Field Guide for the Identification of Damage on Woody Sentinel Plants

Edited by Alain Roques, Michelle Cleary, Iryna Matsiakh and René Eschen

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This book is based upon work from COST Action (FP1401 - Global Warning), supported by COST (European Cooperation in Science and Technology). http://www.cost.eu/COST_Actions/fps/FP1401

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EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

Funded by the Horizon 2020 Framework Programme of the European Union

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CAB International, 2017

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A catalogue record for this book is available from the British Library, London, UK.

Library of Congress control number: 2017034624

ISBN-13: 978 1 78639 441 5

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1
Introduction

R. Eschen

Woody plants, whether planted for economic, environmental or ornamental purposes, are valued resources in all countries. Damage due to pests (including invertebrates and pathogens) can be costly, in terms of both direct loss of crops and control tactics to minimise the impact of pests. The most cost-effective option is either prevention of introduction or early detection and eradication of new species before they become widespread or problematic. Many pests are only detected years after establishment however, which makes eradication nearly impossible, particularly in the case of pathogens. The example of the successful eradication of the fungus *Fusarium circinatum* on pine trees in Italy illustrates that eradication is possible. Such intervention is easier in nurseries and semi-natural environments, but efforts can be very expensive or impossible if the pest has spread before being detected.

Efforts to protect trees from pests often depend on knowledge of the identity and ecology of the pests, as well as their potential impact. This is particularly the case with new pests that are alien (i.e. non-native) to a country, which may be less well studied or even unknown. Alien pests are often introduced accidentally with the intercontinental trade, in particular the trade of living plants. At present, a large number of the newly introduced species are "emerging" species, i.e. species that have not previously been introduced outside their native range (Seebens *et al*., submitted). They are usually not on any list of potential invaders. Authorities in importing countries can respond to the threat of alien species introductions by taking measures to prevent an introduction. These measures may be implemented in the exporting country to avoid transport, or the importing country tries to detect them at the border or soon after introduction. Hence, it is beneficial, if not necessary, to know the identity of the new emerging alien species to be targeted by such measures.

Sentinel planting concept

In order to know what organisms may be associated with a tree species of interest, and what damage they may do if introduced to a new country, it is possible to look at trees in the countries where trees are imported from in so-called *sentinel plantings*. Such plantings can be arboreta, botanical gardens or nurseries (planted for this purpose or not: Fig. 1.1.). The studied tree species can be native to the importing country or native to the exporting country and this difference affects the interpretation of the results. Pests found on commonly traded tree species native to the exporting country may indicate that these pests are likely to be shipped on exported plants. By contrast, looking at tree species that are exotic to the exporting country may not provide indications about the

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likelihood of introduction, but is particularly relevant for the quantification of damage, since the suitability of native species as hosts for introduced pests and their potential impact are almost impossible to predict. Another factor that may influence which pests are found is the age of the trees: on young trees in nurseries foliar pests may be more common than on older trees in arboreta and botanical gardens, which may host more pests of woody organs.

Figure 1.1. Sentinel planting with Chinese trees close to Beijing, China, and people inspecting a tree in the planting for the presence of pests (RE). Inspection of European trees planted in Fuyang, China, for detection of pests and damage potential (AR). Collections in botanical gardens often include exotic trees (Russian Far East, NK).

Studies have shown that sentinel plantings are a very powerful tool to identify organisms associated with tree species. Many of the detected species are unknown associates with the studied tree species or even unknown to science. For example, the vast majority of the insects and fungal pathogens found on European oak trees planted in an experimental sentinel nursery in China could not be identified to species and of those that were identified, most represented new records of those species on the planted tree species (Roques *et al*. 2015, Vettraino *et al*. 2015). The knowledge gathered from such sentinel planting examples can be used to inform regulatory bodies in importing countries to be able to perform pest risk analyses on these pests and decide, if necessary, on measures to mitigate the risk of introducing them. Such measures may include restrictions on the season of import, the origin of the imported plants or chemical or non-chemical treatments.

A guide to identify the most likely causes of damage observed on sentinel plants

This guide is intended as an aid for managers of sentinel plantings, botanical gardens or arboreta, as well as phytosanitary inspectors, who may have knowledge of common pests and diseases of woody plants, but may not know the likely cause of damage that they have not encountered before, for example, because it is a new type of harmful organism or a new type of damage on a known tree species. It is also possible that they are unable to distinguish between damage due to abiotic and biotic factors and between symptoms caused by pathogens and insects. This field guide is the fruit of efforts of a large group of scientists from many countries, both entomologists and pathologists, brought together through COST Action Global Warning (https://www.ibles.pl/cost/). These experts have shared their knowledge and pictures to help the user identify what may cause the damage they see on their woody plants.

When inspecting woody plants for pests, it is possible that the first or only thing to see is damage or disease symptoms. In many cases, the causal agent may not be present any more or not visible, but it is nevertheless important to be able to determine what caused the damage in order to determine whether it is due to abiotic conditions or a pest or disease. The aim of this book is to provide a tentative identification of relatively broad groups of organisms and not definitive identification of the causal agents, which requires more in-depth knowledge than we expect most users to have. Hence, the pictures in this guide need to be regarded as typical examples of the described symptoms. The next Chapter explains how to use the guide, followed by keys (for different organs of conifer and broadleaf species) to guide the user to the relevant sections of the book, based on the questions entomologists and pathologists ask themselves when looking at a damaged or diseased tree in a fashion similar to how a doctor interrogates a patient to arrive at a diagnosis. The largest part of the book is devoted to the description and illustration of damage types and typical causes of the observed damage. The last Chapters provide instructions for taking and preserving samples for further identification by an expert, notification of relevant authorities, and a glossary.

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2
Field diagnosis of damaging agents of woody plants

A.C. Moreira, H. Bragança, C. Boavida and V. Talgø

Introduction

The observation and evaluation of trees or shrubs with symptoms is the first step towards a diagnosis. Several damaging agents can give similar symptoms and because tree damage is often due to a combination of causes, field diagnosis is often complex. An overview of the system will be needed to assess the extent of the problem. For example, the symptom distribution pattern of affected trees is important to determine whether an observed pattern of damage is localised or widespread, which may be indicative of the problem being abiotic (e.g., soil flooding/drought) or biotic, caused by an arthropod pest (insect, mite) or by a pathogen) (Fig. 2.1.).

Fig. 2.1. Cork oak (*Quercus suber*) killed by Phytophthora root rot (*Phytophthora cinnamomi*) in the south of Portugal (left, ACM) and noble fir (*Abies procera*) killed by *P. cambivora* in western Norway (right, VT).

The primary cause of the observed damage is not easy to diagnose without taking a careful and individual approach to the tree. As a first observation for broadleaf trees, the appearance of the crown can be a good indicator of the health status. In particular, determining if the crown presents some degree of defoliation is important, keeping in mind that defoliation may be a reflection of multiple causes. For conifers, chlorotic or necrotic foliage and/or needle cast will help to identify the damaging agent. In any case, the first observations should be assessed further using sound methods. For example, in forests in the Mediterranean region the assessment of the degree of defoliation is based on a scale described by Cadahia *et al.* (1991) and Roloff (2016), which uses a vitality classification system for urban settings. In most cases, a reliable diagnosis requires specialised

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analysis to detect or identify the causal agent or to determine other parameters that may be associated with the problem, such as nutrient deficiencies.

Whole plant observation

A diseased tree or seedling experiences deviations from its normal functioning, caused by some type of biotic agent or environmental stress factor. These changes manifest themselves through various symptoms. In addition to the already mentioned defoliation and chlorosis/necrosis, leaf yellowing, wilting of leaves and shoots, branch and stem cankers, root decay and, eventually, tree mortality may occur. Stress factors may include abiotic conditions, such as drought, flooding, strong wind, extreme temperatures, a diversity of unbalanced soil factors (e.g., the amount of organic matter, soil structure, nutrient content, and pH), and poor management practices. Biotic stresses are caused mainly by plant pathogens and arthropod pests, but interactions with abiotic factors can influence disease development and play a decisive role in tree health.

As tree damage progresses, the weakened tree becomes susceptible to secondary invasions by different fungi and insects, which can make it more difficult to clearly diagnose the primary causal agent. Tree dieback and decline symptoms are typically characterised by a gradual loss of tree vigour, i.e. progressive death of young shoots, branches showing discoloration and wilting or loss of foliage, all of which are examples where a complex of pathogens and insects may be involved. The affected trees must be examined carefully by looking for symptoms (such as curling or perforation of the leaves, webbing, galls, presence of exudations or sawdust) and signs (e.g., larvae, insect eggs or fungal fruiting bodies) in order to identify the primary cause of the damage or disease.

In general, many of the signs of biotic, damaging agents are inconspicuous to an untrained eye and therefore observations in the field often require a good hand lens to spot, for example, fruiting structures at a higher magnification, and a knife to cut-open and expose affected plant tissue to reveal characteristic signs of the causal agents or the agents themselves. However, some signs of biotic diseases are specific and easy to detect, like mushrooms growing at the base of the trunks of affected trees.

Observation of individual tree parts

If only a part of the tree appears affected, careful observation of the affected parts may reveal symptoms of disease or pest attacks which can be identified using the keys in this Field Guide. Each of these parts can show a variety of damage morphotypes, which can be related to groups of causal agents, even when the specific causal agent is unknown. By systematically looking at the symptoms, it is possible to exclude some and close in on the most likely causal agent. On the following pages, we present keys for each part of the tree (Table 2.1.), separately for conifer and broadleaf trees, that will guide the user to the sections in the book that provide descriptions of the damage, and some examples of the causal agents that may cause the observed damage.

Table 2.1. The different parts of broadleaf and coniferous woody parts treated in this field guide and the pages where keys for the identification of potential damaging agents can be found.

	Broadleaf woody plants	Coniferous woody plants
Foliage	20	29
Flowers, fruits and seeds	21	30
Twigs, branches and stems	25	34
Buds and shoots	27	36
Roots and collars	28	37

Observation of where and when the damage occurs should direct the user to the appropriate key, i.e. where the cause of the problem can be found. For example, if only individual branches are affected on broadleaf trees, it is likely that the cause can be found on those branches, as opposed to for example affected leaves that can be seen dispersed over the entire crown. Pests and diseases of foliage, buds, shoots and reproductive organs (flowers, developing fruits, seeds) tend to be seasonal and fungi that cause foliar diseases are typically most serious during wet springs or autumn. Cankers on branches or stems may be more easily observed on broad leaf trees when the trees have lost their leaves, or during the season, when the cankers are fruiting. On conifers, so-called flagging (dieback of basal or distal branches) often reveals canker wounds.

If the whole tree is affected, it is possible that it faces a problem with its roots. Root damage is often caused by soil borne organisms which affect the tree's ability to absorb nutrients and water, thereby leading to drought symptoms and nutrient deficiency. Sometimes this even causes trunk bleeding (resin flow on conifers). Some microbial agents cause "decline and dieback" or "sudden death". In the latter case, the tree dies suddenly with dry leaves still attached.

Diagnosing a root problem can be particularly difficult because several causes can lead to similar symptoms and also because above-ground symptoms tend to appear only after a substantial amount of root damage has occurred, to the point where tree recovery is difficult, if not impossible. When we suspect a root disease, we must look at the roots in the field, and for this it is necessary to dig the soil around the stem/trunk to expose, observe and collect roots and/or soil samples to send, as soon as possible, to a laboratory to be analysed.

Wilt is a symptom that can affect the leaves, petioles, shoots and stem. Early symptoms of wilt include a nearly uniform discoloration of the leaves that appear pale green in colour, later turning yellow and finally brown. Wilt fungi are most often caused by vascular mycosis, and include species of *Fusarium*, *Ophiostoma, Verticillium* or *Ceratocystis*. Wilt can also be induced by the feeding of insects on and in roots and by nematodes. In broadleaf trees, the affected parts lose their turgidity and droop. Wilt diseases are easily confused with root and crown rots or abiotic problems such as drought, water excess, or soil compaction.

It is important to remember that in many cases, a reliable diagnosis requires specialised analysis to detect or identify the causal agent or to determine other parameters that may be associated with the problem, such as nutrient deficiencies. This requires a good description of the situation and symptoms, including good quality pictures where possible, and sending samples to specialised laboratories, as described for arthropods and pathogens in Chapters 3 and 4. When very damaging, regulated or new pests or diseases are found, it is necessary to inform the relevant authorities (Chapter 16).

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3
Arthropod collection and sample preservation for further analysis

N. Kirichenko and G. Csóka

General recommendations

Woody plants can be infested/damaged by various groups of arthropods, thus organs of a plant should be carefully examined for different types of symptoms and for the presence of damaging organisms.

Before collecting arthropod pests, take high quality photographs, including: the whole plant, the symptom/damaged part and a close-up of any feeding arthropods – these may be a premature stage (e.g., larva) or adult. Images of the whole plant (including leaves, flowers and fruit) can help to identify the plant species. Accurate identification of the host plant is important, as a number of herbivorous arthropod species are strictly host specific, and usually organ specific, thus information on the host plant, and the organ affected, can be useful for pest identification.

Collect any feeding arthropods (larvae and adults) or pupae, and eggs if present. If only a single or a few individuals are found, it is better to preserve them immediately in 96-99% ethanol for further morphological and molecular identification. For morphological identification, it is better to preserve aphids, thrips and other tiny insects in 70% ethanol, together with a tiny drop of glycerine, which can prevent fragile insects from shrinking. Use plastic tubes of an appropriate volume with a tight lid to prevent evaporation of ethanol (Figs. 3.1., 3.2.).

If the pest is present in large numbers, some individuals should be preserved in ethanol and others collected with a piece of the plant part on which they feed in a plastic or glass jar or a plastic zip-lock bag; be sure to blow air into a bag before sealing to avoid damaging the specimen. Collected specimens can then be transported for indoor rearing or shipped immediately to a diagnostic laboratory.

When rearing in the laboratory, collect all emerging adults, including parasitoids which could develop inside larva/ pupa of a target species; they may provide an important source of information for biocontrol programs. For collecting and rearing, Petri dishes, plastic tubes with ventilation lids (Fig. 3.3) or plastic boxes are recommended.

Where possible, collect the damaged fragment of the plant, as well as the arthropod causing the damage. Whole seedlings can be collected. Use plastic zip-lock bags or paper bags for storing the material. Pieces of bark with galleries should be dried and kept in paper bags; leaves with spots and other injuries

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should be dried and flattened, then stored between sheets of paper (and scanned, see below); galls should be preserved in ethanol; seeds should be removed from fruits and slightly air-dried, then kept in sealed paper bags.

Label the collected specimens properly providing all essential information: locality, GPS coordinates, host plant, date of collection, collector name, identifying number, type of damage (identified using the protocols in this manual), degree of damage (insignificant, moderate, high) and frequency of attacks (found on one, few or many individual plants in the surrounding area). Label the collected arthropod, sampled organ/part of the plant and photographs with the same identifying number. It will help associate a pest with the type of damage recorded.

Fig. 3.1. Plastic tubes with hermetic lids for preserving insects in ethanol (GC).

Fig. 3.2. A box for storing the tubes (GC).

Directly after collection, send the specimens to the diagnostic laboratory. If impossible to do immediately, store the ethanol preserved specimens in a freezer at -10 to -20°C. They can be kept in this way for a relatively long period of time. Stored live insects with plant material for feeding can be kept in jars or plastic bags at +3°C in the fridge but only for a limited number of days (dependent on arthropod group, but usually around 3 days).

Sampling of arthropods damaging foliage

Foliage (leaves and needles) can be damaged in a number of different ways. Leaves and needles can be chewed with visual loss of all or some of their surface/tissue (skeletisation, perforation, peeling, cutouts, rough eating, etc.), covered by spots of different shapes size and colour (after leaf piercing and mining) and anomalous formations (galls) [1], deformed (twisted, rolled, curled, etc.), spun together into a nest of a different shape and size, covered by wax, froth (or spittle), etc.

[1] Can be confused with necrotic damage caused by pathogens.

Fig. 3.3. Plastic tubes with ventilated lids for collecting and rearing insects (GC).

Fig. 3.4. Beating tree branches and sampling insect larvae using the collecting tray (GC).

Depending on the damage type, the following examination and sampling approaches should be applied:

- Foliage with loss of all or some part of their surface/tissue (skeletisation, perforation, cutouts, rough eating, etc.) should be examined from all sides in order to find feeding larvae or adults. Keep in mind that larvae and adults causing such damage may rapidly escape when they are approached, i.e. they may fall into the litter (both larvae and adults) or adults may fly away. In some cases, it may be necessary to place a layer of fabric (preferably white in colour) to find fallen arthropods or to use a net to collect flying adults trying to escape. If a pest is not seen, beat branches (using a Japanese umbrella, ordinary umbrella or collecting tray) in order to disturb adults, causing them to reveal themselves. Beating is an extremely efficient way to collect free feeding arthropods that feed on foliage (Fig. 3.4).
- Foliage with tiny spots (discolorations) on the surface should be examined on the lower side of the leaf to detect arthropods sucking fluids from the plant: nymph and adults of aphids, leafhoppers, lace bugs and thrips or their moulting exuvia. Feeding insects can be collected in the field with no additional action required.
- Foliage with bigger spots (differently shaped tunnels) should be examined using light to find any larva or pupa of leaf mining insects and any inclusions (frass, exuvia) trapped in the leaf. Larvae and pupae can be collected by opening leaf epidermis with a syringe needle. This can be carried out in the field but, preferably, leaves should be collected (stored in plastic zip-lock bags) and the insects sampled from their mines in the laboratory. If the pest is abundant, larvae and pupae of leaf miners can be kept in the lab to raise adults. Preserve leaves with mines as herbarium specimens as the shape and position of the mine can provide useful data. In some cases, the colour of the symptoms on the leaf (i.e. mined leaves or leaves with flat galls) can be a useful aid in identification and damaged leaves could be scanned. Larvae and

pupae found in mines on dried leaves can still be used for molecular identification.

- Foliage with anomalous surface formations should be checked on the upper and lower side in order to find round, oval, papilla-like or felt-like structures. Galls (round, oval or unshaped formations) can also be found on twigs. After taking photographs, open the gall by carefully cutting only its surface with a sharp knife (be aware that cutting too deep may damage the larva). Collect larvae, pupae or adults found in galls. Alternatively, galls can be transported and opened in the lab. Galls caused by mites (Acari) (e.g., papilla-like, felt-like formations) can also be collected in 95-99% ethanol with a piece of leaf tissue. In the herbarium collection ensure leaves are kept with galls.
- Deformed leaves (twisted, rolled, curled etc.) should be carefully opened in order to find larvae, pupae or adults which often feed inside such shelters. Record the type of shelter; whether silk has been used for construction and whether the deformed leaf is chewed or not.
- Foliage spun together into a nest which can vary in shape and size. Inspect the nest to find and collect larvae/pupae. Please note that some nest building Lepidopteran species are harmful to humans, and can cause severe skin allergies (e.g., larvae of pine processionary moth *Thaumetopoea pityocampa* which colonises pines). Thus, it is important to cover any bare skin to protect body and hands prior to touching nests and larvae.
- Foliage covered by wax, froth (or spittle). If wax is present, inspect leaves as well as petioles and twigs for presence of larvae/adults of scale insects. Insects can be collected in the field with no additional action required. Froth (or spittle) on leaves (can also be found on the leaf petioles or twigs) may indicate the presence of feeding larvae which protect themselves by such excretions against predators and dehydration. Remove froth and collect larva.

In all cases, collect specimens in ethanol or try to rear immature stages to adult in the lab. Take good quality digital images as mentioned earlier.

Sampling of arthropods damaging shoots, twigs, branches and stems

Shoots, twigs, branches and stems of woody plants can have visible damage on the surface – anomalous formations (galls) (on shoots, twigs and branches), eaten bark (on young shoots and twigs mainly), tunnels (galleries) in the bark, cracks, holes or other injuries, swollen shoots, etc. Presence of holes is a sign of damage hidden under the bark, in sapwood, phloem or deeper in the stem.

Depending on the type of damage, the following examination and sampling approaches should be applied:

- Check the surface of shoots, twigs, branches. Collect the fragments of the plant carrying galls. Open the gall using a sharp knife to find and collect larvae from the gall. Some galls develop inside the unopened buds, so pay particular attention to swollen or distorted buds. Open these deformed buds with a pin or forceps; some of these galls are tiny, so a magnifying lens is required. Take photographs before and after cutting the gall.

- Explore visible injuries on bark of shoots, twigs, branches. Wherever bark is eaten (on young shoots and twigs mainly), check as many branches as possible to find the feeding insect.
- A tree or shrub can be infested by insects living inside the bark or underneath it, such as bark beetles or wood boring insects. The following symptoms are indicative of the presence of such pests: brown frass (sawdust-like faecal material) protruding from cracks in the bark, resin flow on the bark surface, discoloured (red or brown) foliage, premature leaf abscission, dying or dead branches on the upper part of the crown. Carefully check plants for the presence of these or similar symptoms, and look for holes on the bark surface (on shoots, twigs, branches and often stem), remove the piece of bark using a sharp knife, chisel or small axe. Check the bark and the space under the bark for galleries which can contain larvae, pupae and beetles. If galleries are empty (no insects), continue debarking to try and find live insects. In the case of seedlings, the whole plant can be debarked. Photograph the affected tree, the holes (or other injuries) on the bark and the galleries with insects if present after removing the bark. These can provide valuable information about diagnostic characteristics useful for pest identification.

In all cases collect insects and put them in ethanol as described above. If there are no adults, but larvae and pupae are abundant, store them with a piece of bark or wood in the lab in order to try and rear them into adults. Sample part of the damaged bark and wood with representative galleries for subsequent diagnostics; dry and store them in normal laboratory conditions in well-sealed paper bags. Insects developing in thinner stems or branches or twigs can likely be reared in the laboratory. Cut the infested branch, shoot or twig and put it into a rearing container after proper documentation including photographs.

Sampling of arthropods damaging flowers, fruits, cones and seeds

The following examination and sampling approaches should be applied:

- Flowers of some woody plants, especially conifers (male flowers and female flowers - conelets), can be chewed or gnawed: with or without resin droplets, with or without spotted areas, with or without silk covering the stalk and, finally with or without distorted flowers.
- On damaged flowers, larvae or adult insects can often be found and collected. If none are found, beat flowering branches to catch the damaging insect. Dissect the damaged flower to check for the presence of larval tunnels filled with frass and check for the presence of larvae amongst pollen grains.
- Some insects (i.e. gall wasps on oak) induce gall formation on flowers. Some of these are tiny and can only be detected using a magnifying lens. If a flower is distorted, dissect pollen bags and look for minute insects. If the stalk is covered by silk, remove the silk and to find the larva. Take photographs of damage and dissection. Preferably, dissection of the flowers and stalks should take place in the laboratory. Collect larvae and preserve in ethanol as described above.

- Fruits and cones may have small holes with or without frass extruding, they can also be deformed and discoloured. Dissect the fruit or cone to find feeding larvae; take photographs before and after dissection. Collect any larvae in ethanol. Some seeds (i.e. oak acorns) do not show any visible sign externally of insects developing inside them (acorn weevil and acorn moth larvae, and some gall wasps). Therefore, dissect a number of healthy looking (or slightly distorted) seeds to ensure no insect is present.
- Seeds need to be extracted from cones and fruits. It is worth bearing in mind that sometimes the insect may have already eaten the seed out and subsequently left. In this case, hole(s) will be observed, and the seed may be filled with frass or emptied through larval feeding. Collect mature seeds in paper bags and carefully examine them in the laboratory. If no visible damage is seen on the seed surface an X-ray is recommended to verify there is no insect present. Infested seeds can kept in the laboratory in Petri dishes or other containers until adults emergence.

Sampling of arthropods damaging roots

The root system of trees and shrubs can be damaged by arthropods, which will influence the health of the whole plant. Root sampling can be exhausting, especially when a big tree has to be examined. Young trees (seedlings) are often more susceptible to root damaging arthropod pests than mature trees.
The following examination and sampling approaches should be applied:

- Check the stem of the tree at its base and note the presence of holes with or without sawdust-like material.
- Clean roots and examine them for the presence of feeding larvae or the signs of their feeding. Small plants (seedlings and bonsai) can be removed from the soil and their roots can be checked. If needed, dissect the roots to check for the presence of pests.
- Check the soil surrounding the damaged roots for the presence of possible damaging organisms
- Photograph the damage and the arthropod causing damage if found. Collect larvae in ethanol.

Further reading

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4
Pathogen sampling and sample preservation for future analysis

S. Prospero, R. O'Hanlon and A. Vannini

General recommendations

1) A diseased plant may be affected by more than one pathogen and display various symptoms. Thus:
   - check the whole plant and do not consider only a specific organ (e.g., stem);
   - if a plant shows a general crown decline without specific above-ground symptoms, check the roots;
   - take samples from all symptomatic organs;
   - the collected samples should represent all the symptoms observed.
2) Do not collect dead plants or plant organs, as these may have been colonized by saprotrophic organisms, they are not useful for the diagnosis.
3) Do not collect samples in rainy weather; wet or humid samples may become colonized by other organisms, making the correct diagnosis more difficult.
4) Collect the whole plant whenever possible (e.g., seedlings, saplings and bonsai).
5) Place the samples in paper or plastic bags of appropriate size: if you use plastic bags, wrap the sample first in a paper towel, especially when samples are humid or wet. If you suspect a quarantine organism, double wrap the samples.
6) Label the samples properly (simple and understandable) right after collection. Use preferably a pencil, as it withstands water. Provide as much information as possible (e.g., name of the collector, date of sampling, coordinates, elevation, exposition, plant species, origin of the plants; outdoor or potted plants, plant age, how spatially distributed the symptomatic plants are, e.g., regular, random or aggregated pattern, incidence and severity of the symptoms, environmental conditions; management history in case of forest/plantation/arboretum).
7) Send the samples immediately after collection to the diagnostic laboratory; storing the samples will reduce the chances of isolating the original pathogen and promote the development of saprotrophic organisms. In case immediate shipping is not possible, store the samples at a cool temperature (at 3-5 °C) and do not allow them to dry out.

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8) If you use a tool for sampling (e.g., secateurs, pruning saw), clean and disinfect it after each sample, e.g., with 70% ethanol or a biocide. This simple measure will considerably reduce the risk of cross contaminations.
9) Take good quality pictures of the whole plant (general view) and close up of each symptomatic part of the tree.
10) <u>Remember</u>: sampling can be time consuming, but a good sample considerably increases chances of a correct diagnosis!

Sampling of bark

Symptoms visible on the bark include outer depression, discoloration, and cracks (cankers), commonly indicating the presence of a necrotic lesion. For collecting samples of bark lesions on stems or branches, the following procedure should be adopted:

1) Identify the margins of the lesion (e.g., change of colour of the bark, end of cracks).
2) Using a knife or a chisel, carefully remove the outer bark to definitively reveal the front of the lesion in the inner bark (if the lesion is clearly identifiable, this step may not be necessary). In this region, the pathogen causing the lesion is most likely active, increasing the chances for its successful isolation. By contrast, in the middle of the lesion the pathogen may not be active anymore and the dead bark already colonized by saprotrophs.
3) Cut and remove a piece of bark of a few cm^2 including both healthy and symptomatic tissue (see Fig. 4.1.a.). The incision should reach the cambium and, in case the wood underneath is also discoloured, a layer of wood should also be removed. To increase the chances of isolating the pathogen, you can collect a few bark samples per lesion. When the lesion is located on a small branch or sprout (see Fig. 4.1.b.), you can remove the whole section of the branch/sprout containing the lesion by sawing 3-5 cm in the healthy tissue beyond the lesion with a pruning saw or cutting with secateurs. In the case of seedlings or saplings, you can cut and collect the whole plant. If stromata or fruiting bodies are present on the surface of the lesion, a bark sample with them should also be taken.
4) Label, pack and send the sample as described above.

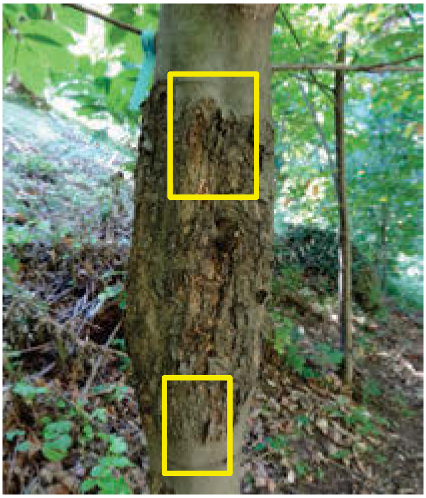
Sampling of wood

Symptoms of a wood infection by a pathogen may include branch wilting to different extents (from localised to general on the crown), leaf size reduction, and discoloration.

For collecting samples of infected wood, the following procedure should be adopted:

1) Choose a declining branch not yet completely wilted. In case of small branches (up to 3-5 cm diameter), cut the whole branch; in case of large branches, collect a cubic sample with a chisel being sure to include a relevant part of the wood. When sampling bark, try to include both symptomatic (discoloured) and healthy wood tissue.

2) In case no discoloration is evident in the wood, proceed as for sampling of roots.
3) Label and pack the sample, and send it to the diagnostic laboratory.


a


b

Fig. 4.1. Collecting samples from bark lesions. (a) Lesion on the main stem: pieces of bark including both healthy and symptomatic tissue of a few cm^2 should be removed (yellow rectangles); (b) Lesion on a young stem (or on thin branches): the entire section of the stem/branch containing the lesion can be removed. WSL.

Sampling of shoots

Visible symptoms may include wilted or necrotic shoots, flagging, discoloration and 'shepherd crook' curved shoot tip. To collect samples from symptomatic shoots, the following procedure should be adopted:

1) Collect the whole shoot by cutting through the healthy tissue about 3 to 5 cm below the symptomatic part
2) As shoots are fragile, it is imperative (more important than for bark samples) to collect them dry and send them as fast as possible to the diagnostic laboratory.

Sampling of leaves and needles

Symptoms visible on the leaves (and needles) consist mainly of necrotic spots of different shapes and colour. For collecting samples from symptomatic leaves (and needles), the following procedure should be adopted:

1) Collect the whole leaf and not only parts of it: when sampling simple leaves, include the petiole and when sampling compound leaves include the leaflets, rachis and petiole.

2) If different types of necrotic spots are present on the leaves of a single plant (e.g., different colour), collect leaves with all representative symptom types.
3) If all leaves on a small branch or twig are wilting, include a piece of the adjacent branch/twig in the sample. Check for a lesion on the branch/twig and if present, cut the branch/twig 3-5 cm in the healthy tissue beyond the lesion (see Sampling of bark) and collect it. In this case, the branch/twig, and not the leaves, may be infected.
4) If symptoms are visible on different foliar stages (e.g., young vs. old leaves), collect symptomatic leaves from all stages.
5) If stromata or fruiting bodies are present on individual leaves, these particular leaves should also be collected.
6) In the case of seedlings or saplings, you can cut and collect the whole plant.
7) As leaves are fragile, it is imperative (more so than for bark samples) to collect them dry and send them as fast as possible to the diagnostic laboratory.

Sampling of roots

Symptoms on the roots include bark lesions, resin flow, or decay. In contrast to symptoms on stem, branches, twigs and leaves, which are easy to detect, symptoms on the roots, except main roots, superficial roots or shallow roots that are partially visible, and root collar, are frequently not visible. Therefore, root sampling can be more laborious.

To collect samples from symptomatic roots, the following procedure should be adopted:

1) If no roots are visible, remove the soil to expose at least the main superficial or shallow roots.
2) Remove the soil from the root surface using a brush.
3) Inspect the individual roots for the presence of lesions, decay or exudates. If something is visible, proceed as for bark sampling. As for branches, in the case of small roots you can remove the whole section containing the lesion by sawing the healthy tissue 3-5 cm beyond the lesion with a pruning saw or by cutting with secateurs. In the case of seedlings or sapling, you can collect the whole root ball.
4) As roots are mostly infected by soil-borne organisms, it is recommended to collect also soil samples from the rhizosphere of trees with symptomatic roots. For this, select four points at a distance of 50-100 cm from the tree (each point representing the corner of a square, with the trunk in the centre). At each point remove the litter from the soil surface and with a spade collect soil until a depth of 20-25 cm (total of 200-300 g of soil for each tree). Pool the soil of the four samples in a plastic bag or container. Remove stones or litter from the sample, fine roots or small roots of the sampled tree can be included.

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5
Diagnostic keys

Key to damage on foliage of broadleaf woody plants

Page numbers of the section are indicated in brackets. Note that several symptoms can appear in combination because of joint damage by several organisms

- Leaves damaged
  - Leaves with some parts eaten
    - Soft tissue of the leaf eaten including veins **6.4. Rough eating** (42)
    - Soft tissue not entirely eaten, leaf veins untouched
      - Only well-defined holes in leaf lamina or cut-outs on leaf margins
        - Gnawing holes in leaf lamina **6.2. Perforation and shot holes** (39)
        - Leaf margins showing cut-outs of any shapes **6.3. Cut-outs** (41)
      - Most of leaf tissue eaten but leaf veins untouched **6.1. Skeletonisation** (37)
  - Leaf deformation
    - Outgrowth of leaf tissue (leaf surface and / or petiole) causing deformation **6.7 Leaf galling** (47)
    - Leaf curled **6.6. Leaf curling** (45)
    - Leaf rolled or folded **6.5. Leaf rolling** (43)
  - Leaves discoloured
    - Leaf with spots or blotches (round or angular, distinctly bordered)
      - Mining (eating) of inner tissue, leaving lower and upper epidermis untouched or mining of petiole **6.13. Leaf mining** (58)
      - Necrotic spots on leaf surface in various shapes, without leaf tissue mining **6.12. Leaf spots** (55)
      - Lower surface covered with yellow/orange/red spores and/or pustules **6.11. Rust diseases** (53)
      - Chlorotic, mosaic-like discoloration, ring-shaped or net-shaped lines, bands extending from the leaf veins, mottling, shriveling of leaves **6.17. Irregular leaf discoloration** (66)
    - Leaves uniformly or asymmetrically discoloured **6.16. Abiotic causes** (63); **15.2. Root rot** (265); **13.2. Vascular diseases** (225)
    - Presence of a powdery layer on leaf surface (upper and/or lower side)
      - Upper or lower surface covered by white powdery material **6.15. Mildews** (62)
      - Black powdery coating on the leaf or grey velvety covering the leaf **6.14. Sooty and grey mould** (60)
  - Leaves spun together by silk into a construction covered or not with frass **6.18. Nest or tents** (68)
  - Presence of coverings on leaf surface and / or petiole
    - Presence of wax or honeydew **6.10. Presence of wax** (51)
    - Presence of froth or spittle **6.9. Presence of froth and spittle** (50)
    - Presence of fine webbing on leaf surface **6.8. Webbing** (49)

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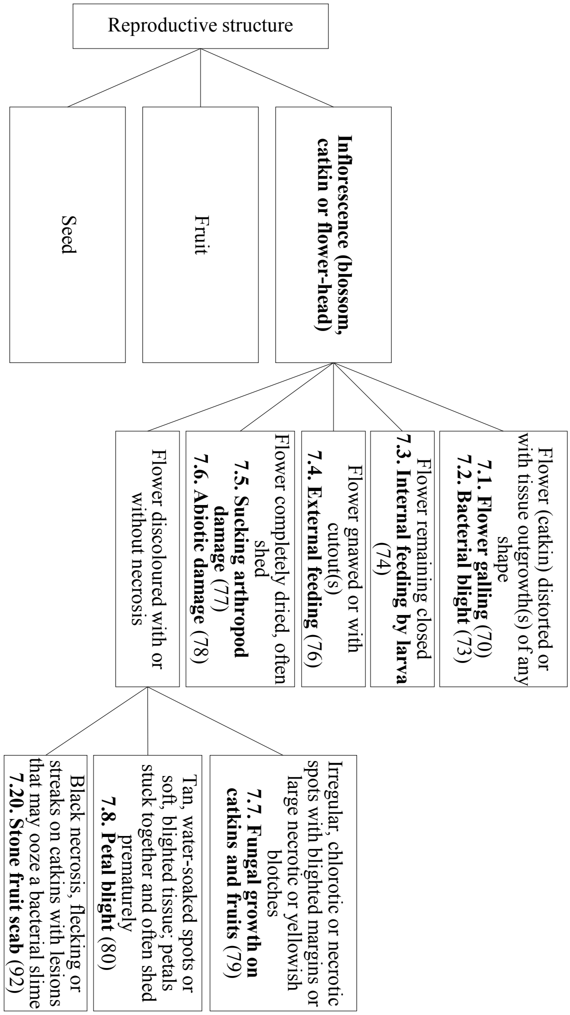
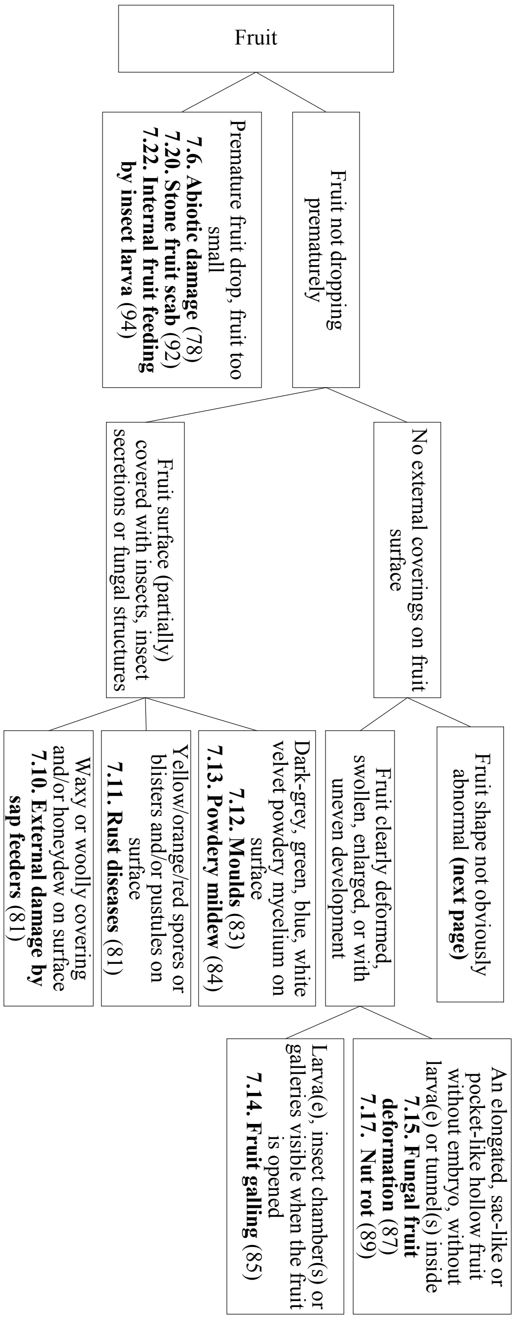
Key to damage on flowers, fruits and seeds of broadleaf woody plants (1) – inflorescence



Key to damage on flowers, fruits and seeds of broadleaf woody plants (2A) – fruit



Key to damage on flowers, fruits and seeds of broadleaf woody plants (2B) – fruit

- **(from previous page)** Fruit shape not obviously abnormal
  - Fruit entirely or partly discoloured
    - Black or tan-brown discoloration on the inside or outside of the fruit
      - With small, raised, cream-coloured fruiting bodies **7.17. Nut rot** (89)
      - Shrivelled stone fruits or intermixed acorn tissues, held together by fungal mycelium. Fruits chalky and sponge-like **7.18. Hull Rot (mummification) of stone fruits** (90) **7.19. Black rot (mummification) of acorns** (91)
    - Extensive crusty, corky, spotting on fruit surface with cracks, lesions or necroses clustered near the stem **7.20. Stone fruit scab** (92)
    - Fruit speckled or russetted **7.23 Mite-induced discoloration** (96)
    - Distinct and gradually coalescing or sharply outlined spots of various, shapes, colours or dimensions
      - No larva or tunnel when the fruit is opened. **7.21. Fruit spot** (93)
      - Presence of larva(e) or tunnel(s) when the fruit is opened **7.22. Internal fruit feeding by insect larva** (94)
  - Shell-hardening black or brown lesions with ooze **7.16. Bacterial diseases and viruses** (88)
  - Fruit not discoloured
    - Scattered deposits of gum (thick sap) or frass (larval excrements) on fruit surface **7.22. Internal fruit feeding by insect larva** (94)
    - No frass or gum on surface
      - No exit hole in surface, but presence of larva(e) or tunnel(s) when fruit is opened **7.22. Internal fruit feeding by insect larva** (94)
      - Presence of exit hole(s) in surface
        - Exit hole(s) irregular **7.24. Larval emergence hole** (97)
        - Exit hole(s) perfectly circular **7.27. Adult emergence hole** (99)

Key to damage on flowers, fruits and seeds of broadleaf woody plants (3) – seeds

Seeds

- Seed deformed or distorted
  - Seed noticeably deformed **7.26. Seed galling** (101)
  - Seed enlarged to several times the normal size, waxy with a yellow layer of spores **7.27. Seed rot** (101)
- Seed partly/completely discoloured
  - With velvet powdery mycelium on seed coat **7.12. Moulds** (83) **7.13. Powdery mildew** (84)
  - Dark spots on cotyledon; cotyledon becomes soft and the outer seed coat turns black **7.27. Seed rot** (101)
- Seed not deformed and not discoloured
  - Irregular hole(s) in outer seed coat; seed at least partly filled with frass **7.22. Internal fruit feeding by insect larva** (94)
  - Circular hole(s) in seed coat. Seed empty, without frass **7.28. Seed insect damage** (102)
- Seed empty when opened (or X-rayed)
  - Larva(e) or pupa(e) in the seed **7.28. Seed insect damage** (102)
  - Without remains of embryo **7.6. Abiotic damage** (78) **7.28. Seed insect damage** (102)

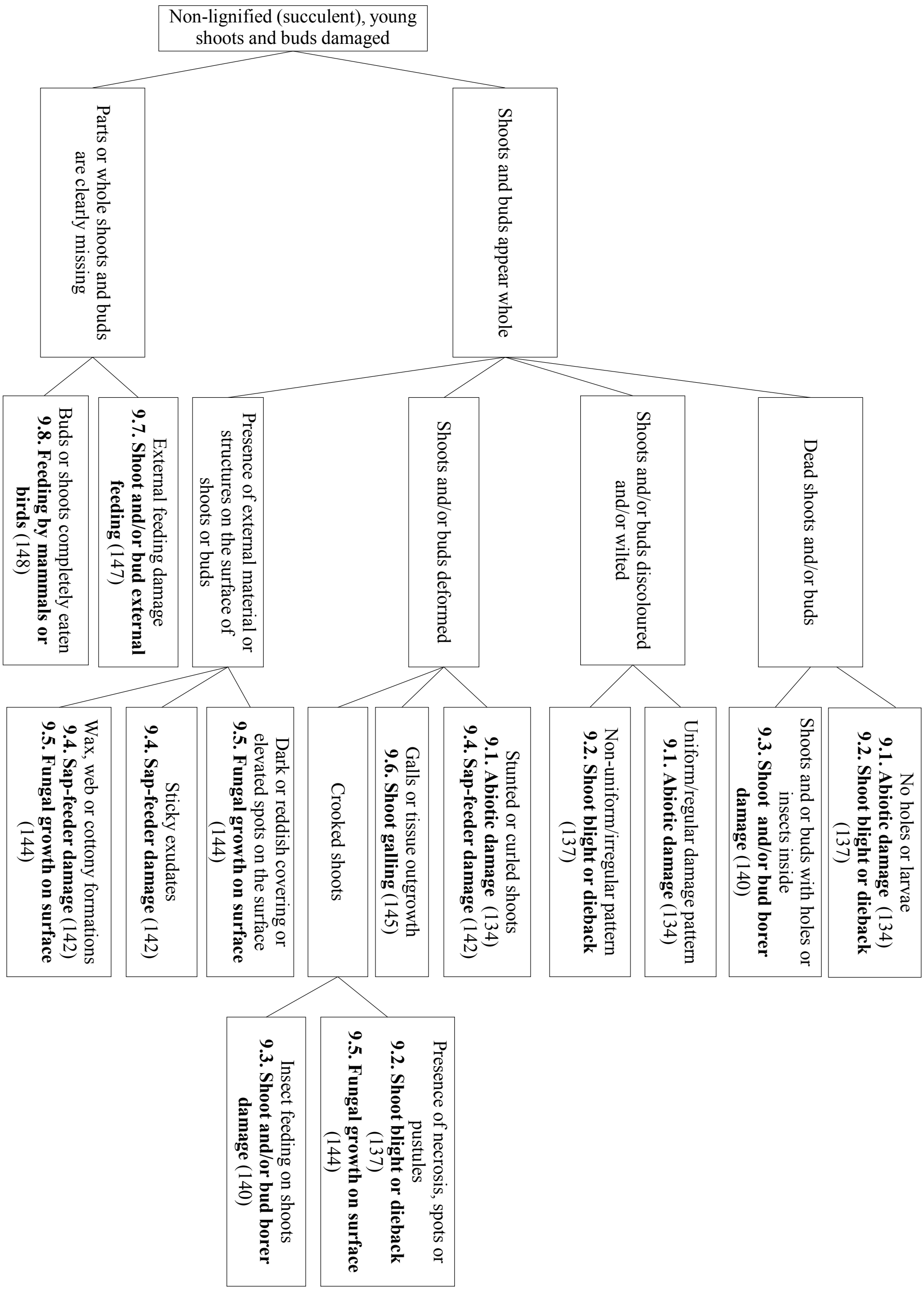
Key to damage on stems, branches and twigs of broadleaf woody plants (1)

- Stems, branches and twigs
  - Evidence of growth deformation
    - Swelling or abnormal rounded outgrowth of woody tissues **8.10. Twig and stem swelling** (122)
    - Abnormal twig development
      - Dense mass of shoots growing from a single point **8.11. Witches' brooms** (125)
      - Dormant buds on shoots, elongated or flattened **8.12. Epicormic shoots/fasciation** (127)
  - No growth deformation
    - Cracks in the bark; splintered breakage of main stem or branches (mechanical cracks)
      - No fruiting bodies, no evidence of insect feeding **8.4. Abiotic damage** (109) **8.1. Root and stem rot** (103) **8.14 Mammal and bird damage** (136)
      - Presence of fruiting bodies (Note: may depend on season) **8.1. Root and stem rot** (103) **8.5 Cankers** (112)
    - No cracks in the bark
      - Branches not wilting entirely **(To next page)**
      - Branches or twigs wilting and dying (leaves remain attached flagging)
        - Single or scattered twigs in the crown turn yellow-brown, wilt and die; climate hot and dry **8.4. Abiotic damage** (109)
        - Single branches dying or dead with wilted leaves
          - Presence of girdling **8.5. Cankers** (112)
          - Presence of discoloured bark **8.13. Bark necrosis** (129)
          - No obvious symptoms on the bark; brown discoloration of the wood (Note: would require cutting into stem) **8.2. Vascular diseases** (106)
        - Evidence of chewing (bark partly removed or missing buds) **8.14 Mammal and bird damage** (131)

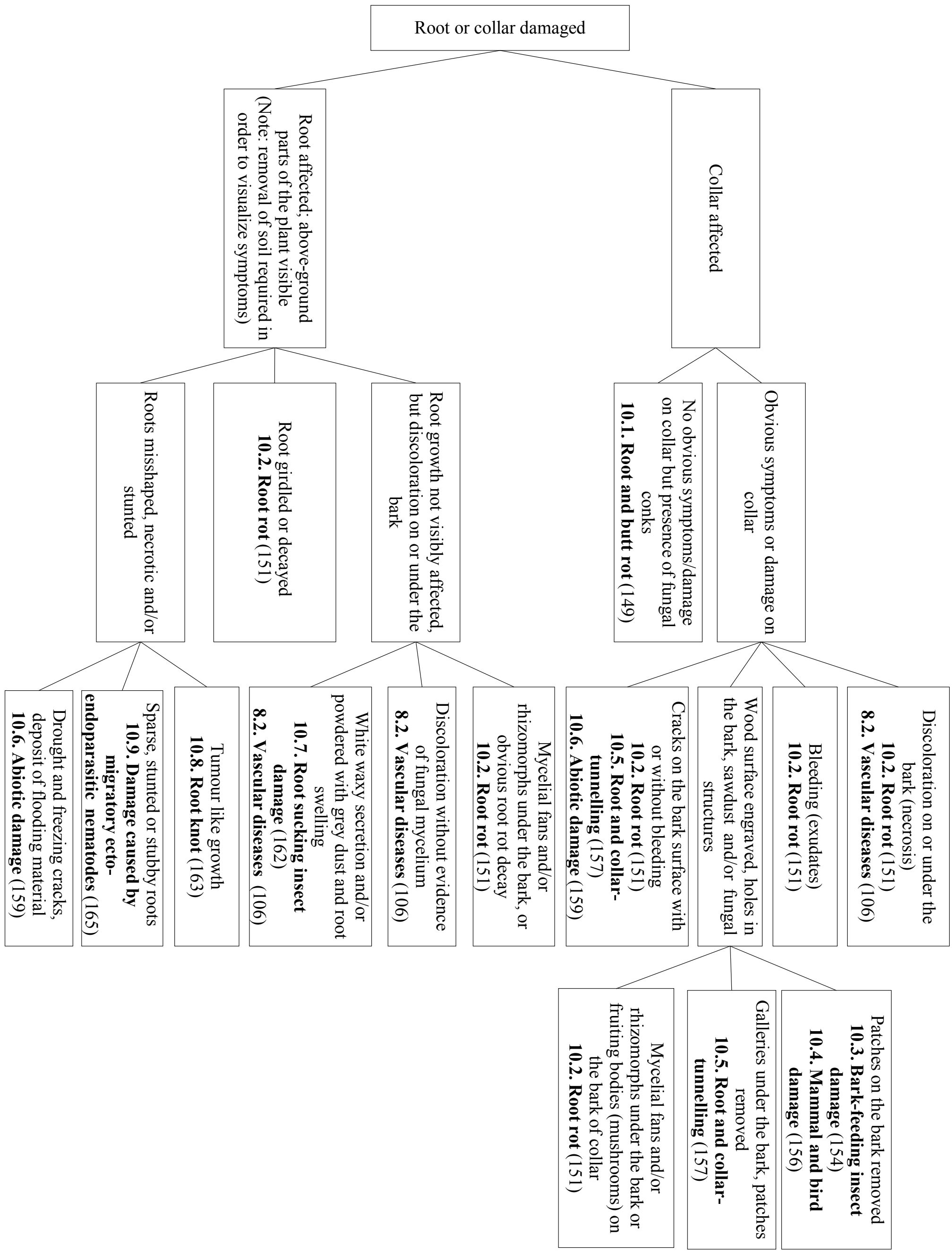
Key to damage on stems, branches and twigs of broadleaf woody plants (2)

- Branches not wilting entirely **(From previous page)**
  - Bleeding (i.e. exudates from the bark)
    - Evidence of insect feeding (holes)
      8.6. Holes and/or bleeding on the bark (114)
      8.7. Twig and/or branch girdling or pruning (116)
    - Without evidence of insect feeding, incl. holes
      - Mechanical damage to bark
        8.4. Abiotic damage (109)
      - Scars on the bark
        8.8. Scars on the bark (118)
      - Necrosis on or under the bark
        8.1. Root and stem rot (103)
        8.5. Cankers (112)
        8.2. Vascular diseases (106)
  - No bleeding
    - Discoloration or necrosis of bark or wood
      - No frass at the base of stem
        - Presence of fruiting bodies (Note: may depend on season)
          8.1. Root and stem rot (103)
        - No fruiting bodies
          8.1. Root and stem rot (103)
          8.2. Vascular diseases (106)
      - Frass and dust on the bark and/or at the base of the tree
        8.3. Frass and dust on the bark and/or at the base of the tree (107)
    - No discoloration or necrosis on the bark or in wood
      - Punctures on the bark and/or scale insect presence
        8.9. Punctures on the bark and/or scale insect presence (120)
      - Brown discoloration on bark surface
        8.5. Cankers (112)
      - Brown discoloration under the bark in the wood (Note: would require cutting into stem)
        8.2. Vascular diseases (106)

Key to damage on shoots and buds of broadleaf woody plants



Key to damage to roots and collars of broadleaf woody plants

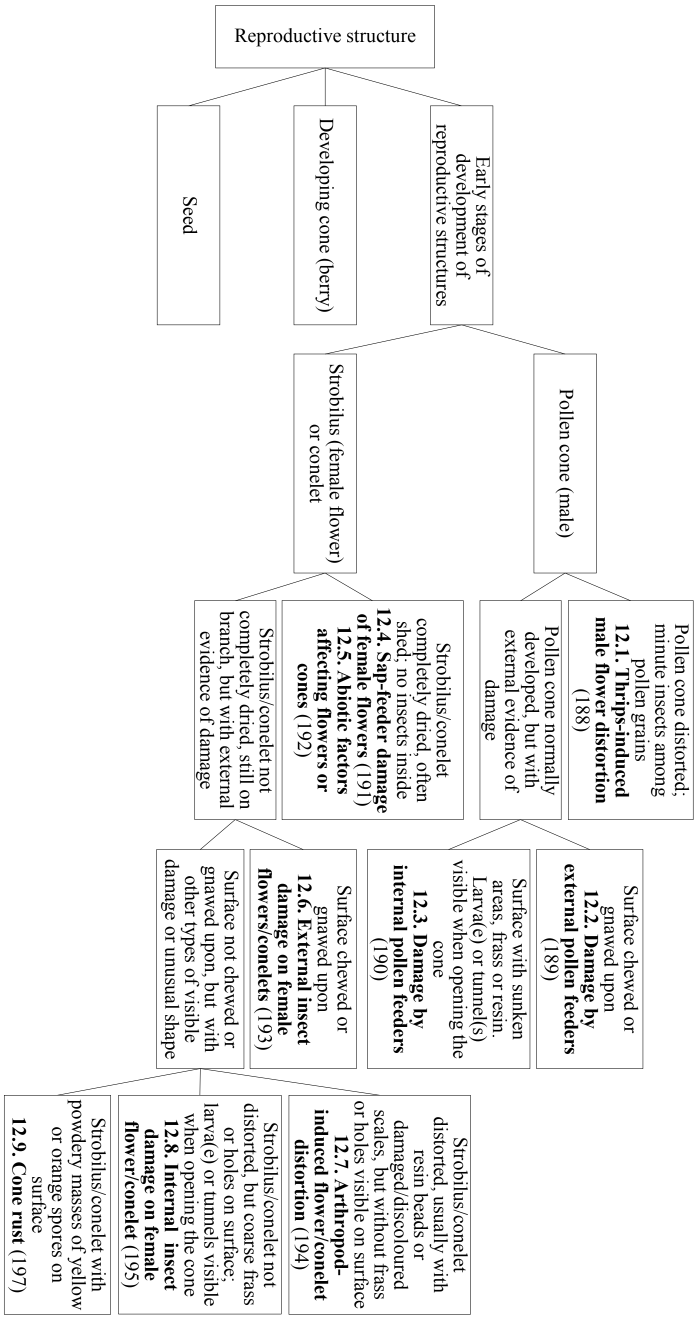


Key to damage on foliage of coniferous woody plants

Needles damaged

- Needle with eaten tissue
  - Needle sharply and regularly cut — **11.3. Rough needle eating** (169)
  - Needle gently (moderately) eaten
    - Needle with lateral and irregular cuts — **11.1. Needle nibbling** (166)
    - Needle gnawed but not cut — **11.2. Needle-gnawing** (168)
- Needle deformation
  - Needle curled due to insect feeding — **11.4. Needle curling** (171)
  - Outgrowth of needle tissue or needle bud caused by a larva — **11.5. Needle galling** (172)
  - Inner tissue of the needles eaten; exterior tissues untouched — **11.6. Needle mining** (173)
- Presence of coverings on needle surface
  - Presence of honeydew, wax and other coverings on needles — **11.7. Needle coverings** (174)
  - Presence of froth and spittle — **11.8. Froth and spittle** (175)
- Needles fully or partly discoloured, with or without necrosis
  - Needles discoloured, shed prematurely — **11.9. Needle cast** (176) **11.15. Abiotic factors** (185)
  - Presence of a mine or a larva at opening — **11.6. Needle mining** (173)
  - Yellow spots, bands and pustules with or without spore masses on the needles — **11.10. Rust diseases** (178)
  - Spots, bands, blotches or elongated zones of necrosis with/without fruiting bodies — **11.11. Needle blight** (180)
- Needles grouped
  - Construction from needles spun together by silk
    - A few needles spun together into a tube with silk — **11.13. Needle clustering** (183)
    - Presence of silk constructions – nests or tents, covered or not with frass — **11.14. Nesting** (184)
  - Fine webbing covering groups of needles — **11.12. Needle webbing** (182)

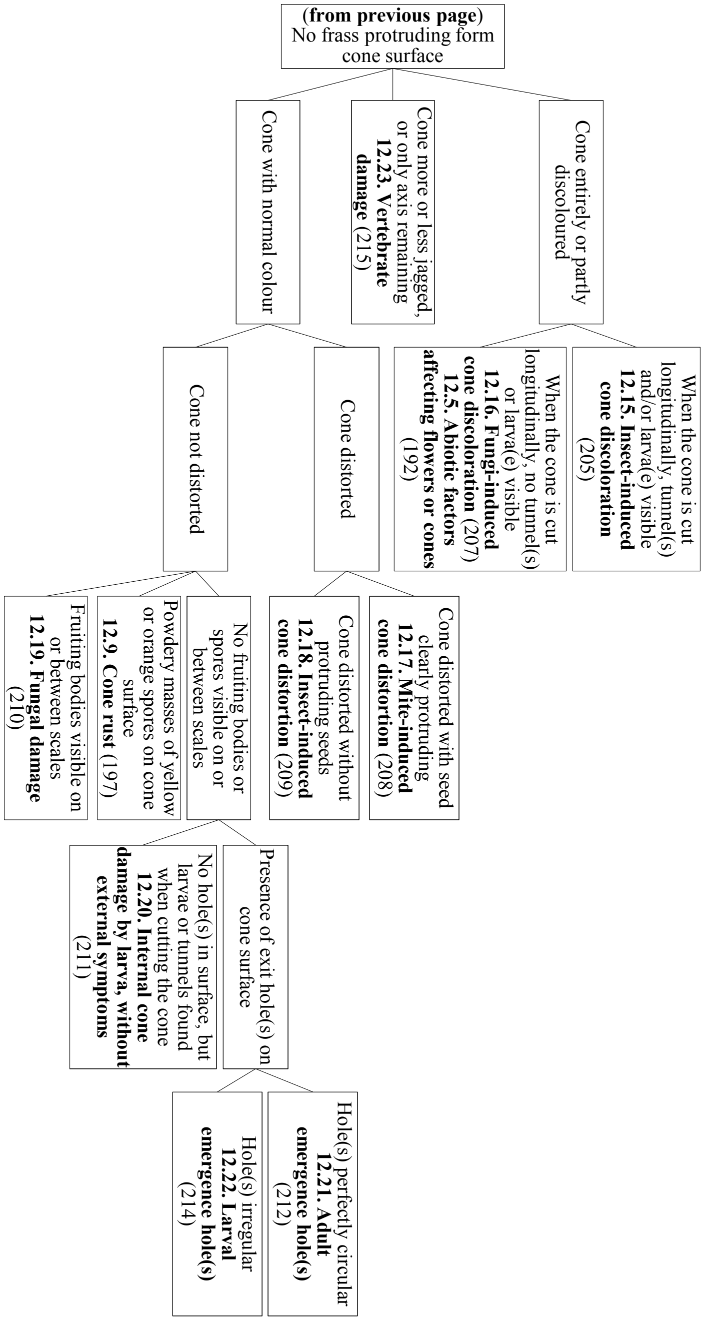
Key to damage on flowers, fruits and seeds of coniferous woody plants (1) – early reproductive stages



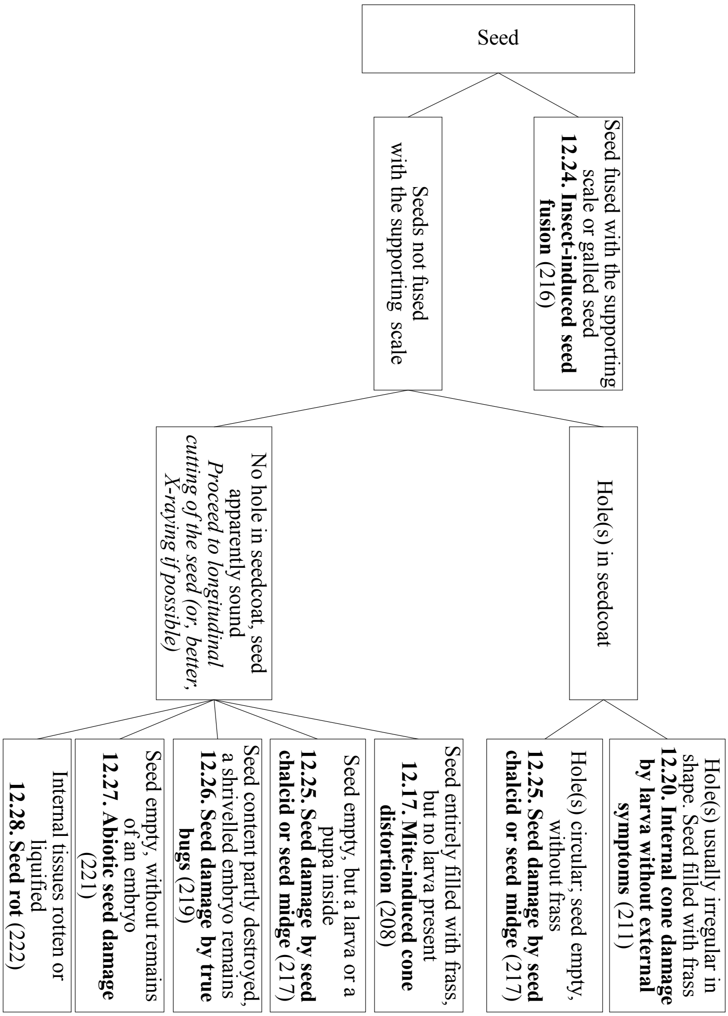
Key to damage on flowers, fruits and seeds of coniferous woody plants (2A) – fruit

- Reproductive structure
  - Early stages of development of reproductive structures
  - Developing cone (berry)
    - Presence of whitish or yellowish, non-resinic, covering on surface **12.10. Sap feeder damage** (199)
    - No whitish/yellowish coverings on surface
      - Resin on cone surface
        - Resin mixed with frass **12.11. External frass protruding due to internal insect feeding** (200)
        - Resin without frass
          - Resin clearly delimited on cone surface **12.12. Diptera-induced resin pitch** (202)
          - Cone surface with irregular resin flows **12.13. Fungus-induced resin flows** (203)
      - No resin on surface
        - Cone open before full maturation **12.14. Fungus-induced cone opening** (204)
        - Cone with normal development but showing damaged parts
          - Frass protruding from cone surface **12.11. External frass protruding due to internal insect feeding** (200)
          - No frass protruding from cone surface **(to next page)**
  - Seed

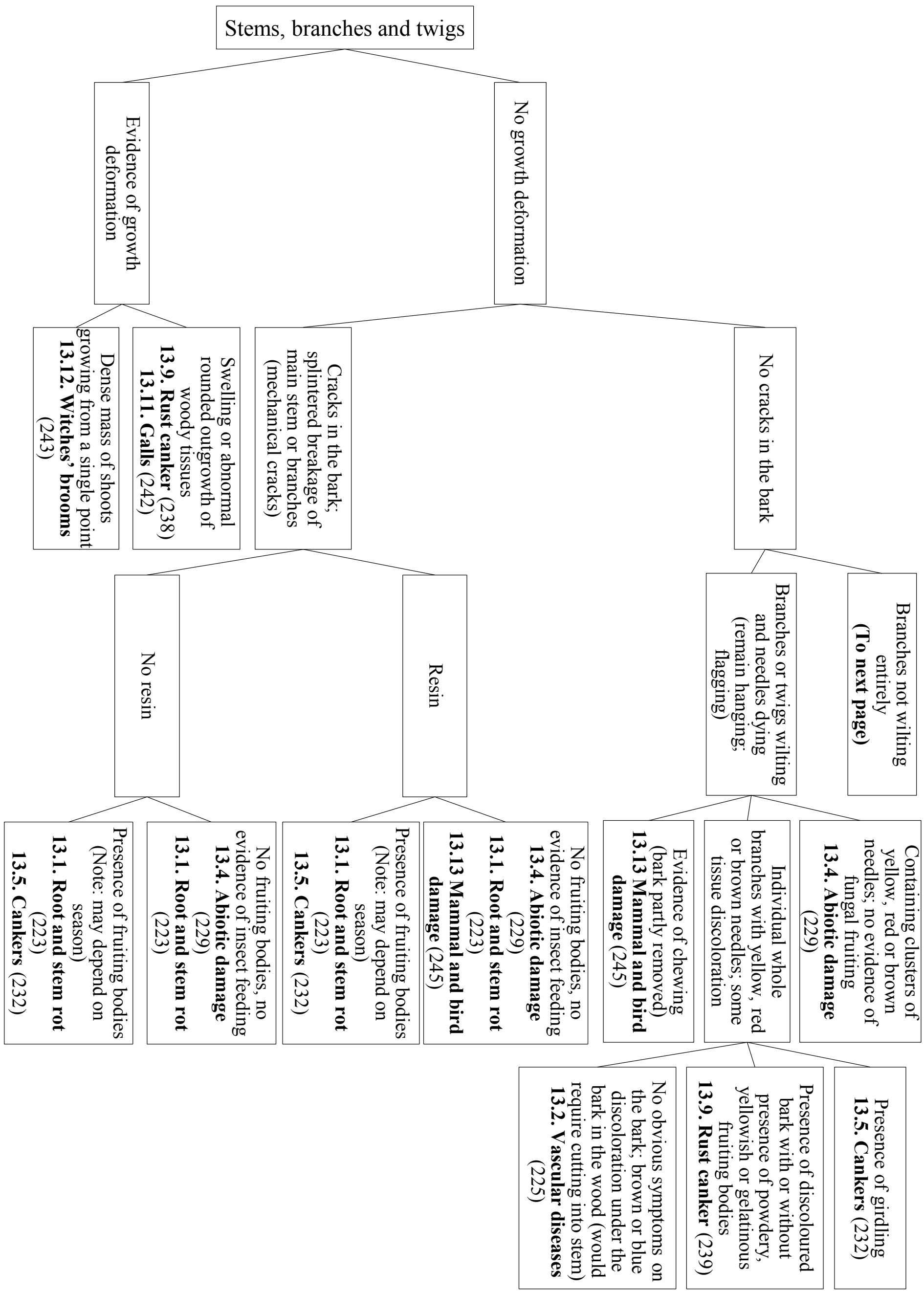
Key to damage on flowers, fruits and seeds of coniferous woody plants (2B) – fruit



Key to damage on flowers, fruits and seeds of coniferous woody plants (3) – seeds



Key to damage on stems, branches and twigs of coniferous woody plants (1)



Key to damage on stems, branches and twigs of coniferous woody plants (2)

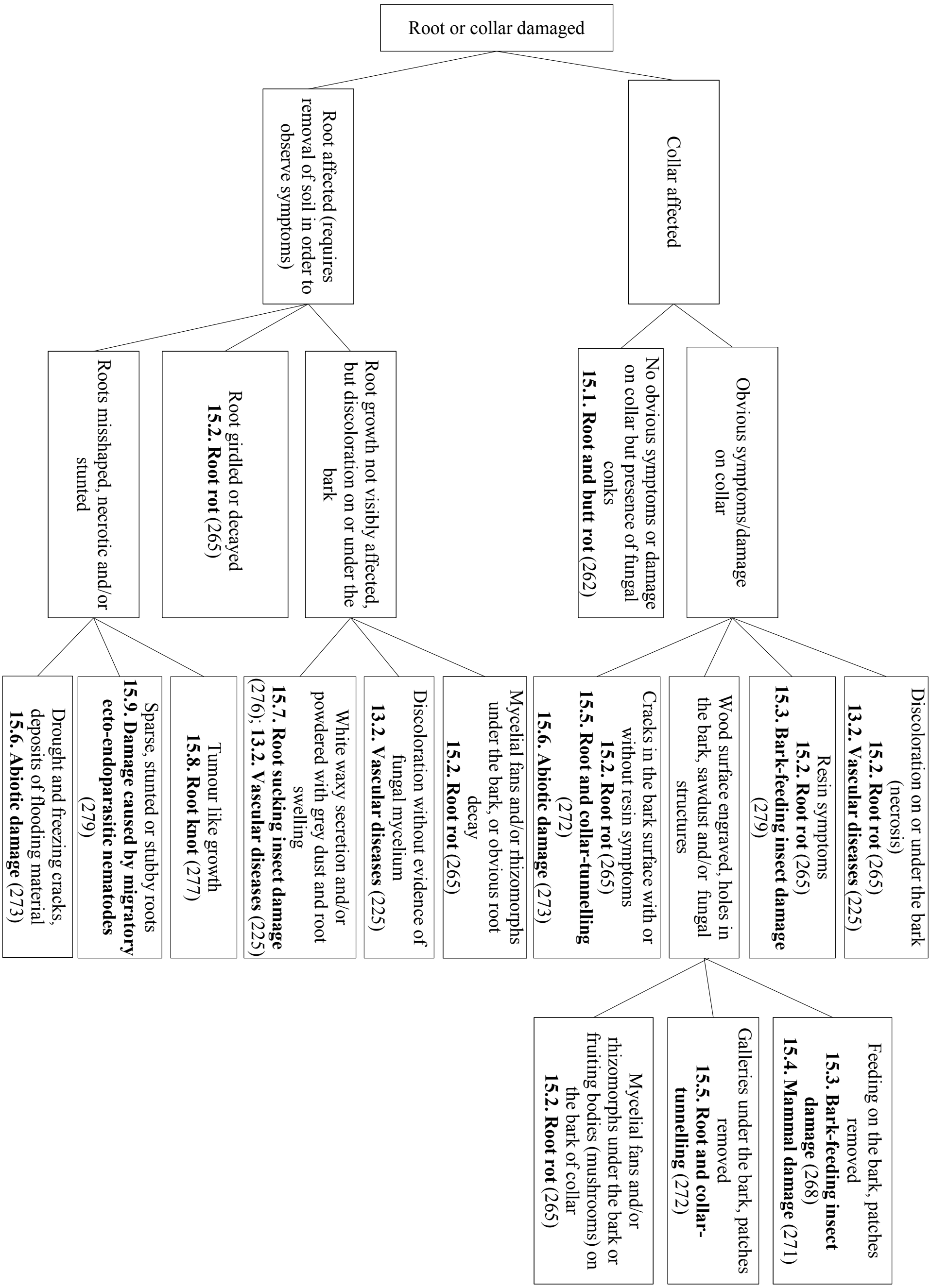
Branches not wilting entirely **(From previous page)**

- Resin
  - Large masses of resin with holes **13.6. Emergence or exit holes and galleries under bark** (234)
  - No holes
    - Mechanical damage to bark **13.4. Abiotic damage** (229)
    - Necrosis on or under the bark
      - With or without presence of callus tissues **13.5. Cankers** (232)
      - With or without presence of powdery, yellowish or gelatinous fruiting bodies **13.9. Rust canker** (239)
- No resin
  - Discoloration or necrosis of bark or wood
    - Punctures on the bark or sucking insects sometimes firmly attached to the bark **13.10. Feeding signs or attached scales** (240)
    - No insect feeding **13.9. Rust canker** (239) **13.5. Cankers** (232)
  - No discoloration or necrosis of bark or wood; whole or part of the crown affected (crown discoloration or crown thinning, i.e. smaller/fewer leaves)
    - No frass at stem base; no obvious symptoms on stem
      - Presence of fruiting bodies of fungi (Note: may depend on season) **13.1. Root and stem rot** (223)
      - No fungal fruiting bodies present **10.2. Root rot** (151) **13.2. Vascular diseases** (225)
    - Frass or dust at the base of the tree **13.3 Feeding and boring signs on bark or into wood** (227)
    - Evidence of insect feeding (holes or scars)
      - Holes in bark **13.6. Emergence or exit holes and galleries under bark** (234) **13.7. Twig boring** (236)
      - Scars on the bark or bark removed/damaged by gnawing **13.8. Maturation feeding** (237)

Key to damage on shoots and buds of coniferous woody plants

- Non-lignified (succulent), young shoots and buds damaged
  - Parts or whole shoots and buds are clearly missing
    - Buds or shoots completely eaten — **14.8. Feeding by mammals or birds** (261)
    - External feeding damage — **14.7. Shoot and/or bud external feeding** (259)
  - Shoots and buds appear whole
    - Presence of external material or structures on the surface of shoots or buds
      - Wax, web or cottony formations — **14.4. Sap-feeder damage** (253); **14.5. Fungal growth on surface** (255)
      - Resin or sticky exudates — **14.7. Shoot and/or bud external feeding** (259); **14.4. Sap-feeder damage** (253)
      - Dark or reddish covering or elevated spots on the surface — **14.5. Fungal growth on surface** (255)
    - Shoots and buds deformed
      - Crooked shoots
        - Insect feeding on shoots — **14.3. Shoot borer damage** (251)
        - Necrosis, spots, swellings or pustules — **14.2. Shoot blight and dieback** (249); **14.5. Fungal growth on surface** (255)
      - Galls or tissue outgrowth — **14.6. Shoot galling** (257)
      - Stunted or curled shoots — **14.1. Abiotic damage** (247); **14.4. Sap-feeder damage** (253)
    - Shoots and/or buds discoloured and/or wilted
      - Non-uniform/irregular pattern — **14.2. Shoot blight and dieback** (249); **14.3. Shoot and/or bud borer damage** (251)
      - Uniform/regular damage pattern — **14.1. Abiotic damage** (247)
    - Dead shoots and/or buds
      - Shoots and buds with holes or insects inside — **14.3. Shoot and/or bud borer damage** (251)
      - No holes or larvae — **14.1. Abiotic damage** (247); **14.2. Shoot blight and dieback** (249)

Key to damage to roots and collars of coniferous woody plants



6
Damage to leaves of broadleaf woody plants

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R. Drenkhan, C. Morales-Rodríguez, I. Matsiakh,
A. Roques, V. Talgø, A.M. Vettraino and J. Witzell

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.

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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.

<u>Additional information</u>: 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.

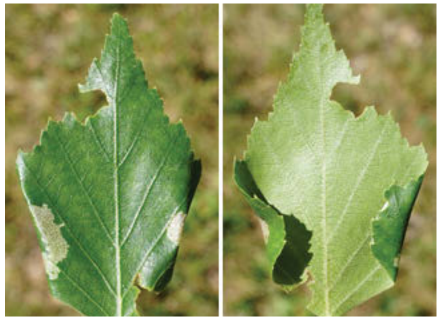

Fig. 6.5.6. Leaf margin of silver birch (*Betula pendula*) pulled down by a moth larva (Lepidoptera, Gracillariidae: *Parornix betulae*), upper view and lower side. Novosibirsk, Russia, NK.

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

<u>Description</u>: 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.
<u>Possible damaging agents</u>: 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.

<u>Additional information</u>: 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.

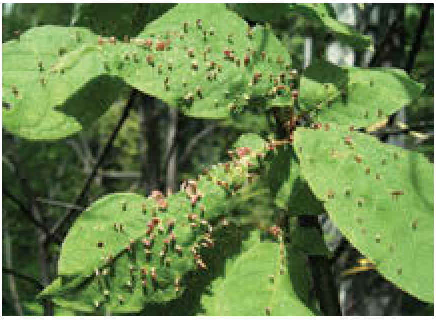

Fig. 6.7.8. Bird cherry (*Prunus padus*) leaves with mite galls (Acari, Eriophyidae: *Eriophyes padi*). Krasnoyarsk, Russia, NK.

<u>Additional information</u>: 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

<u>Description</u>: 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.

<u>Possible damaging agents</u>: 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.

<u>Additional information</u>: 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.

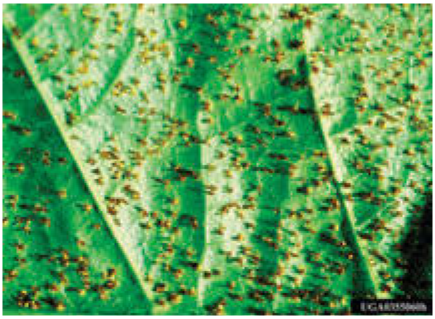

Fig. 6.11.7. Close-up of oak (*Quercus* sp.) leaf with telia on the surface due to fusiform rust fungus (*Cronartium quercuum* f.sp. *fusiforme*). USA, RLA.

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.

<u>Additional information</u>: 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.

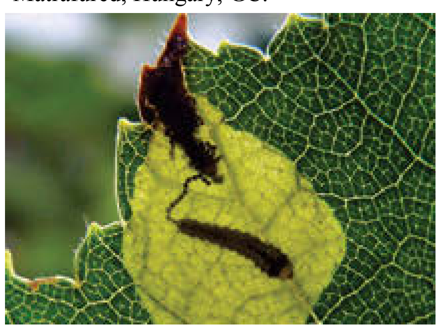

Fig. 6.13.4. Silver birch (*Betula pendula*) leaf with a blotch mine created by a larva (visible to backlight) of a sawfly (Hymenoptera, Tenthredinidae: *Fenusella nana*). Novosibirsk, Russia, NK.

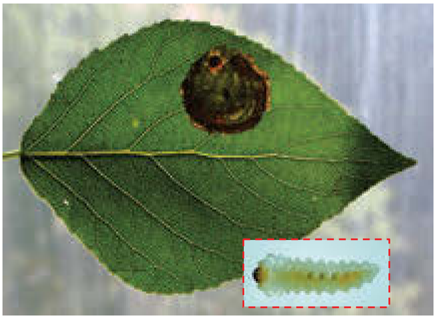

Fig. 6.13.5. Balsam poplar (*Populus balsamifera*) leaf with a blotch mine of a weevil (Coleoptera, Curculionidae: *Isochnus populicola*) and close-up of larva in the insertion. Krasnoyarsk, Russia, NK.

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.

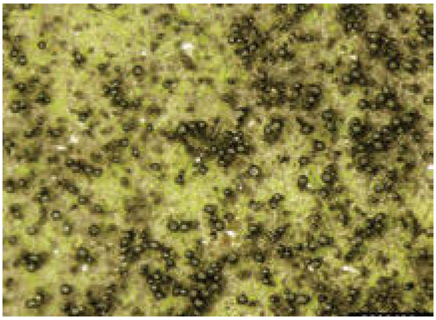

Fig. 6.14.5. Royal star magnolia (*Magnolia stellata*) leaf with ascomata sooty mould (*Capnodium* sp.) on the leaf surface. USA, BW.

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.

7
Damage to reproductive structures of broadleaf woody plants

A. Roques, V. Talgø, J.-T. Fan and M.-A. Auger-Rozenberg

7.1. Flower (blossom, catkin, flower-head) galling

Description: Flower (catkin) distorted, swollen, or with tissue outgrowth(s) of any shape.
Possible damaging agents: Insects: Diptera (Cecidomyiidae midges: Figs. 7.1.5, 7.1.6), Hymenoptera (Cynipidae: Figs. 7.1.3., 7.1.4.), **Mites** (Acari, Eriophyiidae: Figs. 7.1.1., 7.1.2., 7.1.6.), **Fungi** (Ascomycetes, Taphrinales: Figs. 7.1.7., 7.1.8.), **Bacteria, Phytoplasma**.

Fig. 7.1.1. Newly-developed inflorescence of ash (*Fraxinus excelsior*), galled by a mite (Acari, Eriophyiidae: *Aceria fraxinivora*). Marcillac, France, AR.

Fig. 7.1.2. Cauliflower-like gall finally resulting from mite damage shown in Fig. 7.1.1. Hungary, GC.

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Fig. 7.1.3. Berry-like gall on a male catkin of oak (*Quercus* sp.) caused by a gall wasp (Hymenoptera, Cynipidae: *Neuroterus quercusbaccarum*). Hungary, GC.

Fig. 7.1.4. Male catkin of *Quercus myrtifoliae,* deformed by a gall wasp (Hymenoptera, Cynipidae: *Callirhytis myrtifoliae*). Florida, USA, GC.

Fig. 7.1.5. Inflorescence of birch (*Betula* sp.) deformed by a gall midge (Diptera, Cecidomyiidae: *Semudobia betulae*). Hungary, GC.

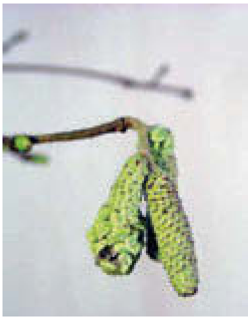

Fig. 7.1.6. Symmetrically swollen catkin of hazelnut (*Corylus* sp.) caused by a gall midge (Diptera, Cecidomyiidae: *Contarinia coryli*) or a gall mite (Acari Eriophyiidae: *Phyllocoptes coryli*). The damaging agent can only be ascertained by catkin dissection. Germany, HJB.

Fig. 7.1.7. Catkin of poplar (*Populus* sp.) deformed by a fungus (Ascomycota, Taphrinales: *Taphrina johansonii*). Hungary, GC.

Fig. 7.1.8. Tongue-like gall on female catkin of alder (*Alnus glutinosa*) induced by a fungus (Ascomycota, Taphrinales: *Taphrina alni*). Germany, HJB.

Additional information: Dissect the gall to check for the presence of insect larva(e) or minute mites. If insects and mites are absent without visible exit holes, check for fungi, bacteria or phytoplasmas. For insect sampling and preservation, see Chapter 3 and for fungal preservation, see Chapter 4.

7.2. Bacterial blight

Description: Tissue infected by bacteria will have a dark (blackish) appearance. Under humid conditions, droplets of bacterial exudates may occur.
Possible damaging agents: Bacteria (Enterobacteriaceae: *Erwinia*).

Fig. 7.2.1. Flowers and fruits of *Cotoneaster bullatus*, with fire blight due to a bacterium (Bacteria, Enterobacteriaceae: *Erwinia amylovora*). Hordaland county, Norway, AS.

Fig. 7.2.2. Young fruits of *Malus* sp., infected by fire blight due to a bacterium (Bacteria, Enterobacteriaceae: *Erwinia amylovora*). Slovakia, JM.

Additional information: Bacteria attacking reproductive structures are often transferred by pollinating insects and may lead to blossom blight, fruit rot and proceed to shoots.

7.3. Internal feeding by larva

Description: Flower remaining closed, with larval tunnels visible when the flower is opened.

Possible damaging agents: Insects: larvae of Coleoptera (Curculionidae (weevils): Figs. 7.3.1, 7.3.2, 7.3.8), Diptera (Anthomyiidae (maggots): Fig. 7.3.3, Cecidomyiidae (midges): Fig. 7.3.6), Hymenoptera (Tenthredinidae (sawflies): Fig. 7.3.4), Lepidoptera (Geometridae: Figs. 7.3.5, 7.3.6., Noctuidae, Tortricidae, Yponomeutidae).

Fig. 7.3.1. *Salix* catkin with brown frass on the top due to damage by a weevil larva (Coleoptera, Curculionidae: *Dorytomus taeniatus*). Cesana Torinese, Italy, AR.

Fig. 7.3.2. The *Salix* catkin shown in 7.3.1 sliced open to show the weevil larva tunnelling the axis (Coleoptera, Curculionidae: *Dorytomus taeniatus*). Cesana Torinese, Italy, AR.

Fig. 7.3.3. *Salix* catkin damaged by a maggot (Diptera, Anthomyiidae: *Egle* sp.), showing woolly fluff expelled by the larva (top) and the emerging maggot larva (bottom). Marcillac, France, AR.

Fig. 7.3.4. Dried tip of a *Salix phylicifolia* catkin, indicating the presence of a catkin-mining sawfly larva (Hymenoptera, Tenthredinidae: *Pontopristia* sp.) inside the catkin stem. Oulu, Finland, TN.

Fig. 7.3.5. Male catkin of walnut (*Juglans regia*) infested internally by moth larvae (Lepidoptera, Geometridae). Marcillac, France, AR.

Fig. 7.3.6. Male catkin of walnut (*Juglans regia*) with emerging unidentified moth larvae (Lepidoptera, Geometridae). Marcillac, France, AR.

Fig. 7.3.7. Flower of *Crataegus* sp. opened to show damage by a midge larva (Diptera, Cecidomyiidae: *Dasineura oxyacanthae*). Copenhagen, Denmark, SH.

Fig. 7.3.8. Flower of *Malus* sp., remaining closed following infestation by a weevil larva (Coleoptera, Curculionidae: *Anthonomus pomorum*), and manually opened to show the larva. Slovakia, JM.

Additional information: Dissect the flower to ascertain the presence of larva(e) or pupa(e). Note larva colour, if it is legless or not, and if it has a visible head or not. For insect preservation, see Chapter 3.

7.4. External feeding

Description: Flower gnawed or with cutout(s) (Figs. 7.4.1, 7.4.2, 7.4.3); fruit fed from exterior (Fig. 7.4.4.).

Possible damaging agents: Insects: Adults of Coleoptera (e.g., Cantharididae, Cetoniidae, Rutelidae, Scarabaeidae: Figs. 7.4.1, 7.4.2, 7.4.4) and Hymenoptera (Tenthredinidae), larvae of Lepidoptera (Fig. 7.4.3).

Fig. 7.4.1. Flower of quince (*Cydonia oblonga*) cut out by unidentified scarab beetles (Coleoptera, Rutelidae). Marcillac, France, AR.

Fig. 7.4.2. Flower of wild rose (*Rosa* sp.) with adult scarab beetles feeding on pollen (Coleoptera, Rutelidae: *Hoplia* sp.). Briançon, France, AR.

Fig. 7.4.3. Flower of quince (*Cydonia oblonga*) damaged by an early-instar moth larva (Lepidoptera, Lasiocampidae: *Malacosoma neusstria*). Marcillac, France, AR.

Fig. 7.4.4. Fruit eaten by adult beetles (Coleoptera, Cetoniidae*:* *Cetonia* sp.). Slovakia, MZ.

Additional information: Observation by chance or by beating flowering branch over a Japanese umbrella. For insect collection and preservation, see Chapter 3.

7.5. Sucking arthropod damage

<u>Description</u>: Flower completely dried, often shed.
<u>Possible damaging agents</u>: Insects: Adults of Thysanoptera (Thrips: Fig. 7.5.1), nymphs and adults of Hemiptera (Aphididae: Fig. 7.5.2).

Fig. 7.5.1. Catkin of *Betula* sp. covered by a colony of bug nymphs (Hemiptera, Acanthosomatidae: *Elasmucha grisea*). Hungary, GC.

Fig. 7.5.2. Flower bud of wild rose (*Rosa* sp.) covered by an aphid colony (Hemiptera, Aphididae: *Macrosiphum rosae*). Slovakia, MZ.

<u>Additional information</u>: Dissect the flower to look at the presence of minute insects (thrips); check the presence of aphid or bug colonies on the external part of the flower or on the pedicel.

7.6. Abiotic damage

Description: Flower completely dried, often shed; seed empty, without frass and without the remains of embryo.
Possible damaging agents: Late frosts, drought, genetic incompatibility.

Fig. 7.6.1. Flowers of *Sorbus* sp. killed by frost and then colonized by aphids. Rodez, France, AR.

Fig. 7.6.2. Apple flower (*Malus* sp.) with dark brown centre, indicating that it was killed by frost. Michigan, USA, ML.

Additional information: Dissect flowers to ascertain the absence of pests as well as of pest damage (e.g., tunnels and frass).

7.7. Fungal growth on catkins and fruits

Description: Catkins and fruits discoloured, with irregular chlorotic to necrotic spots with blighted margins or larger necrotic (yellowish) blotches.
Possible damaging agents: Fungi: Ascomycota (Figs. 7.7.1 – 7.7.4).

Fig. 7.7.1. *Colletotrichum acutatum* (Ascomycota, Glomerellaceae) on *Rhododendron* sp. Norway, VT.

Fig. 7.7.2. Necrosis on a *Salix* catkin caused by an unidentified fungus. Briançon, France, AR.

Fig. 7.7.3. Berries of Mountain ash (*Sorbus aucuparia*) infested by *Colletotrichum acutatum* (Ascomycota, Glomerellaceae). Buskerud county, Norway, VT.

Fig. 7.7.4. Detail of a holly fruit (*Ilex aquifolium*) infested by *Fusarium acuminatum*-like fungi. Rogaland county, Norway, VT.

Additional information: Anthracnose causes dark, slightly sunken lesions on flowers and fruits. Under humid conditions, the disease may develop and spread quickly.

7.8. Petal Blight

Description: Flower discoloured with tan, water-soaked spots or soft blighted tissue; petals stuck together and often shed prematurely.
Possible damaging agents: Fungi (Figs. 7.8.1, 7.8.2).

Fig. 7.8.1. Flowers of *Prunus* sp. infected during bloom by brown rot fungus (Ascomycota, Helotiales: *Monilinia laxa*) to be compared to normally developed fruits on the same branch. Slovakia, JM.

Fig. 7.8.2. Flowers of *Rhododendron* sp., infected by a petal blight fungus (Ascomycota, Helotiales: *Ovulinia azaleae*). Maryland, USA, UME.

Additional information: Petal blight is a commonly occurring problem on *Rhododendron* spp. and other woody plants and may destroy their economic and aesthetic value.

7.9. Damage on flowers by stone fruit scab

Description: Flower discoloured with black/blight necrosis, flecking, streaks on catkins (flowers) and/or with lesions. Stone fruit scab is caused by fungal infection (*Cladosporium carpophilum*), so there cannot be bacterial slime.
Possible damaging agents: Fungi (Ascomycota, Pleosporales).
See photos of final damage in 7.20.

7.10. External damage by sap feeders

Description: Fruit surface (partially) covered with insects, insect secretions or fungal structures, waxy or woolly covers and/or honeydew on surface.
Possible damaging agents: Insects: adults and nymphs of Hemiptera, especially scales (Coccoidae, Diaspididae: Figs. 7.10.1, 7.10.3), aphids (Aphididae: Fig. 7.10.2) and psyllids (Psyllidae: Fig. 7.10.4)

Fig. 7.10.1. Fruits of apple tree (*Malus* sp.) infested by the San Jose scale (Hemiptera, Diaspididae: *Diaspidiotus perniciosus*). Slovakia, JM.

Fig. 7.10.2. Acorn of *Quercus ilex* with the basis covered by aphids (Hemiptera, Aphididae: *Thelaxes* sp.). Toscana, Italy, GC.

Fig. 7.10.3. Twigs and fruits of *Euonymus* sp. covered by scales (Hemiptera, Diaspididae: *Unaspis euonymi*). Hungary, GC.

Fig. 7.10.4. Russeting damage to pear fruit due to feeding by psyllids (Hemiptera, Psyllidae: *Psylla pyricola*). USA, EHB.

Additional information: Note whether the organism present on the surface is protected by a soft or hard covering (scale), or if it is free living (aphid, woolly adelgid). Note the presence of honeydew. The damage symptoms caused by psyllids and mites are rather similar, but psyllid damage is typified by the presence of honeydew on the fruit. For insect preservation, see Chapter 3.

7.11. Rust diseases

Description: Yellow/orange/red spores/blisters and/or pustules on the fruit surface.
Possible damaging agents: Fungi: Basidiomycota (Pucciniales: Figs. 7.11.1 – 7.11.4).

Fig. 7.11.1. Rose hip (*Rosa* sp.) covered by a rust fungus (Basidiomycota, Pucciniales: *Phragmidium* sp.). Akershus county, Norway, VT.

Fig. 7.11.2. Rose flower (*Rosa* sp.) infected by a rust fungus (Basidiomycota, Pucciniales: *Phragmidium* sp.). Briançon, France, AR.

Fig. 7.11.3. Fruit of pear (*Pyrus communis*) with medusa-like head due to a secondary infestation by hawthorn rust (Basidiomycota, Pucciniales: *Gymnosporangium clavariiforme*), the primary host being *Juniperus.* Slovakia, MZ.

Fig. 7.11.4. *Salix* sp. attacked by a rust fungus (*Melampsora* sp.). Sør-Trøndelag County, Norway, VT.

Additional information: Rust fungi are highly host specific, produce up to five spore stages and commonly need an alternate host to fulfil the life cycle.

7.12. Moulds

Description: Dark grey, green, blue or white velvet-like powdery mycelium on reproductive surfaces.

Possible damaging agents: Fungi: Heliothales (Sclerotinicaeae: Figs. 7.12.1 – 7.12.2).

Fig. 7.12.1. Flowers of *Rhododendron luteum* infected by grey mould (Heliothales, Sclerotinicaeae: *Botrytis cinerea*). Akershus county, Norway, VT.

Fig. 7.12.2. Detail of photo 7.12.1.

Additional information: Moulds may grow on honeydew substances secreted by aphids and other insects, turn seed coats blackish, and form dark grey spots on cotyledon surfaces.

7.13. Powdery Mildew

Description: White velvet powdery mycelium on fruits and dark grey spots on cotyledon surfaces of the seeds.

Possible damaging agents: Fungi: Ascomycota (Erysiphales: Figs. 7.13.1 – 7.13.4).

Fig. 7.13.1. Fruit of American gooseberry, *Ribes uva-crispa*, infested by mildew (Ascomycota, Erysiphales: *Podosphaera mors-uvae*). Slovakia, JM.

Fig. 7.13.2. Achene of maple (*Acer* sp.) with necrotized parts due to a fungus (Ascomycota, Erysiphales**:** *Sawadea bicornis*). The necrotized sections were at first chlorotic, and covered with a whitish powdery coating. Zürich, Switzerland, OH.

Fig. 7.13.3. Fruit of peach, *Prunus persica,* infected by powdery mildew (Ascomycota, Erysiphales: *Podosphaera pannosa* var. *persicae*). Slovakia, JM.

Fig. 7.13.4. Fruits and leaves of *Rhododendron* (*Azalea molle* X *sinense*), infected by powdery mildew (Ascomycota, Erysiphales: *Erysiphe azaleae*). Bergen, Norway, VT.

Additional information: Generally, powdery mildew is easy to recognize and most species are host specific.

7.14. Fruit galling

Description: Fruit clearly deformed, swollen, enlarged, or with uneven development. When the fruits are opened, larva(e), insect chamber(s), or galleries are visible.

Possible damaging agents: Insects: Larvae of Diptera (Cecidomyiidae midges: Figs. 7.14.4, 7.14.5) and Hymenoptera (Cynipidae: Figs. 7.14.1 – 7.14.3); **Mites:** Acari (Eriophiidae: Fig. 7.14.6).

Fig. 7.14.1. Acorn of oak (*Quercus robur*), completely deformed by a gall wasp (Hymenoptera, Cynipidae: *Andricus quercuscalicis;* asexual generation). Hungary, GC.

Fig. 7.14.2. Acorn of oak (*Quercus robur*), with a spiny gall due to a wasp (Hymenoptera Cynipidae: *Andricus lucidus*; asexual generation). Hungary, GC.

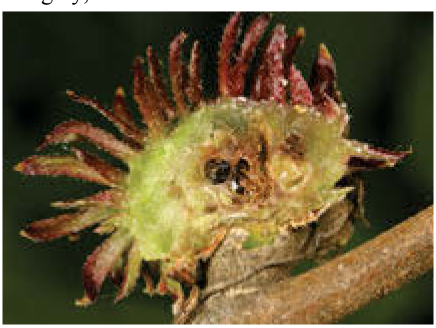

Fig. 7.14.3. Acorn of *Quercus cerris*, sliced open to show the larval chambers of a gall wasp (Hymenoptera, Cynipidae: *Pseudoneuroterus saliens*; sexual generation). Hungary, GC.

Fig. 7.14.4. Fruit of linden (*Tilia cordata*) galled (reddish) by a midge larva (Diptera, Cecidomyiidae: *Contarinia tilliarum*). Hungary, GC.

7.14.5. Young fruit of pear (*Pyrus communis*) galled in the calyx cavity by larvae of pear gall midge (Diptera, Cecidomyiidae: *Contarinia pyrivora*). Slovakia, JM.

7.14.6. Fruit of walnut (*Juglans regia*) with protruding galls on the surface, due to a mite (Acari, Eriophyidae: *Aceria tristriata*). Slovakia, JM.

Additional information: Dissect the gall to check for the presence of insect larva(e) or minute mites. Note if there are distinct larval chambers. The insects and mites may have already left the gall, check also for the presence of exit holes. Such galls may also contain parasites, predators, or inquiline species. For insect preservation, see Chapter 3.

7.15. Fruit fungal deformation

<u>Description</u>: Fruit clearly deformed, swollen, enlarged, or with uneven development. An elongated, sac or pocket-like hollow fruit develops without an embryo, and without larva(e) or larva tunnel(s) inside.
<u>Possible damaging agents</u>: Fungi: Ascomycota (Taphrinomycetes: Figs. 7.15.1, 7.15.2).

Fig. 7.15.1. Plum tree (*Prunus domestica*) with an elongated, slightly curved fruit due to infection by the plum pocket fungus (Ascomycota, Taphrinomycetes: *Taphrina pruni*). Sogn og Fjordane county, Norway, AS.

Fig. 7.15.2. *Prunus* fruits infected by plum pocket fungus (Ascomycota, Taphrinomycetes: *Taphrina pruni*) at an advanced stage, showing a thick flour-like white coating. Later the deformed fruits will dry and rot, but may persist for a long time on twigs as mummies. Slovakia, JM.

Fig. 7.15.3. Fruits of wild cherry (*Prunus padus*) infected by plum pocket fungus (Ascomycota, Taphrinomycetes: *Taphrina pruni*). Akershus county, Norway, VT.

Fig. 7.15.4. Detail of a deformed fruit shown in Fig. 7.15.3.

<u>Additional information</u>: *Taphrina pruni* commonly occurs on plum trees, but can also be found on other woody plants, e.g *Prunus padu*s (Figs. 7.15.3 – 7.15.4).

7.16. Bacterial diseases and viruses

Description: Bacteria form black or brown lesions or blotches where bacterial exudate may ooze out under humid conditions. Virus attacks result in chlorotic ring structures or other patterns on the fruits.
Possible damaging agents: Bacteria (Fig. 7.16.1), **Viruses** (Figs. 7.16.2 – 7.16.4)

Fig. 7.16.1. Oozing canker on walnut (*Juglans regia*) due to a bacterium (Bacteria, Proteobacteria, Xanthomonadales*: Xanthomonas arboricola* pv. *juglandis*). Slovakia, JM.

Fig. 7.16.2. Fruit of peach (*Prunus persica*) with chlorotic ring structures on the fruit surface due to plum pox virus (sharka) (Virus, Potyviridae). Slovakia, JM.

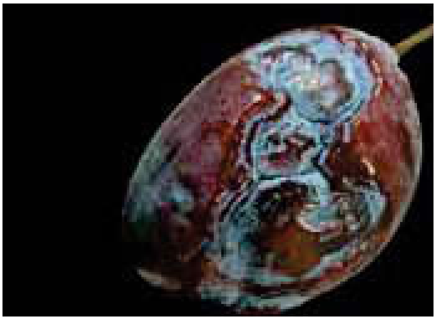

Fig. 7.16.3. Plum fruit (*Prunus domestica*) with blotches due to plum pox virus (sharka) (Virus, Potyviridae). Slovakia, JM.

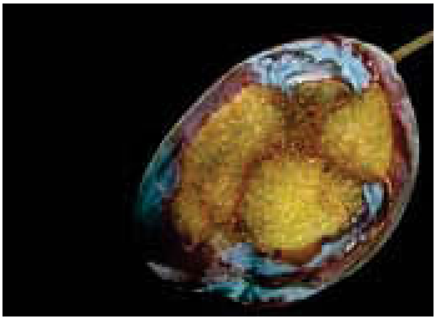

Fig. 7.16.4. Sharka blotches becoming harder as the plum fruit shown in 7.16.3 is maturing. Slovakia, JM.

Additional information: Look for presence of aphids on the plant, which may transmit and inject bacteria into the fruit.

7.17. Nut rot

Description: Fruit entirely or partly discoloured; black or tan-brown discoloration on the inside or outside of the fruit, with presence of small raised, cream-coloured fruiting structures.
Possible damaging agents: Fungi: Ascomycota (Figs. 7.17.1 – 7.17.2).

Fig. 7.17.1. Mummified nuts of hazelnut (*Corylus avellena*) due to a brown rot fungus (Ascomycota, Helotiales: *Monilinia laxa*). Slovakia, JM.

Fig. 7.17.2. Nut of pecan tree (*Carya illinoinensis*) showing shuck rot due to a fungus (Ascomycota: *Glomerella* sp.). USA, WR.

Additional information: Infected nuts often die before they are fully grown. Diseased, mature nuts may have fungal growth on the seed inside the nutshell.

7.18. Hull Rot (mummification) of stone fruits

Description: Fruit entirely or partly discoloured. Shrivelled stone fruits or intermixed acorn tissues held together by fungal mycelium. Fruits turn chalky and sponge-like.
Possible damaging agents: Fungi: Ascomycota (Helotiales: Figs. 7.18.1 – 7.18.4).

Fig. 7.18.1. Apple fruit (*Malus sylvestris*) with superficial, circular, brown spots expanding on the surface due to a brown rot fungus (Ascomycota, Helotiales: *Monilinia fructigena*), Slovakia, MZ.

Fig. 7.18.2. Mummified apple fruit (*Malus sylvestris*) as the final result of damage by a brown rot fungus (Ascomycota, Helotiales: *Monilinia fructigena*), Slovakia, MZ.

Fig. 7.18.3. Mummified plum (*Prunus domestica*) due to a brown rot fungus (Ascomycota, Helotiales: *Monilinia laxa*). Slovakia, JM.

Fig.7.18.4. Fruit of pear (*Pyrus communis*) with a circular brown spot expanding on the surface due to a brown rot fungus (Ascomycota, Helotiales: *Monilinia fructigena*). Slovakia, MZ.

Additional information: Look for presence of mummified fruits on the ground or still attached to the tree.

7.19. Black rot (mummification) of acorns

Description: Fruit entirely or partly discoloured. Shrivelled stone fruits or mixed acorn tissues held together by fungal mycelia. Fruits turn chalky and sponge-like.
Possible damaging agents: Fungi: Ascomycota (Helotiales: Figs. 7.19.1, 7.19.2).

Fig. 7.19.1. Acorns of oak (*Quercus* sp.) partly infected by a ciboria fungus (Ascomycota, Helotiales: *Ciboria batschiana*). Slovakia, AK.

Fig. 7.19.2. Acorns of oak (*Quercus* sp.) totally infected by a ciboria fungus (Ascomycota, Helotiales: *Ciboria batschiana*). Slovakia, AK.

Additional information: Infected acorns will normally fail to germinate.

7.20. Stone fruit scab

Description: Fruit entirely or partly discoloured. Extensive crusty corky spotting on the surface of fruit with cracks, lesions or necrosis, often clustered near the stem end of the fruit.
Possible damaging agents: Fungi: Ascomycota (Pleosporales: Figs. 7.20.1 – 7.20.4).

Fig. 7.20.1. *Pyrus communis* fruit covered by brown-black spots due to pear scab fungus (Ascomycota, Pleosporales: *Venturia pyrina*). Slovakia, JM.

Fig. 7.20.2. *Malus sylvestris* fruit covered by brown-black spots due to apple scab fungus (Ascomycota, Pleosporales: *Venturia inaequalis*). Slovakia, JM.

Fig. 7.20.3. *Prunus persica* fruit covered by brown-black spots due to peach scab fungus (Ascomycota, Pleosporales: *Venturia carpophila*). Slovakia, JM.

Fig. 7.20.4. Nuts of pecan tree (*Carya illinoinensis*) showing increasing degrees of pecan scab (Ascomycota, Pleosporales: *Fusicladium effusum*). USA, WR.

Additional information: Scab greatly reduces the fruit quality for consumption. Thus, proper management is required in the fruit producing industry.

7.21. Fruit spot

Description: Fruit entirely or partly discoloured. Circular or irregular, elongated, bright or dark brown, red, nearly black, distinct and gradually coalescing or sharply outlined spots of various dimensions, but no larva or tunnel present when the fruit is opened.

Possible damaging agents: Fungi: Ascomycota (Capnodiales: Figs.7.21.3 – 7.21.4; Diaporthales: Figs. 7. 21.1 – 7.21.2).

Fig. 7.21.1. Nut of walnut (*Juglans regia*) showing brown patches due to walnut-leaf blotch fungus (Ascomycota, Diaporthales: *Gnomonia leptostyla*). Slovakia, AK.

Fig. 7.21.2. The same damage as 7.21.1., but at the end of the growing season: the blotches having merged. Slovakia, AK.

Fig. 7.21.3. Apricot fruit, covered by spots due to a shot-hole disease fungus (Ascomycota, Capnodiales: *Thyrostroma carpophilum* = *Stigmina carpophila*). Slovakia, JM.

Fig. 7.21.4. Peach fruit (*Prunus persica*) with spots due to a shot-hole disease fungus (Ascomycota, Capnodiales: *Thyrostroma carpophilum* = *Stigmina carpophila*), Slovakia, JM.

Additional information: Be aware that fruit spots may also be caused by bacterial infections.

7.22. Internal fruit feeding by insect larva

Description: Fruit entirely or partly discoloured or with scattered deposits of gum (thick sap: Fig. 7.22.1) or frass (larval excrements: Figs. 7.22.3, 7.22.4) on the surface. When the fruit is cut open, larva(e) or tunnel(s) are visible (Figs 7.22.2, 7.22.6, 7.22.7).

Possible damaging agents: Insects: larvae of Coleoptera (Curculionidae and Rhynchitidae weevils: Figs. 7.22.5, 7.22.6), Diptera (Cecidomyiidae, Phoridae, Sciaridae and Tephritidae fruit flies: Fig. 7.22.7), Hymenoptera (Tenthredinidae sawflies: Fig. 7.22.8) and Lepidoptera (Gelechiidae, Geometridae, Noctuidae, Tortricidae, Yponomeutidae: Figs. 7.22.1 – 7.22.4).

Fig. 7.22.1. Plum fruit (*Prunus domestica*) with gum deposit on the surface, resulting from internal feeding by a moth larva (Lepidoptera, Tortricidae: *Cydia funebrana*). Slovakia, JM.

Fig. 7.22.2. The plum fruit shown in Fig. 7.22.1., sliced to show the moth larva and its damage. Slovakia, JM.

Fig. 7.22.3. Apple fruit (*Malus sylvestris*) with protruding frass resulting from internal damage by a larva of codling moth (Lepidoptera, Tortricidae: *Cydia pomonella*). Slovakia, MZ.

Fig. 7.22.4. Hip of wild rose (*Rosa* sp.) with protruding frass due to a moth larva (Lepidoptera, Tortricidae: *Carposina scirrhosella*). Hungary, GC.

Fig. 7.22.5. Apple fruit (*Malus sylvestris*) attacked by larvae of apple fruit weevil (Coleoptera, Rhynchitidae: *Tatianaerhynchites aequatus*). Slovakia, MZ.

Fig. 7.22.6. Chestnut fruit (*Castanea sativa*) sliced to show damage by weevil larvae (Coleoptera, Curculionidae: *Curculio* sp.). Marcillac, France, AR.

Fig. 7.22.7. Cherry fruit (*Prunus cerasus*) sliced to show the damage caused by a larva of a fruit fly (Diptera, Tephritidae: *Rhagoletis cerasi*). Slovakia, JM.

Fig. 7.22.8. Apple fruit (*Malus sylvestris*) with a gallery along the underside of the epidermis made by a sawfly larva (Hymenoptera, Tenthredinidae: *Hoplocampa testudinea*). Slovakia, JM.

Additional information: Note whether the extruded frass is coarse or light, and combined or not with gum. If the fruit is only partly discoloured and without exit holes, the damaging larvae are still present. Carefully cut the fruit longitudinally, like in Figs. 7.22.2, 7.22.6 and 7.22.7, and check the discoloured parts for the presence of larvae. Note the position of the larvae and the larval tunnels. Then, extract larvae, and note the shape of the tunnel. Note that infested fruits can be secondarily attacked by fungal pathogens. For insect preservation, see Chapter 3.

7.23 Mite-induced discoloration

Description: Fruit noticeably speckled or russeted.
Possible damaging agents: Mites: Acari (Eriophyiidae: Figs. 7.23.1 – 7.23.2).

Fig. 7.23.1. Fruit of plum (*Prunus domestica*) attacked by silver mites (Acari, Eriophyiidae: *Aculus fockeui*). Slovakia, JM.

Fig. 7.23.2. Russeting of pear fruit by pear rust mite (Acari, Eriophyiidae: *Epitrimerus pyri*). California, USA, JKC.

Additional information: Look for the presence of minute mites on the fruit. For collection and preservation, refer to Chapter 3.

7.24. Larval emergence hole

Description: Presence of irregular exit hole(s) on the surface.
Possible damaging agents: Insects: mature larvae, falling down to pupate on the ground, of Coleoptera (Curculionidae and Rhynchitidae weevils: Figs. 7.24.1 – 7.24.3), Diptera (Cecidomyiidae, Phoridae, Sciaridae and Tephritidae fruit flies: Fig. 7.24.6), Hymenoptera (Tenthredinidae sawflies: Fig. 7.24.4), and Lepidoptera (Gelechiidae, Geometridae, Noctuidae, Tortricidae, Yponomeutidae: Fig. 7.24.5); immature larvae of Lepidoptera may move from one fruit to another.

Fig. 7.24.1. Apple fruit (*Malus sylvestris*) with exit holes of larvae of apple fruit weevil (Coleoptera, Rhynchitidae: *Tatianaerhynchites aequatus*). Slovakia, MZ.

Fig. 7.24.2. Fruit of chestnut (*Castanea sativa*) with exit holes of weevil larvae (Coleoptera, Curculionidae: *Curculio elephas*). Gorduno, Switzerland, BW.

Fig. 7.24.3. Hazelnut (*Corylus avellana*) with an exit hole of a weevil larva (Coleoptera, Curculionidae: *Curculio nucum*). Slovakia, JM.

Fig. 7.24.4. Plum (*Prunus sylvestris*) with an exit hole of a sawfly larva (Hymenoptera, Tenthredinidae: *Hoplocampa minuta*). Slovakia, JM.

Fig. 7.24.5. Hip of wild rose (*Rosa spinosissima*) with an exit hole of a moth larva (Lepidoptera, Tortricidae: *Carposina scirrhosella*). Briançon, France, AR.

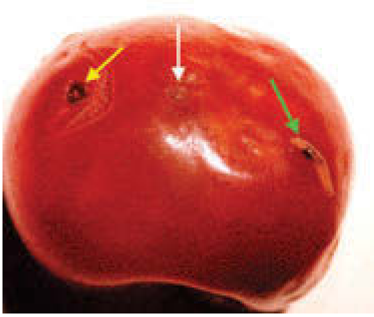

Fig. 7.24.6. Cherry fruit oviposition sting (central arrow), exit hole for larva (left arrow) and the larva (right arrow) of a fruit fly (Diptera, Tephritidae: *Drosophila suzukii*). Howard County, Maryland, USA, GB.

<u>Additional information</u>: Usually, no more larvae are present, but check for the presence of dead specimens which could not emerge from the fruit. Note the shape and size of the exit hole, which can help the identification of the insect.

7.25. Adult emergence hole

Description: Presence of exit hole(s) of regular shape on fruit surface.
Possible damaging agents: Insects: adults of Coleoptera seed beetles (Bruchidae, Curculionidae: Fig. 5.25.3) and Hymenoptera seed chalcids (Eurytomidae: Fig. 5.25.4, Torymidae: Figs. 5.25.1 – 5.25.2).

Fig. 5.25.1. Hip of wild rose (*Rosa* sp.) with an emergence hole of an adult seed chalcid (Hymenoptera, Torymidae: *Megastigmus* sp.). Lijiang, China, AR.

Fig. 5.25.2. Fruit of *Rhus natalensis* showing an adult exit hole of a seed chalcid (Hymenoptera, Torymidae: *Megastigmus transvaalensis*). Ronge Nyika, Kenya, RC.

Fig. 5.25.3. Pods of *Prosopis juliflora* with insect exit holes (among others, seed beetles belonging to Coleoptera, Bruchidae). Moshi District, Tanzania, RE.

Fig. 5.25.4. Almond fruits (*Prunus dulcis*) with exit holes of adult seed chalcids (Hymenoptera, Eurytomidae: *Eurytoma amygdali*). Sallèles, France, AR.

Additional information: Usually, no more insects are present, but check for the presence of dead specimens, which could not emerge from the fruit. Also, check the presence of exit holes on seeds. Note the diameter of the exit hole. Emerging parasites of the phytophagous pests may also bore similar circular holes to emerge from the fruit.

7.26. Seed galling

Description: Seed noticeably deformed.
Possible damaging agents: Insects: Larvae of Diptera (Cecidomyiidae gall midges: Fig. 7.26.1) and Hymenoptera (Cynipidae gall wasps: Fig. 7.26.2), **Mites**: Acari (Eriophyiidae).

Fig. 7.26.1. Seed of birch (*Betula* sp.), galled by a midge larva (Diptera, Cecidomyiidae: *Semudobia betulae*). North Zeeland, Denmark, LKT.

Fig. 7.26.2. Oak acorn (*Quercus* sp.) sliced to show the gall chambers (note the larvae) of a gall wasp (Hymenoptera, Cynipidae: *Callirhytis glandium*). Hungary, GC.

Additional information: Collect mature seeds/acorns. The seed must be opened or, better, X-rayed if possible to ascertain the presence of larvae. Alternatively, for a more easy identification of the damaging species, infested seeds can be reared until adult emergence. For insect preservation see Chapter 3.

7.27. Seed rot

Description: Seed partly/completely discoloured with dark grey, green, blue, white velvet-powdery mycelium on the seed coat.
Possible damaging agents: Fungi: Ascomycota (*Penicillium, Fusarium, Phoma* and others).

Fig. 7.27.1. Seed of European beech (*Fagus sylvatica*) infected by *Penicillium* sp. (Ascomycota, Eurotiales). Vestfold county, Norway, VT.

Fig. 7.27.2. Seed of European beech (*Fagus sylvatica*) infected by fungal rot (Ascomycota, Pleosporales: *Phoma* sp.). Vestfold county, Norway, VT.

7.28. Seed insect damage

Description: Presence of circular hole(s) in external seed coat or presence of larva(e) or pupa(e) in the seed when opened (or larvae/pupae visible using X-rays).

Possible damaging agents: Insects: Larvae of Coleoptera seed beetles (Bruchidae, Curculionidae: Figs. 7.28.4 left – 7.28.5), Diptera seed midges (Cecidomyiidae, Phoridae: Fig. 7.28.7), Hymenoptera seed chalcids (Eurytomidae: Fig. 7.28.6, Torymidae: Fig. 7.28.8) and Lepidoptera (Nepticulidae, Yponomeutidae, Tortricidae: Figs. 7.28.1, 7.28.2, 7.28.3, 7.28.4 right).

Fig. 7.28.1. Seed of maple (*Acer pseudoplatanus*) with an exit hole of a lepidopteran seed moth (Lepidoptera, Tortricidae: *Pammene regiana*). Hungary, GC.

Fig. 7.28.2. Seed of maple (*Acer pseudoplatanus*) with a larva of a lepidopteran seed moth (Lepidoptera, Tortricidae: *Pammene regiana*). Hungary, GC.

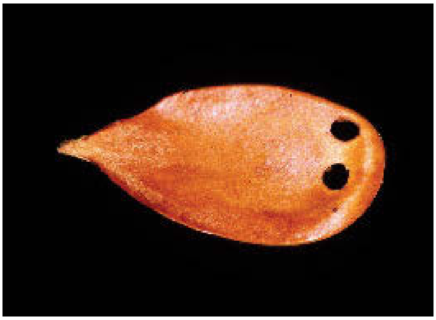

Fig. 7.28.3. Acorn of beech (*Fagus sylvatica*) with emergence holes of a seed moth (Lepidoptera, Tortricidae: *Cydia* sp.). Hungary, GC.

Fig. 7.28.4. Acorns of oak (*Quercus* sp.), sliced to show damage by a weevil larva (Coleoptera, Curculionidae: *Curculio* sp.) (left) and a moth larva (Lepidoptera, Tortricidae: *Cydia* sp.) (right). Hungary, GC.

Fig. 7.28.5 Seed of maple (*Acer pseudoplatanus*) dissected to show the pupa of a seed weevil (Coleoptera, Curculionidae: *Bradybatus kellneri*). Hungary, GC.

Fig. 7.28.6. Seed of pistachio (*Pistacia lentiscus*) with an exit hole of a seed chalcid (Hymenoptera, Eurytomidae: *Eurytoma plotnikovi*). Tabarka, Tunisia, AR.

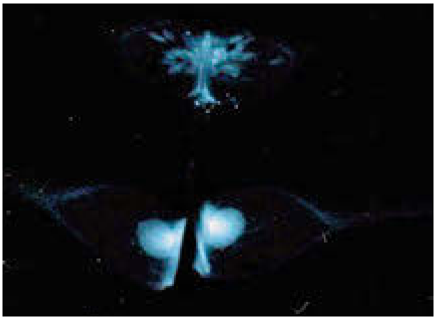

Fig. 7.28.7. X-ray picture of seed of maple (*Acer pseudoplatanus*), to show seed infested by dipteran larva (top) (Diptera, Phoridae: *Megaselia* sp.) and sound seed (bottom). Grenoble, France, AR.

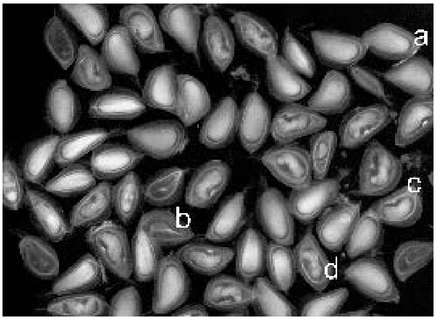

Fig. 7.28.8. X-ray picture of seed of wild rose (*Rosa odorata*), infested by chalcid larva (c) and pupae (d) (Hymenoptera, Torymidae: *Megastigmus* sp.) and sound (a) and empty (b) seed. Lijiang, China, AR.

<u>Additional information</u>: Collect mature seeds. Usually, an infested seed does not differ from a healthy one in shape, colour or weight, although exceptions exist. The seed must be opened or, better, X-rayed if possible to ascertain the presence of larvae. Alternatively, for a more easy identification of the damaging species, infested seeds can be reared until adult emergence. For insect preservation see Chapter 3.

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.

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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.

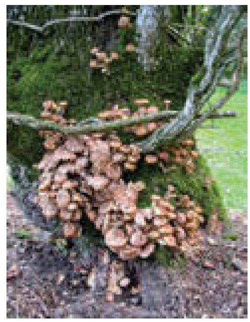

Fig. 8.1.6. Armillaria root rot (*Armillaria* sp.) on oak (*Quercus robur* "Fastigiata"). Akershus county, Norway, VT.

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.

<u>**Additional information**</u>**:** 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 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)).

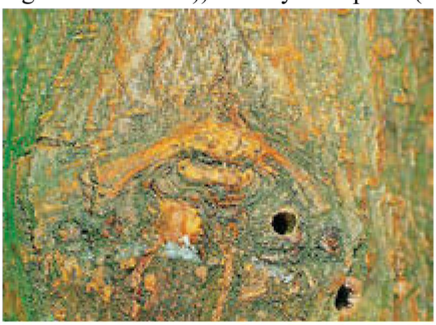

Fig. 8.6.1. Trunk with circular exit holes of unidentified bark beetles or long-horned beetles (Coleoptera, Scolytinae or Cerambycidae). Baja, Hungary, GC.

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, GC.

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.

<u>Additional information</u>: 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.

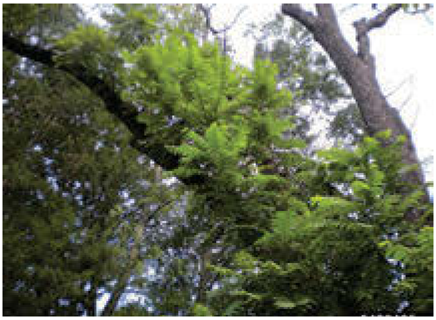

Fig. 8.12.5. Black walnut (*Juglans nigra*) with epicormic branches on the stem (unknown damaging agent). USA, EB.

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 (*Cryptodiaporthe 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.

<u>Additional information</u>: 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.).

9
Damage to shoots and buds of broadleaf woody plants

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9.1. Abiotic damage

Description: Abiotic factors can cause a variety of symptoms in shoots and buds. Symptoms commonly observed on shoots and buds include supressed or aberrant growth, discoloration (chlorosis, reddening, browning, blackening, dark lesions), wounds, dieback of shoots and the death of buds. Except for depositions (salt, chemicals) or glaze (ice), signs of abiotic damage are generally absent. Symptoms usually appear in a pattern, occurring over the whole plant (e.g.,death of young shoots and buds due to frost injury) or directionally (e.g.,on the side facing the source of the adverse conditions or stress). Unlike diseases and pests, damage due to abiotic factors often occurs on different plant species in the same area and does not spread from plant to plant. Dead shoots often drop prematurely, however buds frequently remain attached to shoots (and thus on the plant) after death.
Possible cause of damage: Temperature extremes such as heat or freezing temperatures during growth season, frost and ice glaze, hail storms, misapplied chemicals (fertilizers, herbicides, pesticides, salts) or adverse soil conditions (nutrient imbalance), air pollutants, desiccation due to shortage of water or winter drying (Figs. 9.1.1 – 9.1.6).

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Fig. 9.1.1. Southern magnolia (*Magnolia grandiflora*) leaves damaged by cold injury (low temperatures) which occurred before the leaf unfurled from its bud. USA, EB.

Fig. 9.1.2. Young shoots of staghorn sumac (*Rhus typhina*) damaged by frost and winter injury. Poland, MS.

Fig. 9.1.3. Shoots of hackberry (*Celtis* sp.) covered by white powder after road salt spraying or de-icing salt spray damage. USA, JOB.

Fig. 9.1.4. Red maple (*Acer rubrum*) buds and shoots encapsulated in ice and snow. USA, PDCNR.

Fig. 9.1.5. Young shoot of European beech (*Fagus sylvatica*) damaged by sunscald. Šajdíkové Humence, Slovakia, AK.

Fig. 9.1.6. Shoots and twigs of oak (*Quercus* sp.) with frost damage. USA, MDNR.

Additional information: Several factors causing abiotic damage can act simultaneously, and they may also co-occur with biotic damage, which complicates diagnosis. Abiotic damage can weaken the plant, making it vulnerable to biotic damaging agents such as fungi or insects. If similar symptoms occur on the entire plant, the damage may be associated with the root system (see Chapter 10). The injuries can be due to acute or chronic exposition to adverse abiotic factors. Plants may compensate for the death of shoots and buds by producing new growth.

9.2. Shoot blight or dieback

Description: Shoots and/or buds are discoloured, shoots are wilted or crooked and later dead (necrotic and/or dry). Characteristic symptoms include the gradual dying from the tips of shoots, progressing to larger branches. Dieback typically progresses from the base of the bud to the tip of the shoot or down succulent shoots to petioles and outward via the base of the leaf. In the case of bacterial damage, initial symptoms include a watery, tan coloured exudation from lesions on shoots and buds. Symptoms may be expressed only in young shoots and buds, or they might extend into the twigs and branches.

Possible damaging agents: Fungi: Ascomycota (Figs. 9.2.1 – 9.2.5), **Oomycetes** (Figs. 9.2.6 – 9.2.8), **Bacteria** (Figs. 9.2.9 – 9.2.12).

Fig. 9.2.1. Common aspen (*Populus tremula*) shoots wilted by Venturia shoot blight (Pleosporales, Venturiaceae: *Venturia tremulae*). Morshyn, Ukraine, VK.

Fig. 9.2.2. Black willow shoot (*Salix nigra*) with symptoms of tip dieback due to willow scab pathogen (Pleosporales, Venturiaceae: *Venturia saliciperda*). Ternopil, Ukraine, VK.

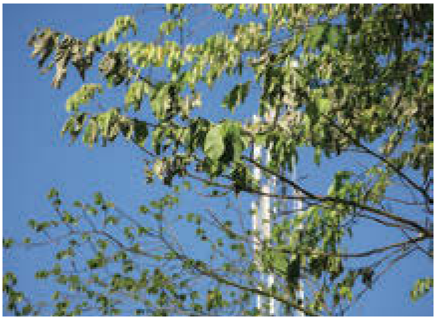

Fig. 9.2.3. Wych elm (*Ulmus glabra*) showing typical dieback of shoots, progressing to larger branches due to Dutch elm disease (Ophiostomatales, Ophiostomataceae, *Ophiostoma novo-ulmi*). Höör, Sweden, JW.

Fig. 9.2.4. Common ash (*Fraxinus exelsior*) shoots crooked by the ash dieback fungus (Helotiales, Helotiaceae: *Hymenoscyphus fraxineus*). Austria, TK.

Fig. 9.2.5. Current year shoot of cherry (*Prunus* sp.) infected and crooked by the blossom blight pathogen (Helotiales, Sclerotiniaceae: *Monilinia laxa*). Lviv, Ukraine, VK.

Fig. 9.2.6. Shoot of blueberry (*Vaccinium* sp.) with blight symptoms due to an Oomycete (Peronosporales, Peronosporaceae: *Phytophthora ramorum*). USA, JOB.

Fig. 9.2.7. Dwarf purple rhododendron (*Rhododendron impeditum*) shoot with non-uniform/irregular patterns of wilt symptoms due to shoot blight by an Oomycete (Peronosporales, Peronosporaceae: *Phytophthora* sp.). Vilnius, Lithuania, DC.

Fig. 9.2.8. Tanoak (*Lithocarpus densiflorus*) shoot with dieback caused by the sudden oak death pathogen (Peronosporales, Peronosporaceae: *Phytophthora ramorum*). USA, JOB.

Fig. 9.2.9. "Flagging" of terminal shoot of European pear (*Malus pumila*) caused by bacteria (*Erwinia amylovora*). Skole, Ukraine, VK.

Fig. 9.2.10. Common filbert (*Corylus avellana*) dieback after necrosis of a new lateral shoot due to bacterial blight (*Xanthomonas arboricola* pv. *corylina*). France, LG.

Fig. 9.2.11. Dead shoots on *Cotoneaster salicifolius* due to fire blight caused by a bacterial infection (Enterobacteriales, Enterobacteriaceae: *Erwinia amylovora*). Rogaland county, Norway, VT.

Fig. 9.2.12. Dead shoot and buds on *Forsythia* x *intermedia* 'Spring glory' due to a bacterial infection (Pseudomonadales, Pseudomonadaceae: *Pseudomonas syringae*). Akershus county, Norway, VT.

Additional information: Symptoms may be in the form of spots or blights on leaves and 1-2 year old shoots, as well as dieback of twigs/branches. Severely infected leaves may appear scorched and become almost completely brown, wilted or cupped. Note: drought symptoms and/or leaf scorch differ because the browning and wilting of leaf tissue begins at the leaf tips and leaf margins and progresses inward. For insect and fungal collection and preservation, see Chapters 3 and 4.

9.3. Shoot and/or bud borer damage

Description: Early symptoms often include only slight chlorosis and growth reduction of shoots; swellings may also be observed on shoots. Buds stop developing and may be deformed or discoloured (blackened). Later on, shoots will wilt and buds will wither. Signs include small holes and expelled frass. Slicing infested shoots may reveal tunnelling larvae inside the shoot, or a hollow space made by larvae that have subsequently left the shoot or bud.

Possible damaging agents: Insects: Larvae of Lepidoptera (Noctuidae: Figs. 9.3.1, 9.3.6; Tortricidae: Figs. 9.3.2, 9.3.4, 9.3.8; Sesiidae: Figs. 9.3.3, 9.3.7; Pyralidae: Fig. 9.3.5; Cossidae: Fig. 9.3.10), Coleopteran weevils and bark beetles (Curculionidae, Scolytinae) and Diptera (Cecidomyiidae: Fig. 9.3.9).

Fig. 9.3.1. Bud of Piedmont azalea (*Rhododendron canescens*) showing hole and budworm larva (Lepidoptera, Noctuidae: *Peridroma saucia*). USA, LLH.

Fig. 9.3.2. Manitoba maple shoot (*Acer negundo*) showing a hole formed by the maple twig borer (Lepidoptera, Tortricidae: *Proteoteras aesculana*). Fort Collins, Colorado, USA, WC.

Fig. 9.3.3. Terminal shoot of green ash (*Fraxinus pennsylvanica*) crooked and wilted by ash borer (Lepidoptera, Sesiidae: *Podosesia syringae*). USA, JS.

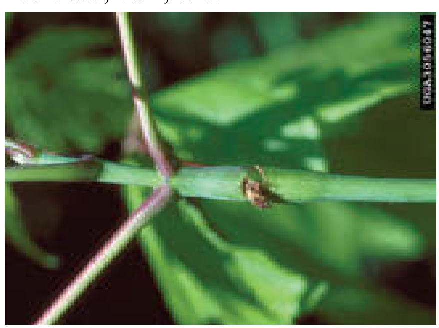

Fig. 9.3.4. Manitoba maple, boxelder *(Acer negundo*), terminal twig swelling with frass at entrance hole created by borer (Lepidoptera, Tortricidae: *Proteoteras willingana*). USA, JS.

Fig. 9.3.5. Frass on the surface of butternut (*Juglans cinerea*) shoots due to damage by a shoot moth (Lepidoptera, Pyralidae: *Acrobasis demotella*). USA, SK.

Fig. 9.3.6. Silver maple (*Acer saccharinum*) shoot with tunnelling stalk borer larva (Lepidoptera, Noctuidae: *Papaipema nebris*). USA, SK.

Fig. 9.3.7. Cherry (*Prunus* sp.) terminal shoot with sticky exudates on the outer tissues of shoot due to damage by borer (Lepidoptera, Sesiidae: *Synanthedon pictipes*). USA, CEY.

Fig. 9.3.8. Peach (*Prunus persica*) shoots attacked by a moth larva (Lepidoptera, Tortricidae: *Grapholita molesta*). France, HA.

Fig. 9.3.9. Jatropha (*Jatropha* sp.) buds mined by unidentified fly larvae (Diptera, Cecidomyiidae). Mexico, TH.

Fig. 9.3.10. Japanese walnut (*Juglans ailantifolia*) shoot full of Lepidoptera larvae (Lepidoptera, Cossidae). Russia, NK.

Additional information: Borer damage may lead to stunted, forked leaders and general loss of shape. For insect collection and preservation, see Chapter 3.

9.4. Sap-feeder damage

Description: Sap-feeding insects or mites are usually observed in large groups and can be mobile or immobile. Indirect symptoms include reduced growth, deformation of shoots or buds, chlorotic, small spots or other discoloration with (sticky liquid) exudation.

Possible damaging agents: Insects: Adults and nymphs of many Hemiptera families (e.g., Aphididae: Figs. 9.4.1 – 9.4.2; Psyllidae: Fig. 9.4.3; Coccidae, Monophlebidae: Fig. 9.4.4; Diaspididae: Fig. 9.4.5; Pseudococcidae) and **Acari:** (e.g., Eriophyidae: Fig. 9.4.6).

Fig. 9.4.1. Alder (*Alnus* sp.) shoots with white cottony infestation of woolly alder aphid (Hemiptera, Aphididae: *Prociphilus tessellatus*). Rio Grande NF, Colorado, USA, WMC.

Fig. 9.4.2. Willow (*Salix* sp.) shoot covered by adult and nymph aphids (Hemiptera, Aphididae: unidentified species) tended by ants. Slovakia, MZ.

Fig. 9.4.3. Apple (*Malus domestica*) bud with psyllid nymphs on the tip of the bud (Hemiptera, Psyllidae: *Cacopsylla mali*). Poland, MS.

Fig. 9.4.4. Shoots of cheesewood (*Pittosporum* spp.) infested by scale insects (Hemiptera, Monophlebidae: *Icerya purchasi*), with fungal growth. USA, LGR.

Fig. 9.4.5. Euonymus scale (Hemiptera, Diaspididae: *Unaspis euonymi*) on shoot of an unidentified plant. USA, CU.

Fig. 9.4.6. Shoots of Southern California walnut (*Juglans californica*) curled by a mite attack (Acari, Eriophyidae: *Aceria neobeevori*). USA, WC.

Additional information: Honeydew (sugar-rich liquid excreted by some insects when feeding) can attract other animals (e.g.,ants) and support growth of fungi on the surface of the shoots and buds (see 9.7.). For insect collection and preservation, Cee chapter 3.

9.5. Fungal growth on surface

<u>Description</u>: Dark, reddish/yellowish, whitish, powdery or cottony coverage, elevated spots or other structures on shoots and buds.
<u>Possible damaging agents</u>: Fungi: Ascomycota, Basidiomycota: powdery mildews, rusts and sooty moulds (Figs. 9.5.1 – 9.5.4).

Fig. 9.5.1. Dead rhododendron (*Rhododendron* sp.) bud with spore-producing little stalks with knobs at the end (Chaetothyriales, Herpotrichiellaceae: *Pycnostysanus azalea*). Østfold county, Norway, VT.

Fig. 9.5.2. Dying shoots (A) and fruiting bodies (B) on birch (*Betula pubescens*) due to fungal attack (Helotiales, Godroniaceae: *Godronia multispora*). Akershus county, Norway, VT.

Fig. 9.5.3. Shoots of barberry (*Berberis vulgaris*) infected by powdery mildew (Erysiphales, Erysiphaceae: *Erysiphe berberidis*). Akershus county, Norway, VT.

Fig. 9.5.4. Shoot of blackberry (*Rubus fruticosus*) infected by a rust fungus (Pucciniales, Phragmidiaceae: *Kuehneola albida*). Akershus county, Norway, VT.

<u>Additional information</u>: Rust fungi are obligate parasites and most of them are characterized by complex life cycles generally involving two unrelated host plants (primary host and alternate host). The sooty moulds benefit from either a sugary exudate produced by the plant or fruit, or from honeydew produced by sap-sucking insects. For insect and fungal collection and preservation, see Chapters 3 and 4.

9.6. Shoot galling

Description: Outgrowths (galls) or swelling on shoot or bud tissues, with insect larvae or mites inside. Depending on the causal agent and host species, galls of different sizes, forms (regular or irregular) and colours (e.g., green, reddish, brownish or light-coloured) occur.

Possible damaging agents: Insects: Adults and larvae of Acari (Eryophiidae: Fig. 9.6.1), adults and larvae of Hymenoptera (Cynipidae: Figs. 9.6.2 – 9.6.4) and Hemiptera (Aphididae: Figs. 9.6.5 – 9.6.6; Psyllidae) and larvae of Diptera (Cecidomyiidae).

Fig. 9.6.1. Damaged ash (*Fraxinus* sp.) buds and shoots due to a mite gall (Acari, Eryophiidae: *Aceria fraxinivora*). Baden, Lower Austria, TC.

Fig. 9.6.2. Damaged oak (*Quercus* sp.) bud due to a cynipid gall wasp (Hymenoptera, Cynipidae: *Cynips glutinosa*). Plátovce, Slovakia, MZ.

Fig. 9.6.3. Shoot of chestnut (*Castanea* sp.) damaged by a gall wasp (Hymenoptera, Cynipidae: *Dryocosmus kuriphilus*). Italy, FS.

Fig. 9.6.4. Terminal shoot of bur oak (*Quercus macrocarpa*), heavily deformed by galling by a gall wasp (Hymenoptera, Cynipidae: *Disholcaspis quercusmamma*), USA, WC.

Fig. 9.6.5. Buds of plains cottonwood (*Populus deltoides* ssp. *monilifera*) damaged by aphid galls (Hemiptera, Aphididae: *Pemphigus populiramulorum*). Colorado, USA, WC.

Fig. 9.6.6. Terminal shoot with bud of plains cottonwood (*Populus deltoides* ssp. *monilifera*) deformed due to aphids (Hemiptera, Aphididae: *Mordwilkoja vagabunda*). Leelanau County, Michigan, USA, SK.

<u>Additional information</u>: Splitting of a developing gall exposes developing larvae. For insect collection and preservation, see Chapter 3.

9.7. Shoot and/or bud external feeding

<u>Description</u>: Shoots or buds are bitten or punctured by adult insects and, occasionally, by larvae outside of the plant. Damage symptoms can include feeding holes, shoot debarking or external chewing.

<u>Possible damaging agents</u>: **Insects:** Adults of Coleoptera (especially Curculionidae), but species of many other groups may occasionally feed on shoots and buds, including those that usually damage leaves, fruits and flowers (e.g., Lepidoptera, Hymenopteran sawflies and bees, true bugs, etc.) (Figs. 9.7.1 – 9.7.4).

Fig. 9.7.1. Damaged bud of apple (*Malus domestica*) with small holes caused by weevil feeding (Coleoptera, Curculionidae: *Anthonomus pomorum*). Poland, MS.

Fig. 9.7.2. Shoot of pecan (*Carya illinoinensis*) with feeding weevil (Coleoptera, Curculionidae: *Conotrachelus aratus*). USA, JAP.

Fig. 9.7.3. Adult ash weevil (Coleoptera, Curculionidae: *Stereonychus fraxini*) feeding on a bud of narrow-leafed ash (*Fraxinus angustifolia*). Novi Sad, Serbia, MD.

Fig. 9.7.4. Shoot of *Tabernaemontana* sp., gnawed by an unidentified adult longhorn beetle (Coleoptera, Cerambycidae). Amani Nature Reserve, Tanzania, RE.

<u>Additional information</u>: For insect collection and preservation, see chapter 3.

9.8. Feeding by mammals or birds

Description: Whole shoots and buds are removed from the plant. Repeated damage often causes formation of multiple stems and a bushy appearance of the plant.
Possible damaging agents: **Mammals** (such as moose, deer, cattle and sheep), squirrels, rodents, or bud-eating **birds** such as grouse (Figs. 9.8.1 – 9.8.2).

Fig. 9.8.1. A twelve-year old English oak (*Quercus robur*), heavily browsed by roe deer (Artiodactyla, Cervidae: *Capreolus capreolus*). Mokrin, Serbia, LPP.

Fig. 9.8.2. Spring buds of pear (*Pyrus* sp.) damaged by fox squirrel (Rodentia, Sciuridae: *Sciurus niger*), USA, WC.

Additional information: Deer and sheep often leave ragged ends where they bite through the stem, and always eat the shoots. Rabbits and hares leave clean diagonal cut ends, leaving the shoots (seen frequently by rabbits and always by hares). Timing of the foraging and different signs such as faeces, tracks, or even hair or feathers around the damaged tree can be useful when identifying the causal agent. Damage should be photographed. For species identification, direct observations or consultations with local zoologists or game managers are needed.

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.

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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 illinoinensis*) 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 (*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).

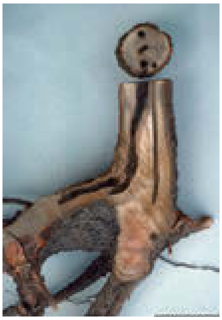

Fig. 10.5.1. Root and lower stem of Sassafras (*Sassafras albidum*) cut to show galleries caused by larvae of longhorn beetles (Coleoptera, Cerambycidae: *Oberea ruficollis*). USA, JS.

Fig. 10.5.2. Roots of Pecan (*Carya illinoinensis*) 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.

<u>Additional information</u>: 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.

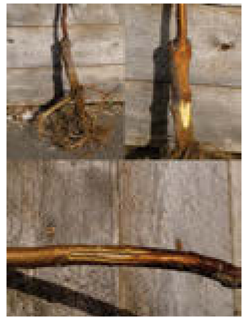

Fig. 10.6.2. Lower trunk and collar part of young apple tree *(Malus domestica*) damaged by cold injury (low temperature). USA, BW.

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.

<u>Additional information</u>: 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.

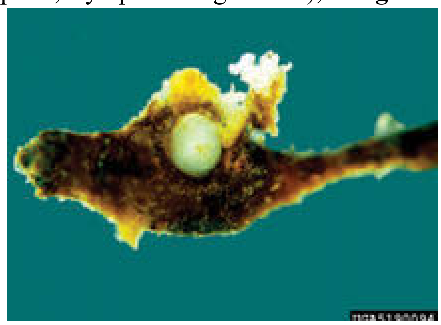

Fig. 10.8.2. Root of Hedge cotoneaster (*Cotoneaster lucidus*) occupied by a female root-knot nematode (Nematoda Heteroderidae: *Meloidogyne ardenensis*). Norway, BH.

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 illinoinensis*) roots galled by root-knot nematodes (Nematoda Heteroderidae: *Meloidogyne partityla*). USA, JWL.

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 glutinossexua*) root collar and roots with presence of galls due to crown bacteria (*Rhizobium radiobacter*). Slovakia, AK.

Fig. 10.8.7. Pecan (*Carya illinoinensis*) 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., *Xiphinema* spp.: Figs. 10.9.1 – 10.9.2).

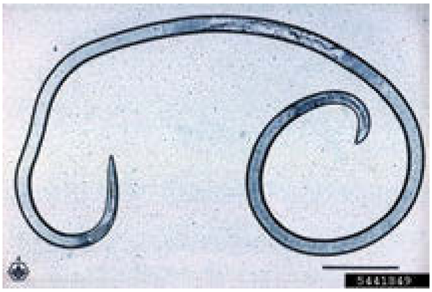

Fig. 10.9.1. Adult female of needle nematode (*Longidorus elongatus*). MP.

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

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

11
Damage to foliage of coniferous woody plants

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11.1. Needle nibbling

Description: Needles are laterally and irregularly nibbled, all layers being consumed in the damaged parts.
Possible damaging agents: Insects: Adults of Coleoptera (Figs. 11.1.1 – 11.1.4), larvae of Hymenoptera (sawflies) and Lepidoptera.

Fig. 11.1.1. Needle of black pine (*Pinus nigra*) damaged by weevils (Coleoptera, Curculionidae: *Pachyrhinus mustela*). Viskyar Mt., Bulgaria, DD.

Fig. 11.1.2. Needle of creeping pine (*Pinus mugo*) with weevil feeding damage (Coleoptera, Curculionidae: *Otiorrhynchus parreyssi*). Rila Mt., Bulgaria, DD.

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Fig. 11.1.3. Needles of Korean red pine (*Pinus funebris*) nibbled by adult scarab beetles (Coleoptera, Scarabaeidae: *Mimela* [= *Rhombonyx*] *testaceipes*). Mountain taiga station, Russian Far East, Russia, NK.

Fig. 11.1.4. Needles of English yew (*Taxus baccata*) nibbled by weevils (Coleoptera: Curculionidae). Vienna, Austria, AR.

<u>Additional information</u>: Look for adult insects. Be aware that they may fly off quickly or drop to the ground. Before checking foliage, place an insect beating tray or an umbrella under the branches to catch fallen adults. For insect collection and preservation, see Chapter 3.

11.2. Needle gnawing

Description: Needles are irregularly gnawed. Only the epidermis is removed, but the needle is not cut or nibbled.
Possible damaging agents: **Insects:** Adults of Coleoptera, especially Curculionidae and Chrysomelidae (Figs. 11.2.1–11.2.4).

Fig. 11.2.1. Needles of Austrian pine (*Pinus nigra*) gnawed by adult weevils (Coleoptera, Chrysomelidae: *Cryptocephalus pini*). Italy, AB.

Fig. 11.2.2. Fresh-damage on pine needles (*Pinus* sp.) by leaf wood beetle (Coleoptera, Chrysomelidae: *Cryptocephalus pini*). Italy, FS.

Fig. 11.2.3. Needles of pine (*Pinus* sp.) gnawed by beetles (Coleoptera, Chrysomelidae: *Colaspis pini*). USA, GJL.

Fig. 11.2.4. Needles of pine (*Pinus* sp.) gnawed by beetles (Coleoptera, Chrysomelidae: *Colaspis pini*). USA, GJL.

Additional information: Look for adult insects, in a similar way as described in section 11.1. For insect collection and preservation, see Chapter 3.

11.3. Rough needle eating

Description: Needles are eaten out, sharply and regularly cut at the base, middle or towards extremity.

Possible damaging agents: Insects: Larvae of Lepidoptera (Figs. 11.3.1 – 11.3.2) and Hymenoptera (i.e. sawflies: Figs. 11.3.3 – 11.3.6); adults of Coleoptera, especially Scarabaeidae (Fig. 11.3.4).

Fig. 11.3.1. Needles of Siberian larch (*Larix sibirica*) cut in half by moth larvae (Lepidoptera, Lymantriinae: *Lymantria dispar*). Bulgan, Mongolia, YB.

Fig. 11.3.2. Needles of Nordmann fir (*Abies nordmanniana*) cut by moth larvae (Lepidoptera, Lasiocampidae: *Dendrolimus sibiricus*) in an indoor experiment. Germany, NK.

Fig. 11.3.3. Scots pine (*Pinus sylvestris*) needle cut by sawfly larvae (Hymenoptera, Diprionidae: *Diprion* sp.). Briançon, France, ABE.

Fig. 11.3.4. Two needle pinyon pine (*Pinus edulis*) needles cut by adult scarab beetles (Coleoptera, Scarabaeidae: *Phyllophaga falsa*). Colorado, USA, WC.

Fig. 11.3.5. Scots pine (*Pinus sylvestris*) needles cut by sawfly larvae (Hymenoptera, Pamphiliidae: *Acantholyda* sp.). Western Rhodopes Mts., Bulgaria, DD.

Fig. 11.3.6. Scots pine (*Pinus sylvestris*) needles cut by sawfly larvae (Hymenoptera, Diprionidae: *Neodiprion sertifer*). Slavyanka Mt., Bulgaria, DD.

Additional information: Check twigs and branches without needles in order to find larvae and adults. For insect collection and preservation, see Chapter 3.

11.4. Needle curling

Description: Needles curled due to insect feeding. Often they are curved at the point of insertion of feeding sheaths.
Possible damaging agents: Insects: Hemiptera, especially aphids (Aphididae: Fig. 11.4.1), larvae of Lepidoptera (Fig. 11.4.2), Adelgidae (Figs. 11.4.3 – 11.4.4).

Fig. 11.4.1. Needles of Silver fir (*Abies alba*) curled by aphid feeding (Hemiptera, Aphididae: *Mindarus abietinus*). Pertouli, Greece, DMA.

Fig. 11.4.2. Needles of European larch (*Larix decidua*) curled by lepidoptera larvae feeding (Lepidoptera, Coleophoridae: *Coleophora laricella*). Mátrafüred, Hungary, GC.

Fig. 11.4.3. Needles of European larch (*Larix decidua*) curled by aphid feeding (Hemiptera, Adelgidae: *Sacchiphantes viridis*). Briançon, France, AR.

Fig. 11.4.4. Curled needles of European larch (*Larix decidua*) showing white wax coverings of adelgids at the curling point (Hemiptera, Adelgidae: *Adelges laricis*). Briançon, France, AR.

Additional information: Search for groups of curled needles on the shoots, but also for tiny holes in, and cases on needles. For insect collection and preservation, see Chapter 3.

11.5. Needle galling

Description: Outgrowth of needle tissue or of the needle bud, each gall containing one or several larvae that feed on the internal tissue of the needle.
Possible damaging agents: Insects: Diptera, especially Cecidomyiidae (Figs. 11.5.1 – 11.5.4), **Mites:** particularly Eriophyiidae.

Fig. 11.5.1. Balsam fir (*Abies balsamea*) needles with midge galls (Diptera, Cecidomyiidae: *Paradiplosis tumifex*). Vermont, USA, RSK.

Fig. 11.5.2. Douglas fir (*Pseudotsuga menziesii*) needles with midge galls (Diptera, Cecidomyiidae: *Contarinia pseudotsugae*); the insert shows the opened needle with the galling larva. Belgium, GSM.

Fig. 11.5.3. Scots pine (*Pinus sylvestris*) needles with midge galls at the base (Diptera, Cecidomyiidae: *Thecodiplosis brachyntera*). Maleshevska planina Mt., Bulgaria, DD.

Fig. 11.5.4. Mugo pine needles (*Pinus mugo*), affected by midge galls (Diptera, Cecidomyiidae: *Thecodiplosis brachyntera*). USA, PK.

Additional information: In some cases, small galls could be confused with needle necrosis caused by fungal agents. To verify it is a gall due to insects or mites, carefully open the gall to look for the causal organism. For insect collection and preservation, see Chapter 3.

11.6. Needle mining

Description: The insect larvae eat the inner tissues of the needles, leaving the exterior untouched.

Possible damaging agents: Insects: Larvae of Lepidoptera (Yponomeutidae, Coleophoridae: Figs. 11.6.1 – 11.6.3) and Coleoptera, particularly Curculionidae (Fig. 11.6.4).

Fig. 11.6.1. Ponderosa pine (*Pinus ponderosa*) damaged by a sheathminer (Lepidoptera, Yponomeutidae: *Zelleria haimbachi*); note the exit holes of caterpillars and mites. USA, DO.

Fig. 11.6.2. Leaves of *Thuja* sp. mined by lepidoptera larvae (Lepidoptera, Yponomeutidae: *Argyresthia thuiella*). Gödöllő, Hungary, GC.

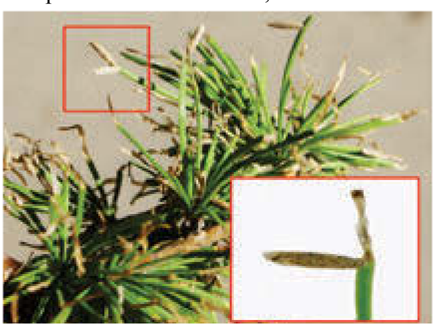

Fig. 11.6.3. *Larix sibirica* damaged by a leaf miner (Lepidoptera, Coleophoridae: *Protocryptis sibiricella*). The insert shows a damaged needle fragment with the leaf miner's case. Novosibirsk, Russia, NK.

Fig. 11.6.4. Needle of *Pinus uncinata* with an exit hole of a weevil (Coleoptera, Curculionidae: *Brachonyx pineti*). Briançon, France, AR.

Additional information: In some cases, mines could be confused with needle necrosis caused by fungal agents. To distinguish between damage due to such agents search carefully for a hole on the surface or open the affected tissue to look for larvae. Soft needles (e.g., *Larix* sp.) damaged by leaf mining arthropods can also be deformed. For insect collection and preservation, see Chapter 3.

11.7. Needle coverings

Description: Presence of honeydew, wax or other coverings on needles. Honeydew occurs like a glossy sticky matter on one or both sides of the needles. Woolly adelgids give the needles a whitish, woolly, covering. Algae produce greenish covering.

Possible damaging agents: Insects: Hemiptera, especially Cercopidae aphids (Aphididae) may produce honeydew. A woolly appearance may result from secretion by hemipteran insects: aphids Aphididae (adelgids, Adelgidae: Figs. 11.7.1, 11.7.2), scales (Coccoidae, Diaspididae: Fig. 11.7.3) and cicadas (Cicadoidea). Greenish covering may be produced by green algae from the division *Chlorophyta* (Fig. 11.7.4).

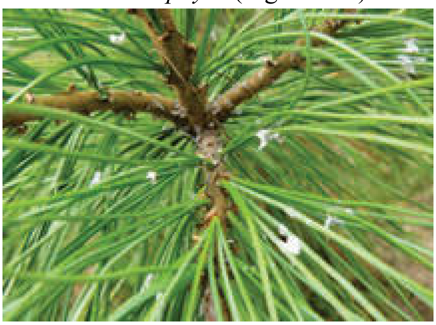

Fig. 11.7.1. Needles of Siberian pine (*Pinus sibirica*) covered by woolly adelgids (Hemiptera: Adelgidae). Woody plants nursery of SIF SB RAS, Krasnoyarsk, Russia, NK.

Fig. 11.7.2. Needles of Siberian larch (*Larix sibirica*) covered by woolly adelgids (Hemiptera: Adelgidae). Central Siberian botanical garden SB RAS, Novosibirsk, Russia, NK.

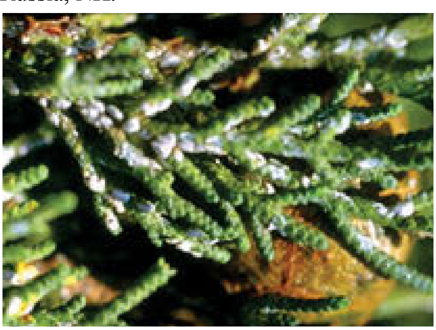

Fig. 11.7.3. Mediterranean cypress (*Cupressus sempervirens*) foliage covered with scales (Hemiptera, Diaspididae: *Lineaspis striata*). Toulon, France, AR.

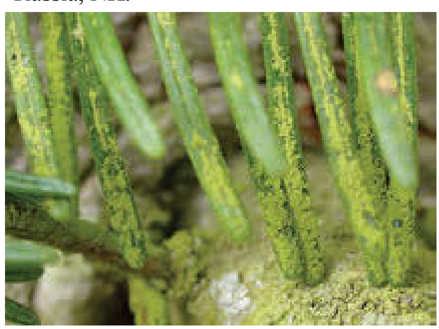

Fig. 11.7.4. Needles of noble fir (*Abies procera*) covered by green algae, belonging to division *Chlorophyta.*Jutland, Denmark, VT.

Additional information: In some cases, these signs could be confused with needle rust, see section 11.10. For insect collection and preservation, see Chapter 3.

11.8. Froth and spittle

Description: Presence of moist balls of bubbles or foam on needles.
Possible damaging agents: **Insects:** Hemiptera, especially Cercopidae (Froghoppers and Spittlebugs: Figs. 11.8.1 – 11.8.4).

Fig. 11.8.1. Eastern white pine (*Pinus strobus*) needles covered by foam of spittlebug nymph (Hemiptera, Aphrophoridae: *Aphrophora cribrata*). USA, BW.

Fig. 11.8.2. Scots pine (*Pinus sylvestris*) with foam produced by a spittlebug (Hemiptera: Cercopidae). USA, CU.

Fig. 11.8.3. *Thuja* sp. foliage with spittlebug foam (Hemiptera: Cercopidae). France, AR.

Fig. 11.8.4. Balsam fir (*Abies balsamea*) with spittlebug foam (Hemiptera, Aphrophoridae: *Aphrophora cribrata*). USA, RSK.

Additional information: The foam is not actually spittle because it comes from the anus of the insects. It protects the nymph (larva) from natural enemies and dehydration, and allows for feeding (sucking sap from phloem). For insect collection and preservation, see Chapter 3.

11.9. Needle cast

<u>Description</u>: Needle cast is caused by various fungi. Damaged needles typically turn yellow or brown with characteristic dark fungal fruiting structures. Often needles are shed prematurely, giving the tree a sparse appearance. Often the only needles remaining are the current season's new growth, but there are fungi which result in current season needle necrosis and subsequent needle loss. Affected trees lose their aesthetic value and may look like they are dying.
<u>Possible damaging agents</u>: Fungi: Ascomycota (Rhytismatales, Pleosporales, Helotiales, Capnodiales: Figs. 11.9.1 – 11.9.6).

Fig. 11.9.1. Red-brown needle discoloration on Scots pine (*Pinus sylvestris*) caused by needle cast fungus (*Lophodermium seditiosum*). Järvselja, Estonia, RD.

Fig. 11.9.2. Norway spruce (*Picea abies)* needles with pycnidia of a needle cast fungus (*Lophodermium piceae*). Skole, Ukraine, VK.

Fig. 11.9.3. White fir (*Abies concolor*) needles damaged by a needle cast fungus (*Lirula abietis-concoloris*). Idaho, USA, VT.

Fig. 11.9.4. Subalpine fir (*Abies lasiocarpa*) needles with small black fruiting bodies on the underside caused by a needle cast fungus (*Rhizosphaera kalkhoffii*). Vest-Agder county, Norway, VT.

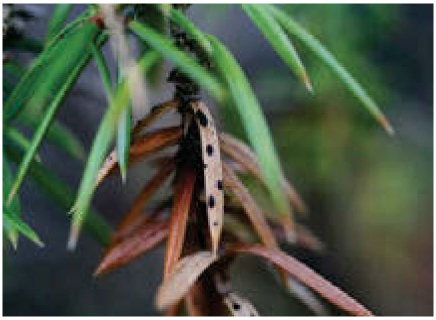

Fig. 11.9.5. Common juniper (*Juniperus communis*) needles with prominent black apothecia of needle cast fungus (*Lophodermium juniperinum*) on the upper surface. Saaremaa, Estonia, RD.

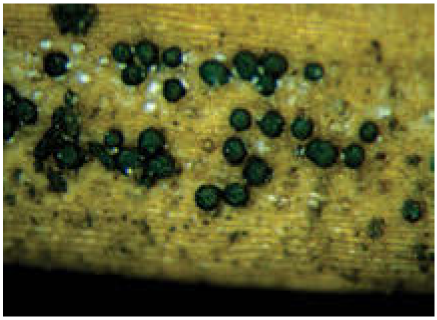

Fig. 11.9.6. Underside of cork bark fir (*Abies lasiocarpa* var. *arizonica*) needle with fruiting bodies (perithecia) of a needle cast fungus (*Phaeocryptopus nudus*). Bergen, Norway, AS.

<u>Additional information</u>: For fungal collection and preservation, see Chapter 4.

11.10. Rust diseases

Description: Needle rust is a disease affecting a variety of conifer species. It mostly causes yellowish spotting and banding on the needles, but in some cases can cause severe premature defoliation. Needle rust can be easily identified by orange spore masses that erupt from infected needles during the growing season. Rust can also cause malformation and reduce growth of conifer trees when it occurs on new needles of emerging shoots.

Possible damaging agents: Fungi: Rust fungi belonging to the Basidiomycota (Pucciniales, Uredinales: Figs. 11.10.1 – 11.10.6).

Fig. 11.10.1. Norway spruce (*Picea abies*) needles damaged by needle rust fungus (*Chrysomyxa ledi*) in springtime. Antsla, Estonia, RD.

Fig. 11.10.2. Norway spruce (*Picea abies*) needles damaged by needle rust fungus (*Chrysomyxa abietis*) in autumn. Antsla, Estonia, RD.

Fig. 11.10.3. Norway spruce (*Picea abies*) in the Austrian Alps with the aecial stage of a rust fungus (*Chrysomyxa rhododendri*) on the needles. Austrian Alps, Austria, TC.

Fig. 11.10.4. Infected needles of Scots pine (*Pinus sylvestris*) with aecia of *Coleosporium* sp. on needles. Antsla, Estonia, RD.

Fig. 11.10.5. Nordmann fir *(Abies nordmanniana)* needles infected by Silver fir needle rust fungus (*Pucciniastrum epilobii*). Rogaland county, Norway, VT.

Fig. 11.10.6. Nordmann fir *(Abies nordmanniana)* needles infected by Melampsora needle diseases (*Melampsora abieti-capraearum*). Rogaland county, Norway, VT.

Additional information: Rust fungi represent some of the most complicated fungal species known. They are categorised by their lifecycles, spore colors, primary or alternate hosts, or the types of symptoms they cause. For fungal collection and preservation, see Chapter 4.

11.11. Needle blight

Description: Needle blight is a general term to describe sudden death or severe disease of conifer foliage. The dieback usually starts at the tip of the needle and may be brown, red, or grey in color. The disease is caused by various fungi that infect and kill (blight) the needles of all ages of a variety of conifer hosts. Usually it starts on the lower branches and moves up the tree. It is most damaging on small trees, but over time can retard growth and weaken mature trees. Continued annual infection by one or more needle blight and/or needle cast fungi can eventually kill even older trees.

Possible damaging agents: Fungi: Needle blight fungi belong to the Ascomycota (Helotiales, Rhytismatales, Capnodiales, Phacidiales, Botryosphaeriales, Dothideales: Figs. 11.11.1 – 11.11.6).

Fig. 11.11.1. Early symptoms of needle blight (*Rhabdocline laricis* [syn. *Meria laricis*]) on European larch (*Larix decidua*). Needles turn dull green and later brown. Tyrolean Alps, Austria, TC.

Fig. 11.11.2. The later stage of discoloration caused by needle blight (*Rhabdocline laricis* [syn. *Meria laricis*]). Needles turn light reddish-brown. Tyrolean Alps, Austria, TC.

Fig. 11.11.3. European larch (*Larix decidua*) needles with symptoms of larch needle blight and characteristic ascomata (*Hypodermella laricis* damage in insert). Styria, Zirbitzkogel Austria, TC.

Fig. 11.11.4. Didymascella leaf blight (*Didymascella thujina*) on foliage of northern white-cedar (*Thuja occidentalis*). Hordaland county, Norway, AS.

Fig. 11.11.5. Dead needles of creeping pine (*Pinus mugo*), with dead tips and brown bands, caused by needle blight (*Lecanosticta acicula,* zoomed needle with damage in insert). Tartu, Estonia, RD, KA.

Fig. 11.11.6. Scots pine (*Pinus sylvestris*) needles with reddish brown damage and red bands caused by needle blight (*Dothistroma* sp.).: Antsla, Estonia, RD, KA.

Additional information: Symptoms of needle blight may also be confused with other pathogen infection, as for example, needle cast (see section 11.9), needle mining by insects (section 11.6) or abiotic damage (section 11.15). For fungal collection and preservation, see Chapter 4.

11.12. Needle webbing

Description: A fine webbing covering groups of needles. Tiny insects can be seen under or in the web. Infested needles may lose their color and drop prematurely, often in a very short period.

Possible damaging agents: Mites: especially spider mites (Acari: Tetranychidae: Figs. 11.12.1 – 11.12.2).

Fig. 11.12.1. Norway spruce (*Picea abies*) needles with webbing due to spider mites (Acari, Tetranychidae: *Oligonychus uninguis*). Czech Republic, PK.

Fig. 11.12.2. Spruce (*Picea* sp.) damaged by mites (Acari, Tetranychidae: *Oligonychus uninguis*). USA, USDA2.

Additional information: Check for presence of webs on twigs and branches. Presence of mites in webbing can be ascertained by shaking the leaves showing such webbings over a white piece of paper. For insect collection and preservation, see Chapter 3.

11.13. Needle clustering

Description: Needles are clustered with silk threads (caused by arthropods). Clusters of needles with brownish to black felt (mycelia) may be caused by needle blight diseases.

Possible damaging agents: Insects: Larvae of Lepidoptera, especially Tortricidae (Figs. 11.13.1, 11.13.2), Geometridae; **Fungi:** Ascomycota (Pleosporales, Helotiales: Figs. 11.13.3, 11.13.4).

Fig. 11.13.1. Needles of European larch (*Larix decidua*) spun together into a tube by a lepidopteran larva (Lepidoptera, Tortricidae: *Spilonota lariciana*). Mátrafüred, Hungary, GC.

Fig. 11.13.2. Needles of European larch (*Larix decidua*) spun together by a lepidopteran larva (Lepidoptera, Tortricidae: *Zeiraphera griseana*), note the sheath cut at the extremity. Briançon, France, AR.

Fig. 11.13.3. Clustered needles of an unknown conifer species, covered by grey or brown mats of mycelium (*Herpotrichia juniperi*). USA, USDA1.

Fig. 11.13.4. Clusters of needles with brown mycelium caused by snowblight (*Phacidium infestans*) on pine (*Pinus* sp.). Mt. Rainier, Washington State, USA, VT.

Additional information: To distinguish arthropod damage from fungal damage, check for the presence of silk at the entrance of the needle cluster and of a larva inside the cluster. For insect and fungal collection and preservation, see Chapters 3 and 4.

11.14. Nesting

Description: Nests (or tents) are the constructions made of needles spun together by silk secreted from insect glands. Larvae feed in nests and can disperse and build new nests. Usually many larvae are present inside such constructions but some species are solitary.

Possible damaging agents: Insects: Larvae of Lepidoptera (Figs. 11.14.1 – 11.14.3), Hymenoptera (Fig. 11.14.4).

Fig. 11.14.1. Red pine (*Pinus resinosa*) with the nest of pine webworm (Lepidoptera, Pyralidae: *Pococera robustella*). USA, SK.

Fig. 11.14.2. Austrian pine (*Pinus nigra*) with a nest of moth larvae (Lepidoptera, Notodontidae: *Thaumetopoea pityocampa*). Orléans, France, NK.

Fig. 11.14.3. Austrian pine (*Pinus nigra*) with a nest and foraging moth larvae (Lepidoptera, Notodontidae: *Thaumetopoea pityocampa*). Orléans, France, NK.

Fig. 11.14.4. Austrian pine (*Pinus nigra*) with a nest covered with larval frass (Hymenoptera, Pamphiliidae: *Acantholyda hieroglyphica*). Subotica, Serbia, LPP.

Additional information: In some cases, nests are well seen even from some distance. If there is visible damage on needles (partially or completely eaten needles), check for the presence of silk, nest or a group of needles that can be spun into nests. The larvae usually feed inside or outside of the nests. Also they may disperse and build new nests on the same or neighbour tree. For insect collection and preservation, see Chapter 3.

11.15. Abiotic factors

Description: Large variations in needle damage occur due to abiotic factors. These are detailed below.

Possible causes of damage:

Drought: Premature browning and shedding of needles. Affected needles generally get brown in all species except larch. On larch, foliage turns yellow. As drought progresses, trees will shed older needles, usually on the lower crown. Other symptoms include:

- Stunted needles. Damage is a result of growth reduction.
- Browning of needle tips.
- Crown dieback. With well advanced drought conditions, foliage discoloration and needle death become more pronounced and tip dieback may be seen. Older trees exhibit symptoms from the top down and from the outside inward.

Frost: Death of foliage, buds and shoots. Frost damage typically occurs on the current year's foliage, especially on the terminal leader and on laterals that are directly exposed to the cold (Fig. 11.15.1). After a frost, symptoms are visible within a few days of frost incidence when foliage becomes limp and fades to yellow. After approximately one week, killed buds turn dark brown and soft. Affected foliage of the branch tips becomes red-brown and limp. These symptoms are often most apparent in the upper crown of smaller trees on the emerging succulent foliage.

Winter drying: Discoloration, death of foliage and opened buds. All conifer species of all ages are susceptible. Trees are discoloured reddish brown over large areas. When viewed from a distance, such areas form bands (a red belt) with clear upper and lower vertical limits. This pattern is seen along slopes in valleys and mountainous areas. Red belt may occur when trees in frozen ground are exposed to abrupt warm, drying winds and then a rapid drop in temperature. Foliage and exposed buds lose moisture. As a result, foliage and buds discolour but remain undistorted. Dead buds become soft over time.

Nutrient deficiency: Yellowing, chlorosis, and necrosis of needles. Nutrient deficiency symptoms include overall loss of vigor, reduced shoot growth, general yellowing (chlorosis) of the needles (Fig. 11.15.2), interveinal chlorosis, marginal necrosis; and in severe cases, total needle necrosis. Nutrient problems rarely kill plants outright, but proper nutrient management is essential for optimizing growth and maintaining high quality plants.

Fluctuations in soil pH: Chlorosis of needles, burn, and death. It is generally accepted that the optimal pH for plant growth and the availability of a broad spectrum of nutrients is between 5.5 and 6.5. As pH drops below or rises above this range, the solubility of nutrient elements may become limiting or toxic.

Air pollution: 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, growth stage and physiological condition, and atmospheric conditions.

Pesticides (fungicides, herbicides): Application injuries exhibit the same symptoms as nutrient disorders and other chemical applications. In most instances, needle blight, marginal and/or spotted necrosis, malformation of needles and total needle discolorations are the visible symptoms

Fig. 11.15.1. Frost damage on Nordmann fir (*Abies nordmanniana*) due to very low temperatures; everything above the snow cover died. Vest-Agder county, Norway, VT.

Fig. 11.15.2. Potassium (K) deficiency on Nordmann fir (*Abies nordmanniana*). Rogaland county, Norway, VT.

Fig. 11.15.3. Necrotic needle tips on larch (*Larix* sp.) in Norway due to windborne ash from a volcanic eruption on Iceland. Rogaland county, Norway, VT.

Fig. 11.15.4. Necrotic needle tips on larch (*Larix* sp.) in Norway due to windborne ash from a volcanic eruption on Iceland. Rogaland county, Norway, VT.

<u>Additional information</u>: Drought damage can be difficult to diagnose as the symptoms are similar to those caused by, and predisposed to, pathogens and insects. Frost injury results from extraordinarily cold temperatures that can happen in the late spring or early fall. Injury in mid-winter is less frequent because tree tissues are often resistant to low temperatures. Spring frost foliar injury is especially common in conifers. Needles in exposed areas or on one side of the tree are killed when they experience warm weather, and hence lose their cold tolerance. Young, newer foliage is often more sensitive to this injury than older foliage. Winter drying may be confused with drought. A distinguishing feature of red belt when it occurs on slopes is the distinct banding. Most nutrient problems are related to nutrient deficiencies, although nutrient toxicities may occur. The extent and nature of nutrient deficiencies can depend on various factors, including soil type or media in production systems, site conditions in the landscape and the plant. Knowing the pH of soils and container media is essential for maintaining adequate growth and development as well as for diagnosing abiotic disorders.

12
Damage to flowers, cones and seeds of coniferous woody plants

A. Roques, V. Talgø, J.-T. Fan and M.-A. Auger-Rozenberg

12.1. Thrips-induced male flower distortion

Description: Flower distorted or shrivelled (Fig. 12.1.1); minute insects present among pollen grains (Fig. 12.1.2).
Possible damaging agents: Insects: Adults of Thysanoptera (Thrips: Fig. 12.1.2)

Fig.12.1.1. Male flowers of Yunnan pine (*Pinus yunnanensis*), deformed by thrips. Lijiang, China, AR.

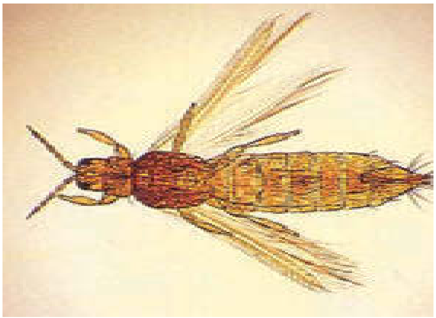

Fig. 12.1.2. A minute thrips (1.5 mm long) that can be found in shrivelled male flowers of *Pseudotsuga macrolepis*. Mexico, DCT.

Additional information: Collect male flowers at time of flowering and dissect pollen bags, look for minute insects (Fig. 12.1.2). For insect collection and preservation, see Chapter 3.

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12.2 Damage by external pollen feeders

Description: Flower surface chewed or gnawed, or with some parts removed.
Possible damaging agents: Insects: adults of many families of Coleoptera (Alleculidae: Fig. 12.2.1, Cantharididae, Curculionidae, Elateridae: Fig. 12.2.2, Meloidae, Scarabaeidae, etc.).

Fig. 12.2.1. Male flower of Scots pine (*Pinus sylvestris*) attacked by adult beetles (Coleoptera, Alleculidae). Briançon, France, AR.

Fig. 12.2.2. A click beetle (Coleoptera, Elateridae: *Athous haemorrhoidalis*) on male flower of Scot pine (*Pinus sylvestris*). UK, AP.

Additional information: Observation usually occurs by chance or by beating flowering branch over a Japanese umbrella. For insect collection and preservation, see Chapter 3.

12.3. Damage by internal pollen feeders

Description: Pollen catkins with sunken areas (Fig. 12.3.1), resin pitch (Fig. 12.3.3) or webbing (Fig. 12.3.2); presence of insect larva(e) between pollen grains (Figs. 12.3.1 - 12.3.4) and/or tunnel(s) filled with frass.
Possible damaging agents: Insects: larvae of various Lepidoptera families (Blastobasidae, Pyralidae, etc.) and Hymenoptera (Xyelidae sawflies).

Fig. 12.3.1. Pollen catkin of slash pine (*Pinus elliotti*) tunnelled by a moth larva (Lepidoptera, Blastobasidae: *Holcocera* sp.). USA, AFH.

Fig.12.3.2. Pollen catkins of pine (*Pinus* sp.) with webbing due to early instar larvae of cone moths (Lepidoptera, Pyralidae: *Dioryctria disclusa*). USA, LB.

Fig. 12.3.3. Pollen catkins of slash pine (*Pinus elliotti*) with resin pitches, indicating attack by hymenopteran sawfly larvae (Hymenoptera, Xyleidae: *Xylea* sp.). USA, AFH.

Fig. 12.3.4. *Xylea* larvae emerged from drying slash pine (*Pinus elliotti*) catkins shown in Fig. 12.3.3. USA, AFH.

Additional information: Collect flowers just before pollen shed and dissect them to find larvae. For insect collection and preservation, see Chapter 3.

12.4. Sap-feeder damage on female flowers

Description: Strobilus, flower or conelet drying, without frass expelled. Presence of resin beads (Figs. 12.4.1 - 12.4.2) or not (Figs. 12.4.3 - 12.4.4).
Possible damaging agents: **Insects:** Thysanoptera (e.g., Phlaeothripidae, Thripidae: Figs.12.4.1 - 12.4.2), Hemipteran seed bug families (e.g., Coreidae, Pentatomidae, Lygaeidae: Fig.12.4.3), **Mites:** Acari (Eriophyiidae: Fig.12.4.4).

Fig. 12.4.1. Dried female flower of Mexican Douglas-fir (*Pseudotsuga macrolepis*) following attack by thrips (Thysanoptera). Mexico, DCT.

Fig. 12.4.2. Female conelet of slash pine (*Pinus elliottii*) with resin pitches, damaged by flower thrips (Thysanoptera, Phlaeothripidae: *Gnophothrips fuscus*). USA, BHE.

Fig. 12.4.3. Conelet of shortleaf pine (*Pinus echinata*), aborted following predation by a seed bug (Hemiptera, Coreidae: *Leptoglossus corculus*) (right), besides healthy conelet (left). USA, AFH.

Fig. 12.4.4. Drying female flower (bottom right, healthy ones towards tip) of Chinese cypress (*Cupressus duclouxiana*) following attack by mites (Acari, Eriophyiidae: *Trisetacus* sp.). Lijiang, China, AR.

Additional information: Look for bite marks on the pedicel (mite damage), resin pitches on surface (thrips damage) or for insect feeding damage by sucking insects (bugs). Usually the insects found at openings in dead flowers or conelets are secondary, detritivorous species (e.g., midge larvae). For insect collection and preservation, see Chapter 3. Such damage can also result from physiological disorders (e.g., absence of pollination) or abiotic factors (e.g., frost: see 12.5.).

12.5. Abiotic factors affecting flowers or cones

Description: Flower, conelet or cone dried without any insect, mite or fungal damage visible at opening, and no exit holes visible.
Possible damaging agents: Late frost, drought, pollution.

Fig. 12.5.1. Female flower of Himalayan larch (*Larix potaninii*) killed by late frost. Lijiang, China, AR.

Fig. 12.5.2. Female flower of Douglas fir (*Pseudotsuga menziesii*) killed by late frost during bud break. USA, USDA1.

Fig. 12.5.3. Female flowers of Norway spruce (*Picea abies*; circled in red) killed by late frost. Latronquière, France, CB.

Fig. 12.5.4. Cone of introduced Mexican pine (*Pinus rudis*) with dried base due to summer drought (no insect tunnels or exit holes). Bormes, France, AR.

Additional information: Dissect the cones and flowers to ascertain the absence of pests, as well as of pest damage (tunnels, frass, etc.). Some insects may be found at opening in dead flowers and cones but they are secondary, detritivorous species and do not tunnel the substrate (e.g., midge and other fly larvae).

12.6. External insect damage on female flowers/conelets

Description: External surface gnawed.
Possible damaging agents: Insects: Adults of Coleopteran beetle families (e.g., Rutelidae, Scarabaeidae: Fig. 12.6.1), larvae of Lepidoptera families (e.g., Geometridae, Tortricidae: Fig. 12.6.2) and Hymenoptera (sawflies).

Fig. 12.6.1. An adult scarab beetle (Coleoptera, Scarabaeidae: *Phyllophaga* sp.) feeding on female flowers of loblolly pine (*Pinus taeda*). USA, AFH.

Fig. 12.6.2. Young cone of European larch (*Larix decidua*), gnawed by a larva of larch budmoth (Lepidoptera, Tortricidae: *Zeiraphera griseana*). Briançon, France, AR.

Additional information: Observation by chance (feeding may occur at night) or by beating flowering branches. For insect collection and preservation, see Chapter 3.

12.7. Arthropod-induced flower/conelet distortion

Description: Strobilus/conelet distorted with parts hypertrophied (Figs. 12.7.1 - 12.7.2), usually with resin pitch beads or damaged/discoloured scales, but without frass or holes visible on the surface. In Cupressaceae, immature seeds can protrude from young berries/cones due to mite infestation (Figs. 12.7.3 - 12.7.4).
Possible damaging agents: Insects: larvae of Diptera (Cecidomyiidae,midges: Figs. 12.7.1 – 12.7.2), **Mites**: Acari (Eriophyiidae: Figs. 12.7.3 - 12.7;4).

Fig. 12.7.1. Conelet of slash pine (*Pinus elliotii*) damaged by midge larvae (Diptera, Cecidomyiidae: *Cecidomyia bisetosa*). USA, AFH.

Fig. 12.7.2. Conelet of Korean pine (*Pinus koraiensis*), deformed by midge larvae (Diptera, Cecidomyiidae: *Cecidomyia pini*). Briançon, France, AR.

Fig. 12.7.3. Female flower of incense juniper (*Juniperus thurifera*) with protruding immature seeds due to mites (Acari, Eriophyiidae: *Trisetacus* sp.). Oukaïmden, Morocco, AR.

Fig. 12.7.4. First-year cone of evergreen cypress (*Cupressus sempervirens*) with scale edges deformed by mites (Acari, Eriophyiidae: *Trisetacus* sp.). Toulon, France, AR.

Additional information: Dissect conelet and look for small larvae, whitish to orange. For insect collection and preservation, see Chapter 3.

12.8. Internal insect damage on female flower/conelet

Description: Strobilus/conelet with expelled frass on surface (Figs. 12.8.1, 12.8.3), sometimes mixed with resin pitches (Fig. 12.8.2). Emergence hole(s) may be present (Fig. 12.8.5) or larva(e) or tunnel(s) visible when dissected (Figs. 12.8.4, 12.8.6).

Possible damaging agents: Insects: Larvae and adults of Coleoptera families (e.g., Scolytinae: *Conophthorus* spp., Anobiidae: *Ernobius* spp.: Figs. 12.8.5 – 12.8.6), larvae of Lepidoptera families (e.g., Pyralidae: *Dioryctria* spp.: Figs. 12.8.2 - 12.8.3, Tortricidae: Figs. 12.8.2 – 12.8.3).

Fig. 12.8.1. Female flowers of *Pinus simaoensis* attacked by unidentified larvae of a bud moth (Lepidoptera, Tortricidae). Simao, China, AR.

Fig. 12.8.2. Conelet of Turkish pine (*Pinus brutia*) showing frass mixed with resin expelled by larva of cone pyralid (Lepidoptera, Pyralidae: *Dioryctria mendacella*). Rhodos, Greece, AR.

Fig. 12.8.3. Conelet of Aleppo pine (*Pinus halepensis*) with frass expelled by larva of cone pyralid (Lepidoptera, Pyralidae: *Dioryctria mendacella*). Marrakech, Morocco, AR.

Fig. 12.8.4. Damaged conelet of Scots pine (*Pinus sylvestris*) stuck to the sustaining twig by resin (left) and opened (right) to show the budmoth larva (Lepidoptera, Tortricidae: *Rhyacionia buoliana*). Briançon, France, AR.

Fig. 12.8.5. Conelet of Turkish pine (*Pinus brutia*) with exit holes of adult deathwatch beetles (Coleoptera, Anobiidae: *Ernobius oertzeni*). Pylos, Greece, AR.

Fig. 12.8.6. Conelet of Yunnan pine (*Pinus yunnanensis*), opened to show a deathwatch beetle larva (Coleoptera, Anobiidae: *Ernobius* sp.). Dali, Yunnan, China, AR.

Additional information: Dissect the conelet and extract larva(e) if still present. For insect collection and preservation, see Chapter 3.

12.9. Cone rust

Description: Strobilus/conelet with powdery masses of yellow-orange spores on the surface. Infected cones turn brown prematurely and are easily identified by the presence of orange-coloured aeciospores, which form between the cone scales in late summer.

Possible damaging agents: Fungi: Basidiomycota (Pucciniales: Figs. 12.9.1 – 12.9.4, Uredinales: Figs. 12.9.5 – 12.9.6).

Fig. 12.9.1. Swollen 1st-year conelet of slash pine (*Pinus elliottii*) covered by bright yellow aeciospores of southern cone rust (Basidiomycota, Pucciniales: *Cronartium strobilinum*). USA, USDA1.

Fig. 12.9.2. Comparison of a disease-free 1st-year conelet (right) of slash pine (*Pinus elliottii*) with a conelet of same whorl (left), which has become 3-4 times larger because of infection by southern cone rust (Basidiomycota, Pucciniales: *Cronartium strobilinum*). USA, ELB.

Fig. 12.9.3. Cone of spruce (*Picea mariana*) with aeciospores produced beneath the cone scales by inland spruce cone rust (Basidiomycota, Pucciniales: *Chrysomyxa pirolata*). Entire cone and cross-section. Canada, JRS.

Fig. 12.9.4. Enlarged cone of *Pinus leiophylla var. chihuahuana* with scales covered by masses of aeciospores of southwestern pine cone rust. (Basidiomycota, Pucciniales: *Cronartium conigenum*). Southern USA, BHE.

Fig. 12.9.5. Norway spruce (*Picea abies*) cone with sporocarps of a rust (Basidiomycota, Uredinales: *Pucciniastrum areolatum*) that destroys the seed. Austria, TC.

Fig. 12.9.6. Norway spruce (*Picea abies*) cones with fruiting bodies containing aeciospores of a rust (Basidiomycota, Uredinales: *Pucciniastrum areolatum*). Slovakia, AK.

<u>Additional information</u>: A light "dusting" of aeciospores is often observed on vegetation beneath trees with diseased cones. Mycelium of uredinial and telial stages are systematic on the petioles of the alternative broadleaf host species (*Prunus* spp., *Pyrola* spp. and *Moneses* spp.). For fungal preservation and collection, see Chapter 4.

12.10. Sap feeder damage

Description: Presence of whitish/yellowish, non-resin, waxy coverings or woolly organisms on surface; possible presence of honeydew (Fig. 12.10.4).
Possible damaging agents: Insects: Hemiptera, especially scales (Coccoidae, Diaspididae: Figs. 12.10.1 – 12.10.3), Adelgidae (Fig. 12.10.4) and aphids (Aphididae).

Fig. 12.10.1. Cone of Atlas cypress (*Cupressus atlantica*) heavily attacked by scales (Hemiptera, Coccidae). Oukaïmden, Morocco, AR.

Fig. 12.10.2. Cone of incense juniper (*Juniperus thurifera*) with scales on the surface (Hemiptera, Coccidae: *Carulaspis juniperi*). Rié, France, AR.

Fig. 12.10.3. Cone of stone pine (*Pinus pinea*), heavily colonized by scales (Hemiptera, Coccidae). Carrapateira, Portugal, AR.

Fig. 12.10.4. Spruce cone (*Picea* sp.) infested by wooly adelgids (Hemiptera, Adelgidae: *Adelges cooleyi*). USA, AFH.

Additional information:
Note whether the organism present on the surface is protected by a soft or hard covering (scale) or free living (aphid, woolly adelgid). For insect collection and preservation, see Chapter 3.

12.11. External frass protruding due to internal insect feeding

Description: Cone or berry with frass extruding from surface (Figs. 12.11.1 – 12.11.5), sometimes mixed with resin (Figs. 12.11.6 – 12.11.8).
Possible damaging agents: Insects: Llarvae of Lepidoptera families (e.g., Gelechiidae, Geometridae, Pyralidae: Figs. 12.11.1, 12.11.2, 12.11.4, Tortricidae: Figs. 12.11.3, 12.11.6, 12.11.7, Yponomeutidae: Fig. 12.11.8), adults and larvae of Coleoptera families (e.g., Anobiidae, Curculionidae Scolytinae; *Conophthorus* spp.: Fig. 12.11.5).

Fig. 12.11.1. Cone of Aleppo pine (*Pinus halepensis*), attacked by larvae of cone pyralids (Lepidoptera, Pyralidae: *Dioryctria* sp.). Pylos, Greece, AR.

Fig. 12.11.2. The cone shown in 12.11.1, bisected to show the damaging larva. Pylos, Greece, AR.

Fig. 12.11.3. Cone of *Keteeleria evelyniana* with frass at basis, expelled by a coneborer larva (Lepidoptera, Tortricidae: *Blastipetrova* sp.). Dali, China, AR.

Fig. 12.11.4. Cone of George's fir (*Abies georgei*) with frass expelled by larvae of cone moths (Lepidoptera, Pyralidae: *Dioryctria* sp.). Dali, China, AR.

Fig. 12.11.5. Cone of eastern white pine (*Pinus strobus*) with frass and resin pitches caused by cone beetles (Coleoptera, Curculionidae Scolytinae: *Conophthorus coniperda*). USA, AFH.

Fig. 12.11.6. Cone of cypress pine (*Callitris* sp.) with frass expelled by a cone moth larva (Lepidoptera, Tortricidae: *Tracholena* sp.). Kamarah, Australia, AR.

Fig. 12.11.7. Cone of Syrian juniper (*Juniperus drupacea*) with frass expelled by larvae of cone tortricid moths (Lepidoptera, Tortricidae: *Pammene mariana*). Parnos mountain, Greece, AR.

Fig. 12.11.8. Berry of incense juniper (*Juniperus thurifera*) with frass expelled by cone moth larvae (Lepidoptera, Yponomeutidae: *Argyresthia reticulata*). Oukaïmden, Morocco, AR.

Additional information: Note whether the expelled frass is coarse or light, and combined with resin or not. Then, open the cone and extract larvae/adults, and note the shape of the tunnel. For insect collection and preservation, see Chapter 3.

12.12. Diptera-induced resin pitch

Description: Cone with a large resin pitch on its surface, but no frass extruding. Cone is at least partly desiccated and discoloured.
Possible damaging agents: Insects: larvae of Diptera (Anthomyiidae: Figs. 12.12.1 – 12.12.4).

Fig. 12.12.1. Cone of *Picea likiangensis* with a resin pitch caused by a cone fly larva (Diptera, Anthomyiidae: *Strobilomyia* sp.). Lijiang, China, AR.

Fig. 12.12.2. European fir (*Abies alba*) cone with dessicated apex and a resin pitch caused by a cone fly larva (Diptera, Anthomyiidae: *Strobilomyia carbonaria*). Briançon, France, AR.

Fig. 12.12.3. Cone of European larch (*Larix decidua*) with typical resinated base due to a cone fly larva (Diptera, Anthomyiidae: *Strobilomyia laricicola*). Briançon, France, AR.

Fig. 12.12.4. Cone of Himalayan larch (*Larix potaninii*) bisected to show the mature cone fly larva in the axis (Diptera, Anthomyiidae: *Strobilomyia lijiangensis*). Lijiang, China, AR.

Additional information: Open the cone and extract the maggot-like larvae present in tunnels. If the resin pitch has fallen from the cone, the discoloration of cones can lead to confusion with symptoms shown in Fig. 12.15.5. For insect collection and preservation, see Chapter 3.

12.13. Fungus-induced resin flow

Description: As a defense, conifers readily produce resin from tissue that is wounded by biotic or abiotic damaging agents, including from cones attacked by fungi. The resin is sticky and nearly colourless when it flows from the wounds, but becomes whitish and solid over time.

Possible damaging agents: Fungi: Ascomycota (Fig. 12.13.1), Basidiomycota (Fig. 12.13.2).

Fig. 12.13.1. Resin flow on Nordmann fir (*Abies nordmanniana*) cones infected by *Neonectria neomacrospora*. Jutland, Denmark, VT.

Fig. 12.13.2. Cones of white spruce (*Picea glauca*) with resin and yellowish aecidia of *Pucciniastrum americanum*. Canada, CFS.

Additional information: Harvesting of cones with heavy resin flow should be avoided to minimize the risk of seed borne diseases. For fungal collection and preservation, see Chapter 4.

12.14. Fungus-induced cone opening

Description: The cones open before maturity due to fungal agents that are dispersed by wind or insects.
Possible damaging agents: Fungi: Ascomycota (Fig. 12.14.1), Basidiomycota (Fig. 12.14.2).

Fig. 12.14.1. Cone of evergreen cypress (*Cupressus sempervirens*), prematurely opened due to cypress canker (*Seiridium cardinale*). Toulon, France, AR.

Fig. 12.14.2. Fruiting bodies (aecidia) of cone rust (*Thekopsora areolata*) between scales of Norway spruce (*Picea abies*). Akershus county, Norway, EF.

Additional information: Fungal attacks on immature cones are problematic in commercial seed production and may also influence natural regeneration. For fungal collection and preservation, see Chapter 4.

12.15. Insect-induced cone discoloration

Description: Cone or berry partly or entirely discoloured, but without frass extruding from surface, or resin pitch.
Possible damaging agents: Insects: Larvae of Coleoptera (Anobiidae: Fig. 12.15.5, Curculionidae: Figs. 12.15.1 – 12.15.4), Diptera (Anthomyiidae, Cecidomyiidae: Fig. 12.15.6) and Lepidoptera (Tortricidae: Figs. 12.15.7 – 12.15.8, Gelechiidae, Yponomeutidae).

Fig. 12.15.1. Cone of Chinese whte pine (*Pinus armandii*) with purple discoloured parts due to internal feeding by unidentified weevil larvae (Coleoptera, Curculionidae). Chuxiong, Yunnan, China, AR.

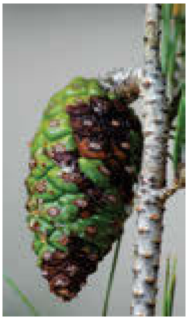

Fig. 12.15.2. Cone of Aleppo pine (*Pinus halepensis*) with blackened parts corresponding to underlying tunnels of cone weevil larvae (Coleoptera, Curculionidae: *Pissodes validirostris*). Marseille, France, AR.

Fig. 12.15.3. Cone of maritime pine (*Pinus pinaster*) entirely discoloured and desiccated (right) following heavy attack by cone weevil larvae (Coleoptera, Curculionidae: *Pissodes validirostris*). Vila Real, Portugal, AR.

Fig. 12.15.4. The damaged cone shown in 12.15.3 bisected to show cone weevil larvae (Coleoptera, Curculionidae: *Pissodes validirostris*). Vila Real, Portugal, AR.

Fig. 12.15.5. Cone of Greek fir (*Abies cephalonica*), with discoloured apex following attack by deathwatch beetles (Coleoptera, Anobiidae: *Ernobius kailidisi*). Taygetos, Greece, AR.

Fig. 12.15.6. Cone of Siberian larch (*Larix gmelini)* with discoloured scales following attack by unidentified seed midges (Diptera, Cecidomyiidae). Jagedaqi, China, AR.

Fig. 12.15.7. Berry of incense juniper (*Juniperus thurifera*) partly discoloured due to cone borer larvae (Lepidoptera, Tortricidae: *Pammene oxycedrana*). Oukaïmden, Morocco, AR.

Fig. 12.15.8. Cone of evergreen cypress (*Cupressus sempervirens*) discoloured following attack by cone borer larvae (Lepidoptera, Tortricidae: *Pseudococcyx tessulatana*). Pylos, Greece, AR.

Additional information: If the cone is only partly discoloured and without exit holes, the damaging larvae are still present. Carefully cut the cone longitudinally (e.g., Fig. 12.15.4) and check the discoloured parts for the presence of larvae. For insect collection and preservation, see Chapter 3.

12.16. Fungi-induced cone discoloration

Description: Dark lesions on immature green cones.
Possible damaging agents: Fungi: Ascomycota (Fig. 12.16.1).

Fig. 12.16.1. Cones of loblolly pine (*Pinus taeda*) with necrosis caused by pitch canker (*Fusarium circinatum*). USA, LDD.

Additional information: No visible fruiting bodies or spores on the surface. For fungal collection and preservation, see Chapter 4.

12.17. Mite-induced cone distortion

Description: Berry distorted, with galled seeds more or less extruding from surface.
Possible damaging agents: Mites: Acari (Eriopyhiidae: Figs. 12.17.1 – 12.17.4).

Fig. 12.17.1. Berries of incense juniper (*Juniperus thurifera*) with protruding seeds due to attack by seed mites (Acari, Eriophyiidae: *Trisetacus quadrisetus*). Soria, Spain, AR.

Fig. 12.17.2. A mite-damaged berry shown in Fig. 12.17.1., bisected to show the seeds entirely filled with frass and very tiny mites. AR.

Fig. 12.17.3. Berries of redberry juniper (*Juniperus cohaluiensis*) with protruding seeds due to attack by seed mites (Acari, Eriophyiidae: *Trisetacus* sp.). Colorado, USA, AR.

Fig. 12.17.4. Berries of checkerbark juniper (*Juniperus deppeana*) with protruding seeds due to attack by seed mites (Acari, Eriophyiidae: *Trisetacus* sp.). New Mexico, USA, AR.

Additional information: Extract the protruding seed, open it and preserve the content (frass plus tiny mites) as detailed in Chapter 3. Galled seeds may contain mite parasites or predators of larger size.

12.18. Insect-induced cone distortion

Description: Cone noticeably distorted, but without seeds extruding from surface.
Possible damaging agents: Larvae of Diptera (Anthomyiidae: Fig. 12.18.4, Cecidomyiidae midges: Figs. 12.18.1 – 12.18. 2) and Thysanoptera (Thrips: Fig. 12.18.3).

Fig. 12.18.1. Cone of Swiss stone pine (*Pinus cembra*) deformed following attack by midge larvae (Diptera Cecidomyiidae *Cecidomyia pini*). Briançon, France, AR.

Fig. 12.18.2. Deformed cone (left) of Swiss stone pine (*Pinus cembra*) compared to a cone with normal development on the same whorl. Briançon, France, AR.

Fig. 12.18.3. Deformed mature cones of slash pine (*Pinus elliottii*) following an attack at the flowering stage by flower thrips (Thysanoptera, Phlaeothripidae: *Gnophothrips fuscus*). USA, AFH.

Fig. 12.18.4. Cone of European larch, *Larix decidua*, distorted and dessicated at its basis (left), following attack by cone fly larvae (Diptera, Anthomyiidae: *Strobilomya laricicola*). On the right, the same cone sliced to show the damaging larva and its tunnels. Briançon, France, AR.

Additional information: Such deformation is usually a consequence of attack during the early stages of cone development. The insects may no longer be present, but check for whitish or orange maggot-like larvae (Diptera) or minute insects (thrips). For insect collection and conservation, see Chapter 3.

12.19. Fungal damage

Description: Cones may be covered with dark fruiting bodies containing spores.
Possible damaging agents: Fungi: Ascomycota (Figs. 12.19.1 – 12.19.4).

Fig. 12.19.1. *Sirococcus* sp. on cone of noble fir (*Abies procera*). Vest-Agder county, Norway, VT.

Fig. 12.19.2. Fruiting bodies (pycnidia) of *Sirococcus* sp. on cone scales of noble fir (*Abies procera*). Vest-Agder county, Norway, VT.

Fig. 12.19.3 Fruiting bodies (pycnidia) of *Sirococcus* sp. on seed of noble fir (*Abies procera*). Vest-Agder county, Norway, VT.

Fig. 12.19.4. *Seiridium cardinale* on a *Thuja* sp. Østfold county, Norway, VT.

Additional information: Fungi may still be the cause of damage if no fruiting bodies are visible. Thus, if seeds are not germinating, isolation on artificial media (agar) is often necessary to determine the cause.

12.20. Internal cone damage by larva, without external symptoms

Description: No frass or exit hole(s) on surface. Colour and development normal, but presence of larvae or tunnels when the cone is cut.

Possible damaging agents: Insects: larvae of Coleoptera (Anobiidae: Fig. 12.20.2, Ptinidae, etc.), Diptera (Cecidomyiidae: Fig. 12.20.4) and Lepidoptera (Gelechiidae, Tortricidae: Figs. 12.20.1, 12.20.3, Yponomeutidae).

Fig. 12.20.1. Cone of Lijiang spruce (*Picea likiangensis*) with normal development, bisected to show a larva of cone moth in the axis (Lepidoptera Tortricidae *Cydia* sp.). Lijiang, China, AR.

Fig. 12.20.2. Cone of Norway spruce (*Picea abies*) with normal development, bisected to show larvae of cone beetles along and in the axis (Coleoptera Anobiidae *Ernobius abietis*). Lot, France, AR.

Fig. 12.20.3. Cone of black pine (*Pinus nigra*) with normal development, bisected to show a cut gallery created by a seed moth (left) (Lepidoptera Tortricidae *Cydia conicolana*). Pylos, Greece, AR.

Fig. 12.20.4. Cone of European larch (*Larix decidua*) with apex removed to show midge larvae (Diptera, Cecidomyiidae: *Resseliella skhuravyorum*). Briançon, France, AR.

Additional information: Note the position of the larvae and the larval tunnels. For insect collection and preservation, see Chapter 3.

12.21. Adult emergence hole(s)

Description: Perfectly circular hole(s) in cone or berry external surface.
Possible damaging agents: Insects: Emerging adults of Coleoptera from several families (Anobiidae: Fig. 12.21.3, Cerambycidae: Fig. 12.21.2, Curculionidae: Fig. 12.21.1) and Hymenoptera (Eurytomidae, Torymidae: Figs. 12.21.4 – 12.21.6).

Fig. 12.21.1. Cone of maritime pine (*Pinus pinaster*) with exit holes of adult cone weevils (Coleoptera, Curculionidae: *Pissodes validirostris*). Buçaco, Portugal, AR.

Fig. 12.21.2. Cone of *Pinus simaoensis* with an exit hole of an adult cerambycid (Coleoptera, Cerambycidae: *Xylotrechus* sp.). Xishuanbanna, China, AR.

Fig. 12.21.3. Cone of Aleppo pine (*Pinus halepensis*) with numerous exit holes of adult cone deathwatch beetles (Coleoptera, Anobiidae: *Ernobius oertzenii*). Dubrovnik, Croatia, AR.

Fig. 12.21.4. Berry of incense juniper (*Juniperus thurifera*) with exit holes of adult seed chalcids (Hymenoptera, Torymidae: *Megastigmus thuriferana*). Saint Crépin, France, AR.

Fig. 12.21.5. Cone of Chinese cypress (*Cupressus duclouxiana*) with an exit hole of seed chalcids (Hymenoptera, Torymidae: *Megastigmus duclouxianae*). Lijiang, China, AR.

Fig. 12.21.6. Cone of Mediterranean cypress (*Cupressus sempervirens*) with exit holes of seed chalcids (Hymenoptera, Torymidae: *Megastigmus wachtli*). Samos, Greece, AR.

Additional information: Usually, insects are no longer present by the time damage is observed, but there may still be dead specimens present that did not emerge from the cone. Note the diameter of the exit hole. Emerging parasites of the phytophagous pests may also bear similar circular emergence hole(s). For insect collection and preservation, see Chapter 3.

12.22. Larval emergence hole(s)

Description: Presence of irregularly-shaped hole(s) on cone or berry external surfaces.

Possible damaging agents: Insects: mature larvae of many Lepidoptera (Gelechiidae: Fig. 12.22.3, Geometridae, Pyralidae: Figs. 12.22.1 – 12.22.2, Yponeumeutidae), Diptera (Anthomyiidae: Fig.12.22.4, Cecidomyiidae) and Hymenoptera (Diprionidae), falling down to pupate on the ground (Fig. 12.22.4), or immature larvae of Lepidoptera switching from one cone or berry to another.

Fig. 12.22.1. Cone of Yunnan pine (*Pinus yunannensis*) with exit hole of a moth larva (Lepidoptera, Pyralidae: *Dioryctria* sp.). Lijiang, China, AR.

Fig. 12.22.2. Cone of Yunnan pine (*Pinus yunannensis*) with exit hole of a moth larva (Lepidoptera, Pyralidae: *Dioryctria* sp.). Lijiang, China, AR.

Fig. 12.22.3. Berry of prickly juniper (*Juniperus oxycedrus*) with exit hole created by a moth larva (Lepidoptera, Gelechiidae: *Brachyacma oxycedrella*); detail of the internal damage on the right. Corsica, France, AR.

Fig. 12.22.4. Cone of European larch (*Larix decidua*) with a larva emerging to pupate in the soil (Diptera, Anthomyiidae: *Strobilomya laricicola*). Briançon, France, AR.

Additional information: Usually, insects are no longer present by the time damage is observed, but there may still be dead specimens present that did not emerge from the cone. For insect collection and preservation, see Chapter 3.

12.23. Vertebrate damage

Description: Cone partially eaten with minor or major jagged edges; sometimes only the axis remains (Fig. 12.23.1).
Possible damaging agents: Mammals: Squirrels (Fig.12.23.1), mice, **Birds** (Fig.12.23.2).

Fig. 12.23.1. Cones of Douglas fir (*Pseudotsuga menziesii*) partially eaten by squirrels. Only the axis remains in some cones. Lot, France, AR.

Fig. 12.23.2. Cones of maritime pine (*Pinus pinaster*) attacked by birds. Lot, France, AR.

Additional information: Symptoms may appear that are characteristic of feeding damage. However, the cones may also be infested by insect larvae which can be used for food by birds. So further investigation is required.

12.24. Insect-induced seed fusion

Description: Seeds fused with scales or galled, cannot disperse out of the cone.
Possible damaging agents: Insects: Larvae of Diptera (Cecidomyiidae gall midges: Figs. 12.24.1 – 12.24.2) and adults and nymphs of Hemipterans: true bugs of several families (e.g., Coreidae: Figs. 12.24.3 – 12.24.4).

Fig. 12.24.1. Cone of Douglas fir (*Pseudotsuga menziesii*) bisected to show galled seeds fused with scales due to gall midge (Diptera, Cecidomyiidae: *Contarinia oregonensis*). USA, AFH.

Fig. 12.24.2. Cone of Norway spruce (*Picea abies*) bisected to show white galls of midges at the junction between axis, scales and seeds (Diptera, Cecidomyiidae: *Kaltenbachiola strobi*). Lot, France, AR.

Fig. 12.24.3. Cone of Scots pine (*Pinus sylvestris*) with a scale dissected to show the seeds fused at its base, following predation by seed bugs (Hemiptera, Coreidae: *Leptoglossus occidentalis*). Rodez, France, AR.

Fig. 12.24.4. Detail of fused seeds that were manually extracted from the cone shown in 12.24.3. AR.

Additional information: When the cone is mature, shake it vigorously to release the seeds; then cut it longitudinally and check those seeds which did not shed/release.

12.25. Seed damage by seed chalcid or seed midge

Description: No visible damage on the seed, but one or several larvae present in the seed (or a circular exit hole where adults have already emerged).
Possible damaging agents: Insects: Larvae of Hymenoptera (Torymidae: Figs. 12.25.1 – 12.25.5, Eurytomidae: Fig. 12.25.6, Cynipidae, etc.) and Diptera (Cecidomyiidae: Figs. 12.25.7, 12.25.8).

Fig. 12.25.1. Seed of common juniper (*Juniperus communis*) opened to show fully-developed larva of seed chalcid (Hymenoptera, Torymidae: *Megastigmus bipunctatus*). Briançon, France, AR.

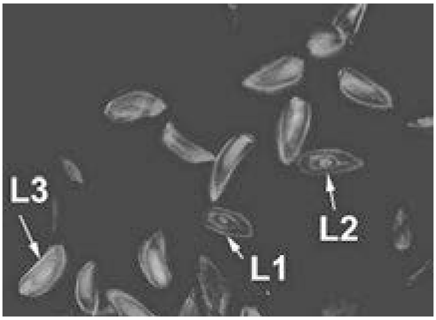

Fig. 12.25.2. Seeds of Chinese cypress (*Cupressus duclouxiana*), X-rayed to show different larval stages of seed chalcids (Hymenoptera, Torymidae: *Megastigmus duclouxianae*). Lijiang, China, AR.

Fig. 12.25.3. Seeds of Douglas fir (*Pseudotsuga menziesii*) with emergence holes of adult seed chalcids (Hymenoptera, Torymidae: *Megastigmus spermotrophus*). Lot, France, AR.

Fig. 12.25.4. X-rayed seeds of Douglas fir (*Pseudotsuga menziesii*) with larvae and pupae of seed chalcids (Hymenoptera, Torymidae: *Megastigmus spermotrophus*). Lot, France, AR.

Fig. 12.25.5. Mature cone of ponderosa pine (*Pinus ponderosa*) with a seed with an exit hole of seed chalcid (Hymenoptera, Torymidae: *Megastigmus albifrons*). Ruidoso, USA, AR.

Fig. 12.25.6. Seed of Siberian larch (*Larix gmelinii*) with an adult seed chalcid about to emerge (Hymenoptera, Eurytomidae: *Eurytoma laricis*). Jagedaqi, China, AR.

Fig. 12.25.7. Seed of balsam fir (*Abies balsamea*) with a midge larva (Diptera, Cecidomyiidae: *Resseliella* sp.). Quebec, AR.

Fig. 12.25.8. X-rayed seeds of European fir (*Abies alba*). One seed is infested by midge larvae (Diptera, Cecidomyiidae: *Resseliella piceae*). Briançon, France, AR.

Additional information: Collect mature seeds. Usually, the infested seed does not differ from the healthy ones in shape, colour or weight, although some exceptions exist. The seed must be opened or, better, X-rayed to ascertain the presence of larvae. Alternatively, to ease identification of the damaging species, infested seeds can be stored until adults emerge. For insect preservation, see Chapter 3.

12.26. Seed damage by true bugs

<u>Description</u>: No visible damage on seed and no larva present when the seed is opened, but seed content more or less consumed. A seed embryo is present, although usually shrivelled.

<u>Possible damaging agents</u>: Insects: Adults and nymphs of Hemiptera: true bugs of several families (Acanthosomitidae, Coreidae: Figs. 12.26.1 – 12.26.2, Lygaeidae: Figs. 12.26.3 – 12.26.4, Pentatomidae, etc.).

Fig. 12.26.1. Conelet of black pine (*Pinus nigra*) predated by a seed bug (Hemiptera, Coreidae: *Leptoglossus occidentalis*). Orléans, France, AR.

Fig. 12.26.2. Comparison of intact seeds (top) of Aleppo pine (*Pinus halepensis*) with seeds predated to various degrees by seed bugs (Hemiptera, Coreidae: *Leptoglossus occidentalis*) (left: X-ray pictures of the seeds; right: the same seeds sliced). Montpellier, France, AR.

Fig. 12.26.3. Cone of evergreen cypress (*Cupressus sempervirens*) predated by an adult seed bug (Hemiptera, Lygaeidae: *Orsillus maculatus*). Toulon, France, AR.

Fig.12.26.4. Seeds of evergreen cypress (*Cupressus sempervirens*) predated by seed bugs (Hemiptera, Lygaeidae: *Orsillus maculatus*) (left: X-ray pictures of the seeds; right: the same seeds sliced). Toulon, France, AR.

Additional information: Observation of bugs predating cones will only occur by chance or by beating cones. Traces of feeding (small dots on cone surface) disappear rapidly. Usually, the infested seed does not differ from the healthy ones in shape and colour, but it is of lower weight due to feeding uptake. The seed must be opened or, better, X-rayed to ascertain the damage extent. Most seeds with more than 10% of the endosperm consumed will not germinate.

12.27. Abiotic seed damage

Description: Seeds are either deflated or appear normally developed (e.g., in most Pinaceae) but are entirely empty at opening (or when analysed by X-rays).
Possible damaging agents: Mostly pollination problems (tissue incompatibility, lack of synchrony between pollination and female flower bud burst).

Fig. 12.27.1. Deflated, unpollinated seeds (in the centre) in a cone of Austrian pine (*Pinus nigra*). Orléans, France, AR.

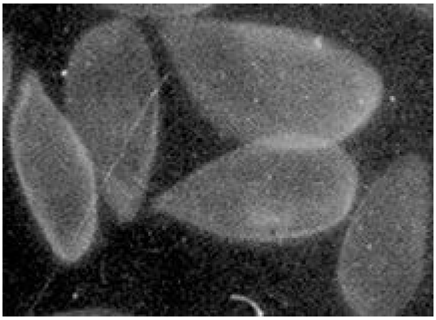

Fig. 12.27.2. Radiograph of seeds of oriental spruce (*Picea orientalis*) showing unpollinated, entirely empty seeds. Les Barres arboretum, France, AR.

Additional information: No embryo remains, often completely shrivelled, which will be visible when the seed is opened, or on X-ray pictures. If remnants of an embryo are observed refer to seed bug damage (section 12.26).

12.28. Seed rot

Description: Even if the seed cover looks intact and healthy, the seed may not germinate. Alternatively, they do germinate, but the seedling dies before or shortly after emerging.

Possible damaging agents: Fungi: Ascomycota (Figs. 12.28.1 – 12.28.3).

Fig. 12.28.1. *Caloscypha fulgens* on subalpine fir seed (*Abies lasiocarpa*) from Canada. VT.

Fig. 12.28.2. *Botrytis cinerea* (sporulation and black sclerotia) on Nordmann fir (*Abies nordmanniana*) seed from Georgia. VT.

Fig. 12.28.3. Radiograph of seeds of slash pine (*Pinus elliottii*) infected by pitch canker (*Fusarium circinatum*), showing deterioration of gametophyte tissues and embryo. USA, TM.

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

13
Damage to stems, branches and twigs of coniferous woody plants

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13.1. Root and stem rot

Description: External, above-ground symptoms on individual trees are variable and include suppressed growth, reduced vigour, discoloured or small-sized needles, premature needle drop, branch dieback, crown thinning, basal resinosis (resin flow), wilt and death of trees. It is not uncommon for root and butt rots to be very advanced, but showing no obvious symptoms.
Possible damaging agents: Fungi: Basidiomycota (Figs. 13.1.1 – 13.1.4), **Chromista**: Oomycota (water moulds:Figs. 13.1.5 – 13.1.6).

Fig. 13.1.1. Fruiting bodies of a root rot fungus (*Armillaria* sp.) at the collar of Norway spruce (*Picea abies*). Skole, Ukraine, VK.

Fig. 13.1.2. Mycelial fans of the root rot fungus *Armillaria ostoyae* at the collar of Scots pine (*Pinus sylvestris*). Sinop province, Black Sea region, AL.

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Fig. 13.1.3. Norway spruce (*Picea abies*) tree broken because of a fungal stem rot (*Heterobasidion annosum*). Birmensdorf, Switzerland, WSL.

Fig. 13.1.4. Fruiting bodies of *Heterobasidion annosum* on Norway spruce (*Picea abies*). Akershus county, Norway, VT.

Fig. 13.1.5. Decline of Nordmann fir (*Abies nordmanniana*) due to root rot caused by an Oomycete (*Phytophthora inundata*). Rogaland county, Norway, VT.

Fig. 13.1.6. Phytophthora root and collar rot caused by *Phytophthora megasperma* on subalpine fir (*Abies lasiocarpa*). Buskerud county, Norway, VT.

Additional information: Root and butt rot fungi are particularly difficult to detect and manage. Most of them occur as pathogens 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 in the roots or penetrate healthy roots directly. In some cases, they kill the cambium at the root collar, whereas in other cases they decay the heartwood of the roots (root rot) or at the stem base (butt rot). Eventually, the rot may expand to the stem of the tree. Symptoms may not become visible until a late stage of the infection (i.e. most of the root system affected). Frequently, trees infected by root and butt rot pathogens are uprooted or broken by, e.g., wind or snow. For pathogen collection and preservation, see Chapter 4.

13.2. Vascular diseases

Description: Pathogens (i.e. fungi, bacteria, nematodes) causing vascular diseases invade the active xylem, causing a failure of the transport of water to the foliage. Consequently, wilting symptoms develop on the leaves. Typically, vascular diseases are characterized by tangential bands or arcs of stain in the sapwood. These are often widest at the root collar and taper away up into the stem and down into the roots. The staining is due to the presence of fungal mycelium in the tracheids and to a discoloration of the tracheid walls. In some cases, the fungus may grow radially through the medullary rays resulting in a pattern of stain that is wedge-shaped in cross section. The needles of affected trees are often smaller than normal. They may turn yellow or brown and either fall prematurely or be retained for a few months. Needle wilting may first appear on one or a few branches but often develops quickly throughout the crown. Resin exudation may occur in the lower part of the trunk.
Possible damaging agents: Fungi: Ascomycota (Figs. 13.2.1 – 13.2.4), **Roundworms**: Nematoda (Fig. 13.2.5 – 13.2.6).

Fig. 13.2.1. Symptoms of wilting caused by a blackstain root fungus (*Ophiostoma wageneri*) on Scots pine (*Pinus sylvestris*). Rava-Ruska, Ukraine, IM.

Fig. 13.2.2. Wood discoloration caused by bluestain fungus *Ophiostoma* sp. on Scots pine (*Pinus sylvestris*). Rava-Ruska, Ukraine, IM..

Fig. 13.2.3. Ponderosa pine (*Pinus ponderosa*) with tangential surface of stained sapwood in lower bole, infected by a black stain root fungus (*Ophiostoma wageneri*). DO.

Fig. 13.2.4. Loblolly pine (*Pinus taeda*) stump with blue stain caused by a bluestain fungus (*Ophiostoma ips*). USA, RFB.

Fig. 13.2.5. Forest of Masson pine (*Pinus massonianna*) with reddening pines due to infestation by the pinewood nematode (*Bursaphelenchus xylophilus*). Zhejiang, China, AR.

Fig. 13.2.6. Symptoms of the pine wood nematode (*Bursaphelenchus xylophilus*) on maritime pine (*Pinus pinaster*). Portugal, WSL.

Additional information: Vascular diseases may occur in patches of dead and/or diseased trees. As vectors (e.g., root-feeding weevils) may be attracted by fresh wounds and stumps, thinning may contribute to initiate disease. For detecting staining, the bark has to be removed and the sapwood inspected. For pathogen collection and preservation, see Chapter 4.

13.3. Feeding and boring signs on bark or into wood

Description: Frass/dust at the base of the tree (Fig. 13.3.1) and/or presence of resin pitches/resin flows on the stem (Fig. 13.3.4). This material comes from holes (both entrance and exit holes of galleries) made by insects living under the bark or in the wood.

Possible damaging agents: Insects: Adults or larvae of different families of Coleoptera beetles: bark and ambrosia beetles (Scolytinae: Figs. 13.3.2 – 13.3.3), weevils (Curculionidae), longhorn beetles (Cerambycidae: Fig. 13.3.1), larvae of horntail sorwood wasps (Hymenoptera: Siricidae), and moths (Lepidoptera, Cossidae, Pyralidae: Fig. 13.3.4, Sesiidae).

Fig. 13.3.1. Stem of Siberian fir (*Abies sibirica*) with dust from galleries of larvae of longhorn beetles (Coleoptera, Cerambycidae: *Monochamus urussovi*). Siberia, Russia, YNB.

Fig. 13.3.2. Stem of Siberian larch (*Larix sibirica*) with dust from an entrance hole of bark beetles (Coleoptera, Curculionidae, Scolytinae: *Ips subelongatus*). Ulanbataar, Mongolia, YNB.

Fig. 13.3.3. Bark of Siberian fir (*Abies sibirica*) with saw dust from the exit holes of bark beetles (Coleoptera, Curculionidae, Scolytinae: *Polygraphus proximus*). Siberia, Russia, YNB.

Fig. 13.3.4. Stem of North-American pine (*Pinus* sp.) with pitch accumulation on the bark resulting from the feeding of pine moths (Lepidoptera, Pyralidae: *Dioryctria zimmermanni*). USA, WC.

Additional information: Try to find the hole from which frass/dust came – it can be at any height but likely not far from the base of the stem. If possible, try to find and sample adult or larvae in the gallery behind the hole; otherwise it will be almost impossible to identify the species. For insect collection and preservation, see Chapter 3.

13.4. Abiotic damage

<u>Description</u>: Large variations in stem, branch and twig damage may occur because of abiotic factors. The most frequent are detailed below.

<u>Possible damaging agents</u>:

Frost (Fig. 13.4.1.): Internal radial shake, frost cracks, growth loss and a general weakening.

- Frost lesions are created by frost-killed cambium. They are rough, callused patches on the main stem. Necrotic bark over time sloughs off to expose the sapwood. Raised lateral woody folds are called frost ribs and they surround older cankers. This type of injury generally occurs on young trees. Subsequent freezing of these lesions generally can cause internal radial shake seen as brownish, resin-soaked rings of disrupted wood.
- Frost cracks are generally seen in older trees. This type of damage is characterized by long, dark vertical cracks in the main stem.
- Late spring frosts are usually more injurious than early fall frosts. Reduced lateral and leader growth or tip dieback are common. Internal radial shake can adversely affect growth rates and wood quality. Frosts lesions or frost cracks act as entry points for decay fungi or can lead to stem breakage.

Snow (Fig. 13.4.2.): 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 (Fig. 13.4.3.): 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 (Fig. 13.4.4.): 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 (Fig. 13.4.5.):

- 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 extended to larger areas. Susceptible trees are often diseased and located along the margin of an 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.

Fire (Fig. 13.4.6.): 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. 13.4.1. Loblolly pine (*Pinus taeda*) stems breakage as a result of frost and winter injury. USA, TT.

Fig. 13.4.2. Top breakage of old Scots pines (*Pinus sylvestris*) due to the snow load on the crown. Olesno, Poland, MN.

Fig. 13.4.3. Scots pine (*Pinus sylvestris*) stems breakage as a result of icing and accumulation of wet snow masses. Katowice, Poland, MN.

Fig. 13.4.4. Scars, bruises and tattered lesions on the upper surface of Norway spruce (*Picea abies*) twigs caused by hail. Slavske, Ukraine, VK.

Fig. 13.4.5. Windthrown Norway spruce (*Picea abies*) trees after the storm Cyryl. Jeleśnia, Poland, MKA.

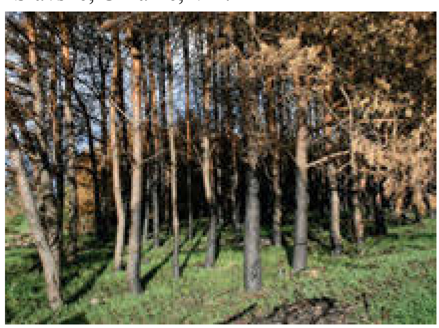

Fig. 13.4.6. Fire damage in Scots pine forest (*Pinus sylvestris*). Brody, Ukraine, VK.

Additional information: Lateral shoots often take over when terminal shoots are frost-damaged. Older seedlings or saplings that have repeatedly experienced frost develop a bushy growth form. Healthy, vigorous seedlings and succulent new needles appear to be more sensitive to summer frost damage. Frost cracks sometimes can be mixed with lightning hits. However, lightning injury leaves a more jagged furrow in the bark and may have an accompanying broken top. A variety of biotic and abiotic agents can cause damage resembling frost damage. For example, repeated frost injury resembles damage caused by animal browsing. Consider climatic conditions and look for signs of animal activities to distinguish between these agents. Heavy snowfall or hail can cause significant mortality in young plantations. Losses occur in patches or as scattered individual trees. Growth is reduced when foliage and buds are removed. In younger trees, deformity results from permanently bent main stems or broken tops due to snow press. Deformity of older trees is caused by top breakage. Hail-related branch or stem scars and top breakage act as entry points for disease. Tree mortality occurs when a tree is toppled. Trees exposed to continuous wind exposure, especially in higher elevations, are vulnerable to winter desiccation damage. Trees that fall because of root rot, break at the root collar and lie in a crisscross pattern in root-disease centres.

13.5. 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.. Resin flow usually occurs on the canker surface and can be particularly pronounced at its margins. Once a canker has girdled the affected tree part, the stem/branch/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, Basidiomycota, mitosporicfungi (Figs. 13.5.1 - 13.5.5).

Fig. 13.5.1. Swollen, resinous cankers caused by the necrotrophic pathogen (*Lachnellula willkommii*) on twigs of larch (*Larix* spp.). Austria, TC.

Fig. 13.5.2. Canker on the stem of pine (*Pinus* spp.) caused by a pine dieback fungus (*Crumenulopsis sororia*). Austria, TC.

Fig. 13.5.3. Resin flow caused by a canker pathogen (*Seiridium cardinale*) on a branch of a cypress tree (*Cupresssus sempervirens*). Italy, WSL.

Fig. 13.5.4. Swollen tissue surrounding a canker caused by *Neonectria fuckeliana* on Norway spruce (*Picea abies*). Akershus county, Norway, VT.

Fig. 13.5.5. Resin flow caused by *Neonectria fuckeliana* and signs of the pathogen (red fruiting bodies) on bark of Norway spruce (*Picea abies*). Akershus county, Norway, VT.

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

13.6. Emergence or exit holes and galleries under bark

Description: Emergence or exit holes are usually visible on the bark. Galleries go under the bark, sometimes into the wood. Often they have hardened resin walls around a hole through the bark into the wood (more often on the bark of stems, less often on twigs or branches). Exit holes may also correspond to insect parasitoids.

Possible damaging agents: Insects: Adults of several families of Coleoptera (Anobiidae, Buprestidae: Fig. 13.6.3, Cerambycidae: Figs. 13.6.3, 13.6.5, Curculionidae: Fig. 13.6.1, Scolytinae: Figs. 13.6.2, 13.6.4, 13.6.5, Lyctidae, etc.), adults of Hymenopteran horntails or wood wasps (Siricidae and Sesiidae).

Fig. 13.6.1. Twig of Yunnan pine (*Pinus yunnanensis*) with emergence holes of adult weevils (Coleoptera, Curculionidae: *Pissodes yunannensis*). Dali, China, AR.

Fig. 13.6.2. Stem of Norway spruce (*Picea abies*) with entrance holes of a bark beetle (Curculionidae, Scolytinae: *Dendroctonus micans*). Trabzon, Turkey, NK.

Fig. 13.6.3. Stem of cypress (*Cupressus sempervirens*) with adult emergence holes of different species of beetles (Coleoptera, Cerambycidae - circular holes; Buprestidae - D-shaped holes). Epidaurus, Greece, AR.

Fig. 13.6.4. Branch of a Norway spruce (*Picea abies*); bark partly removed to expose galleries of a bark beetle (Curculionidae, Scolytinae: *Pityogenes chalcographus*). Korbielów, Poland, MKA.

Fig. 13.6.5. Stem of Siberian fir (*Abies sibirica*) with exit hole of a longhorn beetle (Coleoptera: Cerambycidae: *Monochamus urussovi*). Siberia, Russia, YNB.

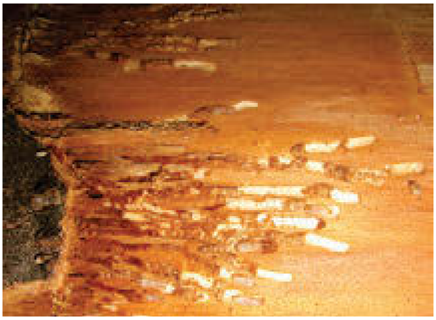

Fig. 13.6.6. Galleries of a bark beetle (Coleoptera, Curculionidae, Scolytinae: *Polygraphus proximus*) under the bark of Siberian fir (*Abies sibirica*). Siberia, Russia, YNB.

Additional information: Try to carefully open the hole and collect adults or larvae in the gallery behind it. Otherwise, it will be almost impossible to identify the species. Note with precision the shape of the hole (e.g., perfectly circular, ovoid, etc.) which can be helpful for identification of the family of the damaging agent. For insect collection and preservation, see Chapter 3.

13.7. Twig boring

Description: Larvae of insects from different orders construct tunnels inside twigs of conifers. Twigs then bend and might dry. Bark of twigs may be eaten by larvae.

Possible damaging agents: Insects: Larvae of moths (Pyralidae, Tortricidae: Figs. 13.7.1, 13.7.2, 13.7.4) and beetles (Curculionidae (weevils: Fig. 13.7.3), Scolytinae (bark beetles)).

Fig. 13.7.1. Twig of ponderosa pine (P*inus ponderosa*) with an opening of a tunnel and a larva of the ponderosa pine tip moth (Lepidoptera: Tortricidae: *Rhyacionia zozana*). California, USA, DO.

Fig. 13.7.2. Twig of a pine (*Pinus* sp.) with an open tunnel of a larva of the European pine shoot moth (Lepidoptera: Tortricidae: *Rhyacionia buoliana*). Poland, MS.

Fig. 13.7.3. Twig of Yunnan pine (*Pinus yunnanensis*) opened to show internal gallery causes by weevils (Coleoptera: Curculionidae: *Pissodes yunannensis*). Note the weevil pupa. Dali, China, AR.

Fig. 13.7.4. Twig of a pine (*Pinus* sp.) with an open tunnel of a larva of the European pine shoot moth (Lepidoptera: Tortricidae: *Rhyacionia buoliana*). Ásotthalom, Hungary, GC.

Additional information: Twigs should be photographed and then carefully opened to allow collection and preservation of the damaging larvae. If you find a viable larva or pupa inside the tunnel, try to rear it to the adult stage and save a moth for proper identification. For insect collection and preservation, see Chapter 3.

13.8. Maturation feeding

Description: Scars on the bark or pieces of bark removed/damaged by gnawing. Might be with or without resin around.

Possible damaging agents: Insects: Adults of Coleoptera (Cerambycidae (longhorn beetles): Fig. 13.8.1) and weevils (Curculionidae: Figs 13.8.2 – 13.8.4).

Fig. 13.8.1. Female of a longhorn beetle (Coleoptera, Cerambycidae: *Monochamus urussovi*) at the moment of maturation feeding on a twig of Siberian fir (*Abies sibirica*). Siberia, Russia, YNB.

Fig. 13.8.2. Seedlings of an unknown conifer species damaged by maturation feeding of a bark beetle (Coleoptera, Cerambycidae: *Hylastes ater*). Chile, WMC.

Fig. 13.8.3. Stem of a young pine (*Pinus* sp.) with signs of maturation feeding of a weevil (Coleoptera: Curculionidae: *Hylobius abietis*). Slovakia, MZ.

Fig. 13.8.4. Twig of Norway spruce (*Picea abies*) with large brown trunk beetle (Coleoptera: Curculionidae: *Hylobius abietis*) and its maturation feeding. Uppsala, Sweden, CH.

Additional information: It is usually impossible to identify an actual damaging agent if it is not collected during the process of maturation feeding. As this kind of feeding usually takes place in spring or early summer, try to start observation early in the season. For insect collection and preservation, see Chapter 3.

13.9. Rust canker

Description: The affected stems, branches or twigs may become swollen and deformed. Resin flow is frequently visible on the canker surface. Abundant production of blister-like fruiting bodies may emerge from cankers and represent the most obvious diagnostic trait. However, these fruiting bodies are produced only at a certain time of the season and may last only for a short period, depending on the weather conditions.
Possible damaging agents: Fungi: Basidiomycota (Pucciniales: Fig. 13.9.1 – 13.9.4).

Fig. 13.9.1. Orange-yellow blisters of a rust fungus (*Cronartium ribicola*) on a branch of Weymouth pine (*Pinus strobus*). Lviv, Ukraine, VK.

Fig. 13.9.2. White pine blister rust fungus (*Cronartium ribicola*) on Weymouth pine (*Pinus strobus*) (aecial stage). Lviv, Ukraine, VK.

Fig. 13.9.3. Singleleaf pinyon (*Pinus monophylla*) with a sporulating stem canker caused by the blister rust pathogen *Cronartium occidentale*. Douglas County, Nevada, USA, BS.

Fig. 13.9.4. Close-up view of fruiting bodies (pycnia) of the fusiform rust fungus (*Cronartium quercuum* f.sp. *fusiforme*) with resin flow. USA, RLA.

Fig. 13.9.5. Necrotic blighted shrivel needles and twisted top of Scots pine (*Pinus sylvestris*) caused by a rust fungus (*Melampsora pinitorqua*). Note: A similar symptom can be caused by shoot moths (see section 13.7). Stradch, Ukraine, VK.

Fig. 13.9.6. Dieback of Eastern white pine (*Pinus strobus*) twigs and deformation due to a rust fungus (*Cronartium ribicola*). Banská Štiavnica, Slovakia, AK.

Additional information: All rust fungi are obligate parasites and most of them are characterized by complex life cycles, generally involving two unrelated host plant species (primary host and alternate host). For pathogen collection and preservation, see Chapter 4.

13.10. Feeding signs or attached scales

Description: More or less visible punctures on the bark left by sucking insects, or sucking insects themselves in cracks of bark or sometimes on the bark and then firmly attached to the bark.

Possible damaging agents: Insects: Hemiptera adults and nymphs (Aphididae: aphids: Figs. 13.10.5 – 13.10.6, Coccidae: scales: Figs. 13.10.1 – 13.10.2 and other families, true bugs (Aradidae: Figs. 13.10.3 – 13.10.4, Coreidae, and other families).

Fig. 13.10.1. Twig of bishop pine (*Pinus muricata*) with adult of the Monterey pine scale attached (Hemiptera, Homoptera, Coccidae: *Physokermes insignicola*). USA, USNCSIP.

Fig. 13.10.2. Twig of fir (*Abies* sp.) with attached adult of a soft scale (Hemiptera, Homoptera, Coccidae: *Physokermes concolor*). USA, USNCSIP.

Fig. 13.10.3. Long-winged female of a flat bug (Hemiptera, Heteroptera: *Aradus cinnamomeus*) in a crack of pine (*Pinus* sp.) bark. Kharkiv, Ukraine, BML.

Fig. 13.10.4. Short-winged female of a flat bug (Hemiptera, Heteroptera: *Aradus cinnamomeus*) in a crack of pine (*Pinus* sp.) bark. Kharkiv, Ukraine, BML.

Fig. 13.10.5. Pine twig (*Pinus* sp.) colonized by aphids (Homoptera, Aphididae: *Cinara strobi*). USA, JB.

Fig. 13.10.6. Stem of a fir (*Abies* sp.) colonized by aphids (Homoptera, Aphididae: *Cinara* sp.). USA, OG.

Additional information: It is usually impossible to identify an actual damaging agent if it is not collected during the process of feeding. Flat bugs usually spend a long time (months or years) at the same regions of the stem (sometimes in the same cracks of bark). Adults of scale insects are firmly attached to the bark. For insect collection and preservation, see Chapter 3.

13.11. Galls

Description: Twigs or branches have swelling or abnormal rounded outgrowth of woody tissues, often with a lot of hardened resin (resin galls). A moth's larva lives inside the gall.
Possible damaging agents: Larvae of Lepidoptera (e.g., Tortricidae: Figs. 13.11.1 – 13.11.3) and Diptera (Cecidomyiidae midges: Fig. 13.11.4).

Fig. 13.11.1. Resin gall of a tortricid moth (Lepidoptera, Tortricidae: *Retinia resinella*) on a branch of pine (*Pinus* sp.). Ásotthalom, Hungary, GC.

Fig. 13.11.2. A tortricid moth (Lepidoptera, Tortricidae: *Retinia resinella*) in the resin gall on pine (*Pinus* sp.). Ásotthalom, Hungary, GC.

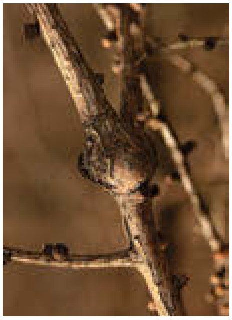

Fig. 13.11.3. Branch of larch (*Larix* sp.) with a gall caused by a tortricid (Lepidoptera, Tortricidae: *Cydia millenniana*). Sopron, Hungary, GC.

Fig. 13.11.4. Stem of white spruce (*Picea glauca*) with galls of the spruce gall midge (Diptera, Cecidomyiidae: *Dasineura piceae*). Minnesota, USA, SK.

Additional information: Galls should be photographed and might then be carefully opened to allow collection and preservation of the damaging larvae. If you find a viable larva or pupa inside the tunnel, try to rear it to the adult stage and save a moth for proper identification. For insect collection and preservation, see Chapter 3.

13.12. Witches' brooms

Description: Witches' broom is a dense cluster of shoots growing from a single point (resembling a broom). These shoots are frequently thicker and shorter than normal ones. Similarly, needles on these shoots may be short and thickened. Consequently, the natural structure of the tree may be changed. The broom may grow for the entire life of the host tree and can reach a considerable size. Cones are usually not formed on witches' brooms.

Possible damaging agents: Fungi: Basidiomycota (Pucciniales), **Hemiparasitic plants** (mistletoe and dwarf mistletoe), **Insects**, **Phytoplasmas**, **Viruses** (Figs. 13.12.1 – 13.12.7).

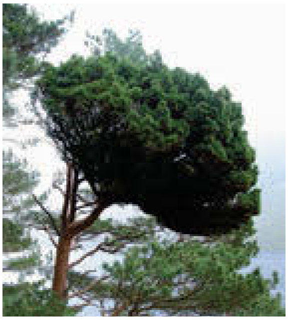

Fig. 13.12.1. Witches' broom on Scots pine (*Pinus sylvestris*). Rogaland county, Norway, VT.

Fig. 13.12.2. Witches' broom caused by the fir broom rust pathogen *Melampsorella caryophyllacearum* on a branch of Silver fir (*Abies alba*). Skole, Ukraine, VK.

Fig. 13.12.3. Blue spruce (*Picea pungens*) with witches' broom caused by the rust fungus *Chrysomyxaarctostaphyli* on the twigs. WMC.

Fig. 13.12.4. Close-up view of telial cushions on foliage of incense cedar (*Calocedrus decurrens*), caused by incense cedar broom rust (*Gymnosporangium libocedri*). USA, DO.

Fig. 13.12.5. Douglas-fir (*Pseudotsuga menziesii*) with witches' brooms caused by Douglas-fir dwarf mistletoe (*Arceuthobium douglasii*). USA, JT.

Fig. 13.12.6. Close-up view of Juniper dwarf mistletoe plant (*Arceuthobium oxycedri*) on Indian juniper (*Juniperus polycarpos*). USA, WMC.

Fig. 13.12.7. Dwarf mistletoe (*Viscum album* subsp. *austriacum*) on a twig of Scots pine (*Pinus sylvestris*). Radechiv, Ukraine, VK.

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

13.13. Mammal and bird damage

Description: In forests trees sometimes have stems, branches or twigs with large signs of mechanical damage (holes, wounds, browsed tips of the branches, etc.) caused by vertebrate animals during their feeding, especially in winter or spring.
Possible damaging agents: Birds (Fig. 13.13.1) and, more often, **mammals** (Figs.13.13.2 – 13.13.6).

Fig. 13.13.1. Stem of Siberian larch (*Larix sibirica*) with holes made by a woodpecker (Aves: Picidae) while it procured resin in spring. Southern Siberia, Russia, YNB.

Fig. 13.13.2. A forest road covered with snow and tips of twigs of Norway spruce (*Picea abies*) cut by squirrel (Mammalia: Sciuridae). St. Petersburg, Russia, AVS.

Fig. 13.13.3. Stem of Norway spruce (*Picea abies*) damaged by wild boar (Mammalia: Suidae: *Sus scrofa*). St. Petersburg, Russia, NVS.

Fig. 13.13.4. A young Scots pine (*Pinus sylvestris*) tree damaged by elk (Mammalia: Cervidae: *Alces alces*). St. Petersburg, Russia, NVS.

Fig. 13.13.5. Stem of Norway spruce (*Picea abies*) damaged by wild boar (Mammalia: Suidae: *Sus scrofa*). St. Petersburg, Russia, NVS.

Fig. 13.13.6. A stem of Norway spruce (*Picea abies*) damaged by elk (Mammalia: Cervidae: *Alces alces*). St. Petersburg, Russia, NVS.

Additional information: Damage signs should be photographed. For species identification, direct observation or consultation with local zoologists or game managers are needed.

14
Damage to buds and shoots of coniferous woody plants

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14.1. Abiotic damage

Description: Abiotic factors can cause a variety of symptoms in shoots and buds. Symptoms commonly observed on shoots and buds include supressed or aberrant growth, discoloration (chlorosis, reddening, browning, blackening, dark lesions), wounds, dieback of shoots and the death of buds. Except for depositions (salt, chemicals) or glaze (ice), signs of abiotic damage are generally absent. Symptoms usually appear in a pattern, occurring over the whole plant (e.g., death of young shoots and buds due to frost injury) or directionally (e.g., on the side facing the source of the adverse conditions or stress). Unlike diseases and pests, damage due to abiotic factors often occurs on different plant species in the same area and does not spread from plant to plant. Dead shoots often drop prematurely, however buds frequently remain attached to shoots (and thus on the plant) after death.

Possible cause of damage: Temperature extremes such as heat or freezing temperatures during growth season, frost and ice glaze, hail storms, misapplied chemicals (fertilizers, herbicides, pesticides, salts) or adverse soil conditions (nutrient imbalance), air pollutants, desiccation due to shortage of water or winter drying (Figs. 14.1.1 – 14.1.8).

Fig. 14.1.1. Norway spruce (*Picea abies*) shoots showing frost injury. Joensuu, Finland, JW.

Fig. 14.1.2. Shoots of Nordmann fir (*Abies nordmanniana*) damaged after application of a fungicide. Rogaland county, Norway, VT.

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Fig. 14.1.3. Shoot of Scots pine (*Pinus sylvestris*) damaged by application of herbicide. Czech Republic, PK.

Fig. 14.1.4. Silver fir (*Abies alba*) shoot damaged by hail, causing death of the distal parts, scars and bruises. Austria, TC.

Fig. 14.1.5. Pine trees (*Pinus* sp.), bent by snow and ice damage (snow load). USA, MDNR.

Fig. 14.1.6. Douglas-fir (*Pseudotsuga menziesii*) bud break damaged by frost. USA, USDA1.

Fig. 14.1.7. Western white pine (*Pinus monticola*) bud damaged by cold injury (low temperature). USA, JOB.

Fig. 14.1.8. Scots pine (*Pinus sylvestris*) terminal and the youngest shoots with drying injury evident above the previous year's snow cover. USA, SK.

Additional information: Several factors causing abiotic damages can act simultaneously, and they may also co-occur with biotic damage, which complicates diagnosis. Abiotic damage can weaken the plants, making them vulnerable to biotic damaging agents (e.g., fungi or insects). If similar symptoms occur in the entire plant, the damage is more likely to be associated with the root system.

14.2. Shoot blight and dieback

<u>Description</u>: Shoots and/or buds are discoloured, shoots are wilted or crooked, later dead (necrotic, dry). Sometimes visible pustules occur as signs of fungal infections. Occurrence of symptoms is usually scattered in a plant, starting from a few shoots and often from the terminal shoots. Symptoms can include oozing of resin and formation of lesions on shoots.

<u>Possible damaging agents</u>: Fungi: Ascomycota (Figs. 14.2.1, 14.2.4); Basidiomycota (Figs. 14.2.2, 14.2.3).

Fig. 14.2.1. Shoot of Austrian pine (*Pinus nigra*), crooked and wilted by a tip blight (Botryosphaeriales, Botryosphaeriaceae: *Diploidia pinea*, formerly *Sphaeropsis sapinea*). Kansas, USA, WU.

Fig. 14.2.2. Crooked and wilted shoots of Scots pine (*Pinus sylvestris*) due to infection by a pine twisting rust (Pucciniales, Melampsoraceae: *Melampsora pinitorqua*). Värmland, Sweden, JeW.

Fig. 14.2.3. Terminal shoots of Norway spruce (*Picea abies*), crooked by a rust fungus (Pucciniales, Pucciniastraceae: *Thekopsora areolata*); later on, shoots die. Østfold, Norway, VT.

Fig. 14.2.4. Shoot tip dieback on red pine (*Pinus resinosa*), due to a blight (Diaporthales: *Sirococcus conigenus*). USA, JOB.

Fig. 14.2.5. Dead shoot of Norway spruce (*Picea abies*) with fruiting bodies of shoot tip blight (Diaporthales: *Sirococcus conigenus*). Skole, Ukraine, VK.

Fig. 14.2.6. Shoot of Douglas-fir (*Pseudotsuga menziesii*) wilting due to an oomycete blight (Peronosporales, Peronosporaceae: *Phytophthora ramorum*). USA, JOB.

Fig. 14.2.7. Dead terminal shoot of Monterey pine (*Pinus radiata*) with resin necrosis caused by pitch canker (Hypocreales, Nectriaceae: *Fusarium circinatum*). USA, DO.

Fig. 14.2.8. "Flagging" of infected terminal shoot of longleaf pine (*Pinus palustris*) caused by pitch canker (Hypocreales, Nectriaceae: *Fusarium subglutinans*). USA, USDA1.

Additional information: Shoot blight and dieback of shoots and buds generally occur together with symptoms on needles. Note that dieback and wilting of young shoots can also be a symptom of borer tunnelling in the shoots (see next page: 14.3). For pathogen collection and preservation, see Chapter 4.

14.3. Shoot and/or bud borer damage

Description: Either shoots or buds, or both, may be infested. Early symptoms on shoots often include only slight chlorosis and growth reduction, with or without swellings. Buds stop developing and may be deformed or discoloured. Later on, shoots will wilt or become malformed. Signs may also include small holes and expelled frass. Slicing of infested shoots may reveal the tunnelling larvae inside the shoot, or a hollow space where the larvae have left the shoot or bud.

Possible damaging agents: Insects: Larvae of Lepidoptera (Tortricidae: Figs. 14.3.1 – 14.3.5, Yponomeutidae: Fig. 14.3.6), Coleopteran weevils and bark beetles (Curculionidae, Scolytinae: Figs. 14.3.7 – 14.3.8).

Fig. 14.3.1. Bud of an unidentified conifer species showing hole and frass of a budworm larva (Lepidoptera, Tortricidae: *Choristoneura freemani*). USA, DMcC.

Fig. 14.3.2. Bud of scots pine (*Pinus sylvestris*) damaged by a shoot moth (Lepidoptera, Tortricidae: *Rhyacionia buoliana*). MS.

Fig. 14.3.3. Pine (*Pinus* sp.) shoot damaged by pine shoot moth (Lepidoptera, Tortricidae: *Rhyacionia buoliana*). USA, DMcC.

Fig. 14.3.4. Reddish shoots of *Pinus densata*, attacked by an unidentified budmoth larva (Lepidoptera: Tortricidae), next to healthy shoots. Lijiang, China, AR

Fig. 14.3.5. Bud of silver fir (*Abies alba*), attacked by a tortricid moth larva (Lepidoptera, Tortricidae: *Epinotia nigricana*). Briancon, France, AR.

Fig. 14.3.6. Shoot damage on thuja (*Thuja* sp.) caused by mining larvae of an arborvitae leafminer (Lepidoptera, Yponomeutidae: *Argyresthia thuiella*). Hungary, GC.

Fig. 14.3.7. Bud feeding on unknown tree species by adult pitch-eating weevil (Coleoptera, Curculionidae: *Pachylobius picivorus*). USA, WND.

Fig. 14.3.8. Boring damage to pine (*Pinus* sp.) shoot by larger pine shoot beetle (Coleoptera, Curculionidae: *Tomicus piniperda*). USA, StP.

<u>Additional information</u>: Borer damage may lead to stunted, forked leaders and general loss of shape. Open the bud to check larval presence and/or damage. For insect preservation, see Chapter 3.

14.4. Sap-feeder damage

Description: Sap-feeding insects or mites are usually observed in large groups and can be mobile or immobile. Indirect symptoms include reduced growth, deformation of shoots or buds, chlorotic, small spots or other discoloration with (sticky liquid) exudation.

Possible damaging agents: Insects: Adults and nymphs of many Hemipteran families (Adelgidae: Fig. 14.4.6, Aphididae: Figs. 14.4.1 – 14.4.2, Coccidae, Kermesidae: Fig. 14.4.5, Pseudococcidae: Fig. 14.4.3) and Acari (e.g., Tetranychidae: Fig. 14.4.4).

Fig. 14.4.1. Shoots of spruce (*Picea abies*) deformed by adults of shoot aphid (Hemiptera, Aphididae: *Cinara pilicornis*). Italy, AB.

Fig. 14.4.2. Stunted or curled shoots of balsam fir (*Abies balsamea*) due to twig aphids (Hemiptera, Aphididae: *Mindarus abietinus*). USA, EBW.

Fig. 14.4.3. Unidentified conifer bud covered by mealybug adults (Hemiptera, Pseudococcidae: *Dysmicoccus ryani*). USA, USNCSIP.

Fig. 14.4.4. Spruce (*Picea* sp.) buds covered by conspicuous webbing spun by spider mites (Acari, Tetranychidae: *Oligonychus ununguis*). USA, USDA.

Fig. 14.4.5. Shoot of Norway spruce (*Picea abies*) with round, reddish-brown formations covered with a delicate powdery wax due to bud scale (Hemiptera, Kermesidae: *Physokermes piceae*). Skole, Ukraine, VK.

Fig. 14.4.6. Hemlock (*Tsuga* sp.) shoots with white cottony formations due to a woolly adelgid (Hemiptera, Adelgidae: *Adelges tsugae.*), USA, EW.

Fig. 14.4.7. Shoot of Norway spruce (*Picea abies*), covered by a colony of an unidentified aphid (Hemiptera: Aphididae). Austria, TC.

Fig. 14.4.8. Shoot of silver fir (*Abies alba*) with stunted growth and browned needles due to a woolly adelgid (Hemiptera, Adelgidae: *Dreyfusia* sp.). Austria, TC.

Additional information: Honeydew (sugar-rich liquid) can attract other animals (e.g., ants) and support growth of fungi on the surface of the shoots and buds (see next page: 14.5). For insect collection and preservation, see Chapter 3.

14.5. Fungal growth on surface

Description: Dark, reddish/yellowish, whitish, powdery or cottony coverage, elevated spots or other structures on shoots and buds.
Possible damaging agents: Fungi: Ascomycota, Basidiomycota: powdery mildews, rusts, sooty moulds (Figs. 14.5.1 – 14.5.4).

Fig. 14.5.1. Sooty moulds on shoots of Norway spruce (*Picea abies*) in connection with an infestation by a scale (Hemiptera, Coccidae: *Physokermes inopinatus*). Häckeberga, Sweden, JeW.

Fig. 14.5.2. Norway spruce (*Picea abies*) shoot covered by rust fungus (Pucciniales, Coleosporiaceae: *Chrysomyxa woroninii)*. Kolari, Finland, JK.

Fig. 14.5.3. Dead shoot of Norway spruce (*Picea abies*) covered by fungal sclerotia (Helotiales, Sclerotiniaceae: *Botrytis cinerea*). Southeastern Norway, VT.

Fig. 14.5.4. Dead shoot of subalpine fir (*Abies lasiocarpa*) covered by fungal fruiting bodies (Dothideales, Dothioraceae: *Delphinella abietis*). Hedmark county, Norway, VT.

Fig. 14.5.5. New shoot of Scots pine (*Pinus sylvestris*) with yellowish structures (aecia) containing aeciospores of a rust (Pucciniales, Melampsoraceae: *Melampsora populnea*). Czech Republic, PK.

Fig. 14.5.6. Shoot of mountain pine (*Pinus uncinata*) showing a thick mat of grey to dark brown mycelium of felt blight (Pleosporales, Melanommataceae: *Herpotrichia* sp.) after coverage by snow. Névache, France, AR.

<u>Additional information</u>: Rust fungi are obligate parasites and most of them are characterized by complex life cycles generally involving two unrelated host plants (primary host and alternate host). The sooty moulds benefit from either a sugary exudate produced by the plant or fruit, or honeydew if the plant is infested by honeydew-secreting insects or sap suckers. For pathogen collection and preservation, see Chapter 4.

14.6. Shoot galling

Description: Outgrowths (galls) or swelling of shoot or bud tissues, with insect larvae or mites inside. Depending on the causal agent and host species, galls of different size, form (regular or irregular) and colour (e.g., green, reddish, brownish or light-coloured) occur.
Possible damaging agents: Insects: Adults and larvae of Hemiptera (Adelgidae: Figs. 14.6.4 – 14.6.6, Aphididae, Psyllidae), larvae of Diptera (Cecidomyiidae midges: Figs. 14.6.1 – 14.6.3) and Hymenoptera (Eurytomidae); adults and larvae of Acari (Eryophiidae).

Fig. 14.6.1. Shoot of incense-cedar juniper (*Juniperus thurifera*), galled at the tips by midge larvae (Diptera, Cecidomyiidae: *Etsuhoa thuriferana*). Monegros, Spain, AR. Compare galls (green reddish) to young cone (blue).

Fig. 14.6.2. Shoot of bald cypress (*Taxodium distichum*), galled by cypress flower gall midge (Diptera, Cecidomyiidae: *Taxodiomyia cupressi*). Texas, USA, HAP.

Fig. 14.6.3. Galls at the shoot tips of incense-cedar juniper (*Juniperus thurifera*), due to an unidentified midge larvae (Diptera: Cecidomyiidae). Calacuccia, Corsica, France, AR.

Fig. 14.6.4. Norway spruce (*Picea abies*) shoot with "pineapple galls" caused by a gall adelgid (Hemiptera Adelgidae; *Adelges viridis*). Isoluoto, Finland, JW.

Fig. 14.6.5. Dead shoot on Norway spruce (*Picea abies*) with a dried gall caused by an adelgid (Hemiptera, Adelgidae: *Adelges viridis*). Götaland, Sweden, VT.

Fig. 14.6.6. Damaged shoot and needles (left) of Nordmann fir (*Abies nordmanniana*) caused by a woolly adelgid (Hemiptera, Adelgidae: *Dreyfusia nordmannianae*). Götaland, Sweden, VT.

Additional information: Splitting the developing gall allows collection of the developing larvae and/or adults. Galls may also contain parasites or predators. For insect collection and preservation, see Chapter 3.

14.7. Shoot and/or bud external feeding

Description: Shoots or buds are chewed or punctured from the outside by adult insects or, occasionally, by larvae. Damage symptoms can include feeding holes, shoot debarking or external chewing.

Possible damaging agents: **Insects:** Adults of Coleoptera (especially Curculionidae) but many other groups that damage needles may occasionally feed on shoots and buds (e.g., Hymenoptera sawflies and Lepidoptera: Figs. 14.7.1 – 14.7.5).

Fig. 14.7.1. Pine (*Pinus yunnanensis*) shoot with tiny feeding punctures by adult weevils (Coleoptera, Curculionidae: *Pissodes yunannensis*). Dali, China, AR.

Fig. 14.7.2. Pine (*Pinus sylvestris*) shoot externally chewed by adults of large pine weevil (Coleoptera, Curculionidae: *Hylobius abietis*). Javoriv, Ukraine, VK.

Fig. 14.7.3. Terminal and lateral shoots of pine (*Pinus strobus*) wilting (dying) due to an active infestation of white pine weevil (Coleoptera, Curculionidae: *Pissodes strobi*). USA, SK.

Fig. 14.7.4. Pine (*Pinus sylvestris*) shoot showing resin flow due to feeding by adult weevils (Coleoptera, Curculionidae: *Pissodes notatus*). Skole, Ukraine, VK.

Fig. 14.7.5. Twig of slash pine (*Pinus elliottii*) with feeding wounds of adult weevil (Coleoptera, Curculionidae). USA, JRM.

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

14.8. Feeding by mammals or birds

Description: Whole shoots and buds are removed from the tree. Repeated damage often causes formation of multiple stems and bushy appearance of the plants.
Possible damaging agents: Mammals: moose, deer, cattle, sheep, squirrels, rodents, **Birds**: e.g., grouse (Figs. 14.8.1 – 14.8.4).

Fig. 14.8.1. Torn edge cut of a terminal shoot of Scots pine (*Pinus sylvestris*) indicates browsing damage by deer (Artiodactyla, Cervidae). Czech Republic, JL.

Fig. 14.8.2. Clean, slanted cut at terminal shoot of pine (*Pinus* sp.) due to rabbit (Lagomorpha, Leporidae) browsing, USA, DJM.

Fig. 14.8.3. Norway spruce (*Picea abies*) with cervid (Artiodactyla, Cervidae) browsing damage. Czech Republic, JL.

Fig. 14.8.4. Production of multiple stems in subalpine fir (*Abies lasiocarpa*) due to repeated browsing by deer (Artiodactyla, Cervidae). USA, SKH.

Additional information: Deer and sheep often leave ragged ends on shoots and always eat the shoots. Rabbits and hares leave clean diagonal cuts on ends, leaving the shoots lying (often by rabbits, always by hares). Timing of the foraging, and different signs such as faeces, tracks, or even hair or feathers around the damaged tree can be useful when identifying the causal agent. Damage signs should be photographed. For species identification, direct observation or consultation with local zoologists or game managers is needed.

15
Damage to roots and collars of coniferous woody plants

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15.1. Root and butt rot

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

Possible damaging agents: Fungi: Basidiomycota (Russulales: Figs. 15.1.1 – 15.1.4, Polyporales: Figs. 15.1.5 – 15.1.8), Hymenochaetales (Fig. 15.1.9).

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

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

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

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

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

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

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

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

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

Additional information: Root and butt rots are wood-decay diseases mainly caused by Basidiomycota fungi. Entry of these organisms may occur through direct penetration of host roots or through wounds in the lower part (i.e. the butt) of the tree. Eventual tree mortality (resulting from blowdown or girdling of the root collar) depends on several factors such as the age and vigour of the host plant, the organism(s) involved and environmental factors that may affect their interaction.

Trees with root and butt rot typically exhibit crown symptoms. For conifers this might include reduced increment growth, a stress cone crop (numerous and smaller-sized cones), and chlorosis (yellowing) and thinning of foliage. Internally, diseased roots exhibit decay patterns, mycelia or staining in the wood that may extend from a few centimetres to several metres into the butt portion of the tree. Wood decayed by white rot fungi in general turns whitish because of bleaching by oxidation and loss of lignin, but color and texture can vary by the organism involved such that the decay appears stringy, spongy, laminated (separating along annual rings), or mottled, with or without formation of black zone lines. Wood decayed by brown rot fungi appears brown in color, dry, and often crumbly with horizontal and vertical fissures. For root pathogen sampling and preservation, see Chapter 4.

15.2. Root rot

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

15.3. Bark-feeding insect damage

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

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

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

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

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

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

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

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

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

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

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

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

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

15.4. Mammal damage

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

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

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

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

15.5. Root and collar-tunnelling

Description: When cut, tunnels or galleries are visible in the cambial tissue under the bark of the roots and/or collar. Severe damage may lead to wilting and, eventually, death of the tree.
Possible damaging agents: **Insects**: Larvae of Coleoptera (Buprestidae, Cerambycidae: Figs. 15.5.2. – 15.5.3) and Lepidoptera (Hepialidae, Sesiidae: Fig. 15.5.1).

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

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

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

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

15.6. Abiotic damage

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

Possible damaging agents:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

15.7. Root sucking insect damage

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

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

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

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

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

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

15.8. Root knot

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

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

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

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

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

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

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

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

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

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

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

15.9. Damage caused by migratory ecto-endoparasitic nematodes

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

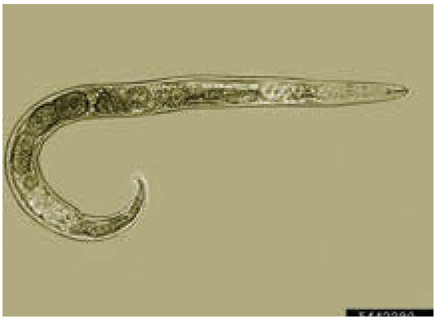

Fig. 15.9.1. Light micrograph of a pin nematode (Nematoda, Tylenchulidae: *Paratylenchus* sp.). JDE.

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

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

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

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

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Informing authorities about new pest records on woody plants

R. Eschen

The aim of sentinel plantings is the detection of new, or unknown pest-host associations before these pests arrive in a new area, but the monitoring of sentinel plantings may also reveal attack of exotic plant species by native organisms. Previous studies in sentinel plantings indicate that it may be possible to find pests on previously unknown hosts with relatively little effort, which both highlights the value of this tool and indicates that new harmful organisms may be identified that require the attention of the authorities. The data collected may therefore be of interest to the National Plant Protection Organization (NPPO) and it is recommended to inform them of any interesting or suspicious findings.

NPPOs work to protect plants, forest ecosystems and plant-based livelihoods of a country and to facilitate safe international trade with plants and plant products. To do this, they operate a country's phytosanitary legislation, regulations and procedures, which includes inspection of forests and nurseries, inspection of imported plants and plant products in points of entry and implementation or coordination of measures when pest outbreaks are detected. NPPOs are often part of the Ministry of Agriculture or the Ministry of the Environment.

If regulated pests are found, the NPPO must be informed as soon as possible. This is important, because it helps in managing such damaging organisms and in protecting the natural resources of the country from further damage. Moreover, the presence of previously undocumented regulated organisms has implications for international trade and informing the NPPO can enable them to adequately manage risk. Early detection of potential phytosanitary problems is essential for this.

In some countries, it is obligatory to notify the NPPO of any new records of alien species, or of harmful species that are not commonly found in that country (i.e. it is written in the law). Hence, data about new pest records, including new pest-host relationships, or especially findings of regulated quarantine pests must be transmitted to the NPPO. In case of doubts, it is advisable to contact your NPPO. They may in certain cases be able to assist with the identification of the organisms that are found.

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17
Glossary

I. Papazova-Anakieva

The following glossary was compiled to help the reader of this field guide understand some of the more technical vocabulary related to the identification of causal agents of damage. Rather than reinvent definitions, we decided to use existing definitions from published sources where possible. Numbers in superscript indicate the source of each definition.

Abiotic damage Damage to plants caused by non-living agents such as heat, frost, or fertilizers.[2]

Acaricide Pesticide used to control mites.[3]

Adelgid Sap-sucking insect in the family Adelgidae (Order Hemiptera). All species feed on conifers and most produce waxy wool.[3]

Aeciospore One of the several different kinds of spores produced asexually by a rust fungus.[3]

Aecium (plural aecia) Specialized reproductive structure found in some rusts and smuts which produces aeciospores.[3]

Alate Winged form of an insect; a term used most frequently with regard to aphids. Also see apterous.[3]

Anamorph The asexual fruiting form of a fungus. See teleomorph.[3]

Anthracnose A disease characterized by small, limited, black lesions.[3]

Apterous Wingless form of an insect. Also see alate.[3]

Arthropod A creature in the Arthropoda (‘with jointed legs’), which includes the insects and mites.[3]

Ascospore Sexually produced spore of a fungus in the taxonomic Division Ascomycotina, which includes most of the microfungi which cause tree diseases.[3]

Asexual spore A spore produced by mitosis; in contrast to a sexual spore produced by meiosis.[2]

Axial In the direction of the axis or pith; longitudinal.[3]

Basidiospore Sexually produced spore of a fungus in the taxonomic Division Basidiomycotina, which includes the gill fungi, the rusts and most of the bracket fungi.[3]

Blight Common name for a number of different diseases on plants, especially when plant tissue injury occurs suddenly; for example, needle blight, blossom blight, and shoot blight.[2]

Bracket fungus A fungus whose fruit bodies resemble brackets, shelves or hoofs, e.g. *Piptoporus, Coriolus, Fomes.*[3]

Cambium In woody plants, the thin layer of cells between the xylem and phloem that gives rise to new cells.[2]

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Canker A killed area on the stem or branch of a plant, usually shrunken and oval or circular in shape.[2]

Causal organism The pathogen that causes a given disease.[2]

Cecidomyid Two-winged fly in the family Cecidomyiidae (Order Diptera); many species in this group are gall midges.[3]

Chlamydospores Thick-walled fungus spores produced asexually. Often important for survival of the fungus during unfavourable conditions.[2]

Chlorosis Abnormal yellow or yellow-green coloration of normally green foliage.[3]

Coccid Soft or waxy scale insect in the family Coccidae (Order Hemiptera).[3]

Conidia Asexual reproductive spores of fungi, often produced in great numbers. Also called conidiospores. cf. basidiospore, ascospore.[2]

Control (of a pest) Suppression, containment or eradication of a pest population.[1]

Cotyledons The seed leaves of a plant. In conifers, the cotyledons are first to emerge and carry the seed out of the soil.[2]

Cortex Tissues of a young seedling stem or root lying between the vascular tissues and the epidermis.[2]

Cuticle Waxy layer on the outside of a leaf.[2]

Cynipid Gall wasp in the Family Cynipidae (Order Hymenoptera).[3]

Diapause Period of suspended development whereby an insect can remain in the same stage for longer than normal.[3]

Dieback Often loosely used to mean 'death'. Here used to mean the progressive death of a tree or branch from its extremities towards the roots.[3]

Ectoparasite A parasite that feeds from outside the plant.[2]

Endophytic fungus A fungus which can survive inactive and harmless inside a plant. Such fungi may cause disease if conditions suitable for their active growth arise.[3]

Epidermis The layer of cells just beneath the cuticle on a stem or leaf.[2]

Eriophyid Mites in the Superfamily Eriophyoidea (Subclass Acari). Includes rust, blister and gall mites. The last are mainly in the family Eriophyoidea, have a sausage-shaped body about 0.1-0.2 mm long and four legs at the anterior (front) end.[3]

Fertilizer burn Chlorosis or necrosis of seedling tissue resulting from excessive or misapplied fertilizer.[2]

Fibrous root system A desirable root form that contains a mass of fine roots.[2]

Frass Bore dust, excrement and other debris left by bark beetles and other feeding insects.[3]

Fungicide chemical used to kill or inhibit fungi.[2]

Gall Abnormal plant growth.[3]

Germ tubes The hyphae that first emerge from spores.[2]

Gill fungus A fungus whose fruit bodies are toadstools like the edible mushroom, with gills beneath the caps.[3]

Hibernaculum Chamber made from "silken" web in which insect larvae hibernate.[2]

Holdfast Specialized fungus cell that attaches to the surface of the host.[2]

Honeydew Sugary solution excreted by sap-sucking insects.[3]

Host The plant that is attacked, infected, or otherwise damaged by a pest.[2]

Host pest list A list of pests that infest a plant species, globally or in an area.[1]

Host range Species capable, under natural conditions, of sustaining a specific pest or other organism.[1]

Hypha(-e) A single vegetative filament of a fungus.[2]

Hypocotyl The portion of a seedling between the cotyledons and the root.[2]

Imperfect stage See teleomorph.[2]

Incidence (**of a pest**) Proportion or number of units in which a pest is present in a sample, consignment, field or other defined population.[1]

Incipient decay Wood infected (and often stained) by a wood rotting fungus but not yet evidently decayed.[3]

Incursion An isolated population of a pest recently detected in an area, not known to be established, but expected to survive for the immediate future.[1]

Inoculation The transfer of a pathogen onto a host.[2]

Inoculum That part of a pathogen that causes initial infection of a host; a spore, for example.[2]

Insecticide A chemical used to kill or inhibit insects.[2]

Instar The stage of development that occurs between moults of the larvae of an insect.[2]

International Standard for Phytosanitary Measures (IPPC) An international standard adopted by the Conference of FAO, the Interim Commission on phytosanitary measures or the Commission on phytosanitary measures, established under the IPPC.[1]

Macroconidia The larger of two kinds of asexual spores produced by fungi such as Fusarium.[2]

Mesophyll cell Chlorophyll-containing cell of the leaf, between the upper and lower leaf surfaces.[3]

Microsclerotium Small, thick-walled, multi-celled resting structure produced by some fungi.[2]

Monitoring An official ongoing process to verify phytosanitary situations.[1]

Multi-septate Having several septations, or cross walls.[2]

Mycelium The collective mass of vegetative filaments, or hyphae, of a fungus.[2]

Mycorrhizae The symbiotic association between plant roots and particular fungi.[2]

Natural enemy An organism which lives at the expense of another organism in its area of origin and which may help to limit the population of that organism. This includes parasitoids, parasites, predators, phytophagous organisms and pathogens.[1]

Necrosis Death of plant tissue, usually characterized by a change in colour to brown or black. (adjective: necrotic).[3]

NPPO National Plant Protection Organization.[1]

Nymph Larva or immature stage of an insect such as a leafhopper, aphid or psyllid which changes into an adult by developing reproductive organs and usually wings, rather than by changing into a pupa from which the adult emerges, as do beetles, butterflies and moths. Their form resembles that of the adult.[3]

Occlusion The overgrowth of a wound with (callus) tissue produced subsequently.[3]

Oospore Sexual spore produced by the water moulds (Oomycetes). Commonly acts as a resting spore when soil conditions are unfavourable for fungus growth.[2]

Outbreak A recently detected pest population, including an incursion, or a sudden significant increase of an established pest population in an area.[1]

Ovipara(-e) Sexually reproducing female of an aphid; the form that lays the eggs which overwinter.[3]

Oviposit To lay eggs.[2]

Parasite An organism which lives on or in a larger organism, feeding upon it.[1]

Parasitoid An insect parasitic only in its immature stages, killing its host in the process of its development, and free living as an adult.[1]

Parenchyma Soft, living plant tissue consisting of simple thin-walled cells with intervening air spaces.[3]

Parthenogenesis Type of reproduction in which unfertilized females produce viable eggs or young. Common among aphids and closely related groups.[3]

Pathogen Micro-organism causing disease.[1]

Pathogenicity The capacity of an organism to cause disease.[2]

Pathovar A variety of a pathogenic species. Often used where the main feature distinguishing it from the species is its host range. (Abbreviated to pv.).[3]

Pathway Any means that allows the entry or spread of a pest.[1]

Perennate (of a canker, lesion or disease). To continue to enlarge or develop year after year.[3]

Perfect stage That portion of the life cycle of a fungus in which sexual fusion and meiosis take place. See teleomorph.[2]

Pest Any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products.[1]

Pest diagnosis the process of detection and identification of a pest.[1]

Pest risk analysis The process of evaluating biological or other scientific and economic evidence to determine whether an organism is a pest, whether it should be regulated, and the strength of any phytosanitary measures to be taken against it.[1]

Pest risk assessment (for quarantine pests) Evaluation of the probability of the introduction and spread of a pest and the magnitude of the associated potential economic consequences.[1]

Pest risk management (for quarantine pests) Evaluation and selection of options to reduce the risk of introduction and spread of a pest.[1]

Pest status (in an area) Presence or absence, at the present time, of a pest in an area, including where appropriate its distribution, as officially determined using expert judgement on the basis of current and historical pest records and other information.[1]

Pesticide Any substance used to kill or inhibit any pest. Includes fungicides, herbicides, fumigants, insecticides, nematicides, rodenticides, desiccants, defoliants, plant growth regulators, and others.[2]

Petiole Stalk that attaches a leaf to the stem.[3]

Phloem Portion of the vascular system of a seedling that is responsible for the downward transportation of sugars from the needles to the roots. Formed just outside the cambium, the phloem is also called the inner bark.[2]

Phylloxerid Sap-sucking insect in the family Phylloxeridae (Order Hemiptera).[3]

Phytosanitary import requirements Specific phytosanitary measures established by an importing country concerning consignments moving into that country.[1]

Phytosanitary procedure Any official method for implementing phytosanitary measures including the performance of inspections, tests, surveillance or treatments in connection with regulated pests.[1]

Phytosanitary regulation Official rule to prevent the introduction and/or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests, including establishment of procedures for phytosanitary certification.[1]

Phytotoxic Poisonous to plants.[3]

Plant quarantine All activities designed to prevent the introduction and/or spread of quarantine pests or to ensure their official control.[1]

Predator A natural enemy that preys and feeds on other animal organisms, more than one of which are killed during its lifetime.[1]

Primary inoculum Inoculum that causes the first infections in the crop; usually inoculum produced by overwintering structures such as chlamydospores or sclerotia.[2]

Propagule A reproductive unit of the pathogen; spores, hyphae, or microsclerotia of fungi, for example.[2]

Proximal The part (of the limb, root, leaf etc.) nearest the point of attachment. Cf. distal.[3]

Psyllid Member of the Family Psyllidae (Order Hemiptera). Many species cause galls or other leaf deformities.[3]

Pupa(-e) Immobile, non-feeding stage of an insect between larva and adult when many internal changes take place (metamorphosis); chrysalis.[3]

Puparium Hard case formed by many flies (Diptera) from the last larval skin and within which the pupa is formed.[3]

Pustule A blister-like fungal structure formed on the host tissue, from which erupts a fruiting body.

Pycnidium (**pycnidia**) An enclosed fruit body containing conidia, of some microfungi.[3]

Quarantine Official confinement of regulated articles for observation and research or for further inspection, testing and/or treatment.[1]

Quarantine pest A pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled.[1]

Quarantine station Official station for holding plants or plant products in quarantine.[1]

Rachis Main axis of a compound leaf, to which the leaflets are attached.[1]

Reference specimen Specimen, from a population of a specific organism, conserved and accessible for the purpose of identification, verification or comparison.[1]

Regional Plant Protection Organization An intergovernmental organization with the functions laid down by Article IX of the IPPC.[1]

Rostrum Visible mouthparts of a sucking insect such as an aphid, leafhopper or scale insect.[3]

Rust fungus A pathogenic fungus in the Order Uredinales, so called from the conspicuous rust-coloured or yellow spore masses it produces.[3]

Rust mite See eriophyid.[3]

Sanitation Removal of infested or infected plants or plant parts from the growing site to prevent spread of the pest to healthy plants.[2]

Saprophyte An organism which subsists on dead plant material. Some prefer the term ‘saprobe’ when referring to fungi and bacteria as these are, strictly speaking, not ‘phyta’ (plants).[3]

Scab (i) A plant disease characterized by roughened, raised, scab-like patches on infected tissues; (ii) a disease not characterized by scabs but caused by fungi closely related to *Venturia inaequalis*, the cause of Apple scab.[3]

Sclerotium Thick-walled, multiple-celled resting structure of a fungus.[2]

Secondary inoculum Inoculum that is produced on the plant as the result of earlier infection.[2]

Sentinel plant Plant maintained outside of its natural ranges, e.g. in a botanic garden, arboretum or in a nursery, used for monitoring presence of, and damage by pests and diseases that, although native to their current location, are non-native and currently not introduced in the host's country of origin.

Siphuncular cone One of a pair of conical structures (cornicles) situated on the dorsal (upper) surface of the abdomen (5th or 6th segment) of an aphid.[3]

Sooty mould Saprophytic fungus growing on Honeydew.[3]

Spider mite Small, active, silk-spinning mite (Order Acariformes, Family Tetranychidae) with either eight legs (adult) or six legs (immature stages). It feeds on the leaf surface by sucking up the contents from cells it has pierced with its mouthparts.[3]

Sporangium A fungus cell that holds asexual reproductive spores, often zoospores.[2]

Spore A single- to many-celled reproductive body in fungi that can develop into a new fungus colony.[2]

Spore tendrils Thread-like masses of spores extruded from the fruit bodies of some micro fungi.[3]

Sporodochium Mound-shaped asexual fruiting body of a fungus.[2]

Spread Expansion of the geographical distribution of a pest within an area.[1]

Stomata Pores in the leaf used for gas exchange in transpiration and photosynthesis.[2]

Straw dust A mulching material made primarily from ground-up grass straw.[2]

Stylet An elongated piercing mouthpart of an insect or nematode.[2]

Substrate Plant tissue on or in which another organism is growing.[3]

Suppression The application of phytosanitary measures in an infested area to reduce pest populations.[1]

Surveillance An official process which collects and records data on pest occurrence or absence by survey, monitoring or other procedures.[1]

Survey An official procedure conducted over a defined period of time to determine the characteristics of a pest population or to determine which species occur in an area.[1]

Symptom The evidence of disease or injury, such as wilting, yellowing, or death of tissues.[2]

Systemic Entering and then acting within the entire organism. Used specially to describe the action of pesticides or diseases within a plant.[2]

Teleomorph The sexual fruiting form of fungus. Many fungi produce spores both by fusion of male and female sex cells (the perfect state) and vegetatively (the imperfect state or states). As each fruiting form or state receives a name according to its morphological and developmental characteristics, one fungus often has two valid names and sometimes more.[3]

Teliospore Spore of a rust fungus which (usually) carries the fungus through the winter and gives rise to infective basidiospores in the spring.[3]

Terminal The uppermost shoot or leader of a seedling.[2]

Test Official examination, other than visual, to determine if pests are present or to identify pests.[1]

Therapy Treatment of an existing disease or disorder. [3]

Tortrix Small moth in the Family Tortricidae (Order Lepidoptera) (adjective tortricid).[3]

Treatment Official procedure for the killing, inactivation or removal of pests, or for rendering pests infertile or for devitalization.[1]

Urediniospore An asexual spore of a rust fungus which germinates usually without an overwintering or resting period. These are therefore sometimes called summer spores.[3]

Vector An organism that carries a pathogen to a plant.[3]

Visual examination The physical examination of plants, plant products, or other regulated articles using the unaided eye, lens, stereoscope or microscope to detect pests or contaminants without testing or processing.[1]

Viviparous Giving birth to live young.[3]

Weevil Beetle with characteristic elbowed antennae usually borne on a snout (Family Curculionidae, Order Coleoptera).[3]

Witches' broom An abnormal proliferation of lateral branches on a stem.[2]

Yeast-like Consisting of an amorphous spore mass which has arisen as the result of the repeated division of single-celled spores.[3]

Zoospore An asexually produced, infective, motile spore of Phytophthora species and related fungi.[3]

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Field Guide for the Identification of Damage on Woody Sentinel Plants

Edited by Alain Roques, Michelle Cleary, Iryna Matsiakh and René Eschen

This book is a heavily-illustrated, internationally applicable, practical guide for the identification of likely causal agents of damage to trees and woody shrubs. It is intended for use in sentinel plantings – a new tool to identify pests in the country of origin, used to inform pest risk analysis and risk mitigation measures – where agents often may not be known and only damage visible.

Field Guide for the Identification of Damage on Woody Sentinel Plants:

- Aids the identification of the type of agent that may have caused observed damage, including pathogens, invertebrates and abiotic factors.
- Explains how to take and preserve samples and how to proceed to obtain a more definitive identification of pests.
- Includes a general damage chapter in addition to specific chapters on damage to leaves, buds and shoots, roots, trunk, and flowers, fruits and seeds.
- Contains 800 full colour, high-quality photographs to aid analysis.

This is an essential guide for plant health professionals, including inspectors for plant protection organizations, foresters and nursery managers, in addition to students of forest entomology and pathology.

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Front cover photos: (top) Walnut catkin internally infested by geometrid moth larvae, Marcillac, France (Alain Roques); (bottom) Survey of sentinel plantings at Fuyang, Zhejiang, China (Fan Jian-ting).