Buxus colchica*) damaged by boxwood rust fungus (*Puccinia buxi*) in autumn. Tkibuli, Republic of Georgia, IM.

**Fig. 6.11.2.** Leaves of boxwood (*Buxus colchica*) damaged by boxwood rust fungus (*Puccinia buxi*) in summer. Ambrolauri, Republic of Georgia, IM.

**Fig. 6.11.3.** Leaf of rose (*Rosa* sp.) damaged by rose rust fungus (*Phragmidium mucronatum*). Lviv, Ukraine, VK.

**Fig. 6.11.4.** Berlin poplar (*Populus*×*berolinensis*) leaves with rust caused by leaf rust fungus (*Melampsora* sp.): Lviv, Ukraine, VK.

**Fig. 6.11.5.** Leaf of European mountain ash (*Sorbus aucuparia*) with rust caused by sorbus rust fungus (*Gymnosporangium cornuta*). Akershus, Norway, VT.

**Fig. 6.11.6.** Leaf of pear (*Pyrus* sp.) damaged by leaf rust fungus (*Gymnosporangium* sp.). Sandefjord (Vestfold county), Norway, VT.

**Fig. 6.11.7.** Close-up of oak (*Quercus* sp.) leaf with telia on the surface due to fusiform rust fungus (*Cronartium quercuum* f.sp. *fusiforme*). USA, RLA.


**Fig. 6.11.8.** Hawthorn (*Crataegus* sp.) leaves with yellow spotting on the upper side of leaves infected by American hawthorn rust fungus (*Gymnosporangium globosum*). USA, JH.

**Additional information:** In some cases, there may be dozens of pustules on a single leaf. Severely affected leaves often turn yellow and drop prematurely. Heavy infection often reduces the vigour of the plant. In extreme cases (e.g., with antirrhinum rust) the plant can be killed. For sampling and preservation see Chapter 4.

## 6.12. Leaf spots

**Description:** Necrotic spots on the leaf surface, without any insect mine below and no trace of tiny punctures by insects or mites. Depending on the causal agent and the host tree, the size of the damaged area of a leaf may vary from a few millimetres in diameter (spots) to almost the whole leaf (patches). The shape may vary from regular (e.g., circular) to completely irregular, and the colour may range from white, via yellow and red, to black. The patterns shown below are thus only indicative. Bacterial leaf spots are small dark brown to black spots with a yellow halo. Oomycete leaf spots often occur at the tips and margins of leaves where water accumulates. The spots enlarge rapidly, becoming circular, zonate, and purplish brown to brown in colour. On the lower leaf surface, spots have a water-soaked or dry grey appearance and hard globules of plant exudate are sometimes present. As spots increase in size they coalesce and quickly destroy the leaf. In some bacterial or Oomycete leaf spot diseases, the centre of the leaf spot will dry up and fall out, giving the leaf a "shot hole" appearance.

**Possible damaging agents: Fungi:** Ascomycota (Helotiales, Capnodiales, Botryosphaeriales, Pleosporales, Diaporthales, Rhytismatales: Figs. 6.12.1 – 6.12.5), **Bacteria** (Fig. 6.12.6), **Chromista:** Oomycetes (water moulds: Figs. 6.12.7 – 6.12.8).

**Fig. 6.12.1.** Leaf of Persian walnut (*Juglans regia*) with typical spots of marssonina leaf blight fungus (*Marssonina* sp.). Melitopol, Ukraine, VK.

**Fig. 6.12.2.** Leaf of white mulberry (*Morus alba*) with angular and distinctly bordered *Phloeospora* leaf spots fungus (*Phloeospora maculans*). Lower Donaudorf, Austria, TC.

**Fig. 6.12.3.** Sour cherry (*Prunus cerasus*) leaves with reddish, round and minute spots of Cherry leaf spot diseases (*Blumerella jaapii*) on the surfaces of leaves. Lower Austria, TC.

**Fig. 6.12.4.** Sycamore (*Acer pseudoplatanus*) leaves infected by a tar spot disease (*Rhytisma acerinum*). Ternopil, Ukraine, VK.

**Fig. 6.12.5.** European beech (*Fagus sylvatica*) leaf with damaged tip of leaf due to oak anthracnose fungus (*Apiognomonia errabunda*). Rijeka, Croatia, TC.

**Fig. 6.12.6.** Leaf of Scots elm (*Ulmus glabra*) infected with rod-shaped, gram-negative bacterium (*Pseudomonas syringae*). Akershus, Norway, VT.

**Fig. 6.12.7.** Leaves of Japanese andromeda (*Pieris japonica*) attacked by an oomycete plant pathogen (*Phytophthora ramorum*). Ørsta, Norway, VT.

**Fig. 6.12.8.** Wilting of Rhododendron leaves caused by an oomycete plant pathogen (*Phytophthora ramorum*). Cornwall, UK, TC.

**Additional information:** Some fungi can cause leaf blotch, i.e. irregular sized and shaped dead or discoloured areas on leaves, distinguishable from leaf spot mainly on the basis of indistinct or diffuse margins and irregular shape and size.

Sometimes large areas of leaves are discoloured, greenish grey to black and covered by spores having a velvety surface scab. For sampling and preservation of pathogens see Chapter 4.

## 6.13. Leaf mining

**Description:** Cavities (so-called mines) in leaf lamina, with eaten inner tissue and untouched lower and upper epidermis. In some cases, such cavities are located exceptionally inside the epidermis. Feeding patterns, particularly shape of the mine (tunnel, flat blotch, tentiform blotch, combination of tunnel and blotch, etc.), location of mine within the leaf (upper surface, lower surface, full depth), arrangement of frass in mines (line, long threats, loose granules, etc.), together with host plant identity can often be the diagnostic characteristics for taxonomic identification of a known insect.

**Possible damaging agents: Insects:** Larvae of some Lepidoptera (Figs. 6.13.1 – 6.16.3), Hymenoptera (Fig. 6.13.4), Coleoptera (Fig. 6.13.5) and Diptera (Fig. 6.13.6).

**Fig. 6.13.1.** Horse chestnut (*Aesculus hippocastanum*) leaves with numerous blotch mines of moth larvae (Lepidoptera, Gracillariidae: *Cameraria ohridella*). Moscow, Russia, NK.

**Fig. 6.13.2.** Sycamore maple (*Acer pseudoplatanus*) leaves with serpentine mine of a moth larva (Lepidoptera, Nepticulidae: *Stigmella speciosa*). Mátrafüred, Hungary, GC.

**Fig. 6.13.3.** Poplar (*Populus* sp.) leaf with a serpentine mine in the epidermis with larva visible at the end of the mine and close-up of larva in the insert (Lepidoptera, Gracillariidae: *Phyllocnistis labyrinthella*). Novosibirsk, Russia, NK.

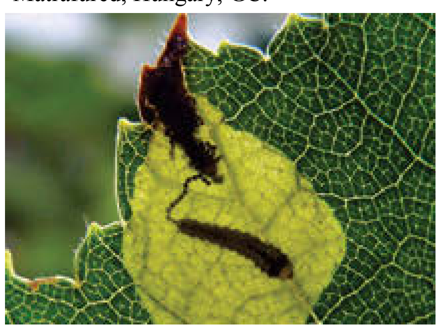

**Fig. 6.13.4.** Silver birch (*Betula pendula*) leaf with a blotch mine created by a larva (visible to backlight) of a sawfly (Hymenoptera, Tenthredinidae: *Fenusella nana*). Novosibirsk, Russia, NK.

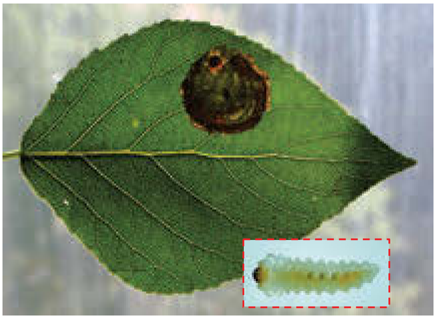

**Fig. 6.13.5.** Balsam poplar (*Populus balsamifera*) leaf with a blotch mine of a weevil (Coleoptera, Curculionidae: *Isochnus populicola*) and close-up of larva in the insertion. Krasnoyarsk, Russia, NK.

**Fig. 6.13.6.** Black poplar (*Populus nigra*) leaf with a blotch mine of an agromyzid fly (Diptera Agromyzidae: *Agromyza albitarsis*), Novosibirsk, Russia, NK.

**Additional information:** Carry out surveys throughout the vegetation period, because some mines are present early in leaf development whilst some appear later in the season. Look for mines – spots or tunnels (with some degree of discoloration) on the leaf surface with dark traces or grains of frass inside (however, note that some mines can be free of frass as larvae of some insects clean their mines ejecting frass outside of mines). For insect collection and preservation, see Chapter 3.

## 6.14. Sooty and grey mould

**Description:** Dark brown to black superficial fungal growth on the aerial parts of plants, particularly upper leaf surfaces. Leaves have a soot-like or powdery deposit, but symptoms can also appear as larger mycelial mats that may crack or peel away from the leaf surface during dry conditions.

**Possible damaging agents: Fungi:** Sooty and grey moulds belonging to Ascomycota (Capnodiales, Pleosporales: Figs. 6.14.1 – 6.14.6).

**Fig. 6.14.1.** Boxwood (*Buxus colchica*) leaf covered by sooty mould fungus (*Fumago* sp.). Ozurgeti, Republic of Georgia, IM.

**Fig. 6.14.2.** *Tilia platyphyllos* with sooty mould (*Fumago* sp.). Lviv, Ukraine, VK.

**Fig. 6.14.3.** Leaf of California laurel (*Umbellularia californica*) covered by sooty mould (general). USA, JOB.

**Fig. 6.14.4.** Magnolia (*Magnolia* spp.) leaves with and without sooty mould accumulation from magnolia scale (Hemiptera, Coccidae: *Neolecanium cornuparvum*) feeding. Kentucky, USA, SV.

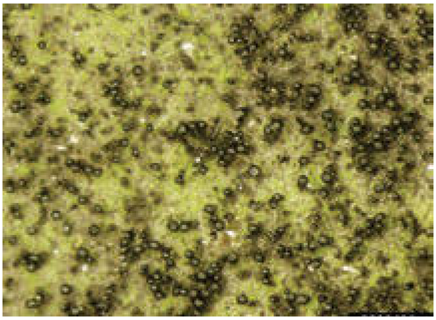

**Fig. 6.14.5.** Royal star magnolia (*Magnolia stellata*) leaf with ascomata sooty mould (*Capnodium* sp.) on the leaf surface. USA, BW.

**Fig. 6.14.6.** Holly (*Ilex* sp.) leaf covered with sooty mould associated brown soft scale (Hemiptera, Coccidae: *Coccus hesperidum*). USA, WC.

**Additional information:** Sap-sucking pests, such as aphids, scale insects, mealybugs or whiteflies, can often be found on the plant, above the point where sooty mould is growing. Sooty mould develops on the honeydew produced by insects or on plants stressed by abiotic factors. For pathogen sampling and preservation, see Chapter 4.

## 6.15. Mildews

**Description:** Powdery mildews correspond to white, powdery-appearing fungal growth on the upper surface of the lower leaves. Infected leaves have dry, corky, scab-like spots where fungal growth is not obvious. With downy mildews, small yellow spots develop on the upper sides of the leaves while white to bluish-white fluffy growth forms appear on the underside of the leaves. As the leaf spots die, the fluffy growth darkens to grey in colour.

**Possible damaging agents: Fungi:** Powdery and downy mildews belonging to Ascomycota (Erysiphales, Peronosporales, Sclerosporales: Figs. 6.15.1 – 6.15.4).

**Fig. 6.15.1.** Leaves of winter creeper (*Euonymus fortune*) with downy mildew fungus (*Oidium euonymi-japonici*) on the leaf surfaces. Tricolor, Kobuleti, Republic of Georgia, IM.

**Fig. 6.15.2.** Pedunculate oak (*Quercus robur*) leaves covered by powdery mildew (unidentified species). Sentinel plantation, Fuyang, China, AR.

**Fig. 6.15.3.** Narrow-leafed ash (*Fraxinus angustifolia*) leaf with powdery mildew fungus (*Phyllactinia fraxini)* on the lower leaf surface. Igneada, Turkey, IM.

**Fig. 6.15.4.** Leaves of horse chestnut *Aesculus hippocastanum* with powdery mildew fungus (*Erysiphe flexuosa*) on the upper surfaces. Bergen, Norway, VT.

**Additional information:** Leaves may become twisted, distorted, then wilt and die. Mortality of the host is not typical, although this disease could become a serious problem under conditions of high moisture and poor air circulation. In downy mildews, infections are first noticeable as light green spots on the upper side of the leaf that turn brown with time. Infected leaves and branches may be distorted and die. For sampling and preservation of pathogens, see chapter 4.

## 6.16. Abiotic causes

**Description:** Large variations in leaves damage occur due to abiotic factors; these are detailed below.

**Possible causes of damage:**

**Drought:** Wilting, yellowing, necrosis, premature leaf drop, crown dieback.

- Wilting is the most common initial symptom of drought stress. Leaves will curl or droop. Leaves of trees stressed by drought may appear yellowed or burned at the margins. Drought stress, however, reduces growth before visible symptoms such as wilting or leaf shedding become apparent.
- Leaves of deciduous trees often develop a marginal scorch. As drought progresses, trees may begin to shed leaves. Trees can also exhibit general thinning of the canopy, poor growth and stunting.
- With well advanced drought conditions, foliage discoloration becomes more pronounced and tip dieback may be seen. Older trees exhibit symptoms from the top down and from the outside inward. In extreme cases, drought can result in plant death.

**Frost:** Frost damage can occur in spring with a late frost or in winter and each of them shows different effects. Spring frost generally affects new leaves and it causes wilting, discoloration, puckering and premature dropping of the young leaves.

**Nutrient deficiency:** Symptoms include overall loss of vigour, general yellowing or chlorosis of the leaves, interveinal chlorosis, marginal necrosis and, in severe cases, total leaf necrosis. Nutrient problems rarely kill plants outright, but proper nutrient management is essential for optimizing growth and maintaining high quality plants.

**Air pollution:** Impacts are most commonly seen on the foliage. Injury symptoms include interveinal necrosis, marginal or tip necrosis, white or brown flecking or stippling on the leaf surface and chlorosis. Injury depends on other environmental and atmospheric conditions. Factors include the type, concentration and the length of exposure to the pollutant; the plant species, its stage of growth and physiological condition; and atmospheric conditions.

**Pesticides:** Application injuries exhibit the same symptoms as nutrient disorders and other chemical applications. In most instances, leaf chlorosis, marginal and/or spotted necrosis, and total leaf necrosis are the visible symptoms.

**Herbicides:** Herbicidal activity on trees can be expressed by several visual symptoms depending upon the nature of the chemical used. Symptoms of herbicide action on weeds include leaf cupping and twisted, distorted growth. Chlorosis, curling or similar distortion may be the sign of injury from herbicides. These same symptoms are found on non-target plants.

**Fig. 6.16.1.** The early yellowing of leaves and defoliation of little leaf linden (*Tilia cordata)* due to drought. Lviv, Ukraine, VK.

**Fig. 6.16.2.** Leaves of fuzzy deutzia (*Deutzia scabra*) curled due to drought stress. Lviv, Ukraine, VK.

**Fig. 6.16.3.** Drought stress effect on black poplar (*Populus nigra*) leaves. Melitopol, Ukraine, VK.

**Fig. 6.16.4.** Leaves of eastern black walnut (*Juglans nigra*) damaged by spring frost. Uzgorod, Ukraine, VK.

**Fig. 6.16.5.** Spring frost causes wilting of the leaves of *Magnolia obovata*. Mukachevo, Ukraine, VK.


**Fig. 6.16.6.** Oak (*Quercus* spp.) leaves with marginal chlorosis due to air pollutants. USA, PK.

**Fig. 6.16.7.** Horse chestnut (*Aesculus hippocastaneum*) leaves burned by volcano ash from Iceland in 2011. Stavanger, Norway, VT.

**Fig. 6.16.8.** Horse chestnut (*Aesculus hippocastaneum*) leaves burned by volcano ash from Iceland in 2011. Stavanger, Norway, VT.

**Additional information:** Drought stress can cause some plant species to enter into an imposed dormancy. Many drought-stressed plants also show increased sensitivity to de-icing salts, air pollutants and pesticides. With severe drought conditions, new foliage is shed, shoots die back to lateral buds and eventually extensive tree mortality may occur. Due to spring frost, the foliage is irregular and not uniform when the trees foliate again after damage. Older leaves can normally survive frost despite marginal discoloration. Injured terminal buds may generate forked stems or multiple-leaders. Bud damage can be diagnosed by the discoloured or green and water-soaked aspect. Air pollution injury usually occurs in the summer, when temperatures help reaction rates. Herbicide injury produces many of the same symptoms as nutrient deficiencies or toxicities. Nutrient deficiencies and toxicities can be eliminated as causes by leaf tissue and soil analysis.

## 6.17. Irregular leaf discoloration

**Description:** Chlorotic, mosaic-like discoloration, ring-shaped or net-shaped lines, reduced leaf size, bands extending from the leaf veins, mottling, shrivelling of leaves. Chlorotic, in later stages, dark brown to black elongated lesions associated with vascular tissues e.g., usually forming along leaf veins or leaf midribs. Sucking insect damage displays a stippled pattern of yellow, brown or whitish dots on the leaf surface (seen on the upper side of leaf). If damage is significant, it leads to the discoloration of leaves (see also Leaf mining (6.13)).
**Possible damaging agents: Viruses** (Figs. 6.17.1 – 6.17.2), **Insects:** Hemiptera with piercing-sucking mouthparts (aphids, mealybugs, scale insects, true bugs and whiteflies) and thrips (Thysanoptera: Fig. 6.17.6), **Mites**: especially spider mites (Acari: Tetranychidae: Figs. 6.17.4 – 6.17.5), **Phytoplasmas** (Figs. 6.17.7 – 6.17.8), **Fungi.**

**Fig. 6.17.1.** Vein discoloration caused by Chestnut Mosaic Virus (ChMV). Lanxade, France, AV.

**Fig. 6.17.2.** Leaf of *Sambucus nigra* infected by Cherry leaf roll virus. Vienna, Austria, TC.

**Fig. 6.17.3.** Leaf of *Syringa josikaea* with stippled pattern of whitish dots due to cicadas (Hemiptera: Cicadoidea). Krasnoyarsk, Russia, NK.

**Fig. 6.17.4.** Leaf of *Quercus pubescens* with yellowish mosaic-like discoloration due to an oak-feeding phylloxerid (Hemiptera, Phylloxeridae: *Phylloxera quercus*). Tregnago Verona, Italy, AB.

**Fig. 6.17.5.** Lower side of *Quercus pubescens* leaf with yellowish mosaic-like discoloration due to an oak-feeding phylloxerid (Hemiptera, Phylloxeridae: *Phylloxera quercus*). Tregnago Verona, Italy, AB.

**Fig. 6.17.6.** Privet (*Ligustrum* spp.) leaves with whitish mosaic-like discoloration due to privet thrips feeding (Thysanoptera, Thripidae: *Dendrothrips ornatus*). USA, WC.

**Fig. 6.17.7.** Green ash (*Fraxinus pennsylvanica*) leaves afflicted with ash yellows phytoplasma disease (Candidatus: *Phytoplasma fraxini*). Colorado, USA, WJ.

**Fig. 6.17.8.** Pear (*Pyrus* sp.) showing enlarged vein with leaf curl induced by pear decline phytoplasma (Candidatus: *Phytoplasma pyri*). Italy, LGI.

**Additional information:** In case of insect, check the surface of leaves in order to find white and yellow stippling. If observed, check lower sides of leaves and petioles in order to detect aphids sucking fluids from plants. Adults and nymphs of leafhoppers, lace bugs and thrips feed on the underside of the leaves and dark excrement can also be observed. Spider mites (adults, immature stages and eggs) are also found on the underside of leaves, with webbing but no excrement. Sucking insects are often present in large numbers. For sampling and preservation of insects and pathogens, see Chapters 3 and 4.

## 6.18. Nest or tents

**Description:** Nests or tents made of leaves spun together by silk (secreted from insect glands). Usually many larvae are present inside these constructions. Often larvae will be rough eating the leaf's lamina inside or around nests.

**Possible damaging agents: Insects:** larvae of Lepidoptera (Yponomeutidae, Pyralidae, Erebidae, Notodontidae, Lasiocampidae, etc.: Figs. 6.18.1 – 6.18.8).

**Fig. 6.18.1.** European spindletree (*Euonymus europaeus*) with a nest of an yponomeutid moth (Lepidoptera, Yponomeutidae*: Yponomeuta cagnagella*). Novosibirsk, Russia, NK.

**Fig. 6.18.2.** Detail of the foraging colony, (Lepidoptera, Yponomeutidae*: Yponomeuta cagnagella*). Novosibirsk, Russia, NK.

**Fig. 6.18.3.** Boxwood (*Buxus colchica)* leaves spun together by larvae of a box tree moth (Lepidoptera, Pyralidae: *Cydalima perspectalis*). Martvili, Republic of Georgia, IM.

**Fig. 6.18.4.** Caterpillar nest of brown-tail moth (Lepidoptera, Lymantriidae: *Euproctis chrysorrhoea*) on pedunculate oak (*Quercus robur*) leaves. Gyula, Hungary, GC.

**Fig. 6.18.5.** Oak (*Quercus* spp.) leaves spun together into a nest by larvae of a pyralid moth (Lepidoptera, Pyralidae: *Acrobasis tumidella*). Mátrafüred, Hungary, GC.

**Fig. 6.18.6.** Black cherry (*Prunus serotina*) leaves spun together by fall webworm (Lepidoptera, Erebidae: *Hyphantria cunea*). USA, BW.

**Fig. 6.18.7.** Sycamore (*Acer* spp.) leaves spun into a nest by eastern tent caterpillar (Lepidoptera, Lasiocampidae: *Malacosoma americanum*). USA, JAP.

**Fig. 6.18.8.** Plum/cherry (*Prunus* sp.) leaves spun into a nest by larvae of bird-cherry ermine (Lepidoptera, Yponomeutidae: *Yponomeuta evonymella*). Slovakia, MZ.

**Additional information:** The larvae usually feed in or around the nests, but they may disperse and build new nests on the same or neighbouring trees. For insect collection and preservation, see Chapter 3.