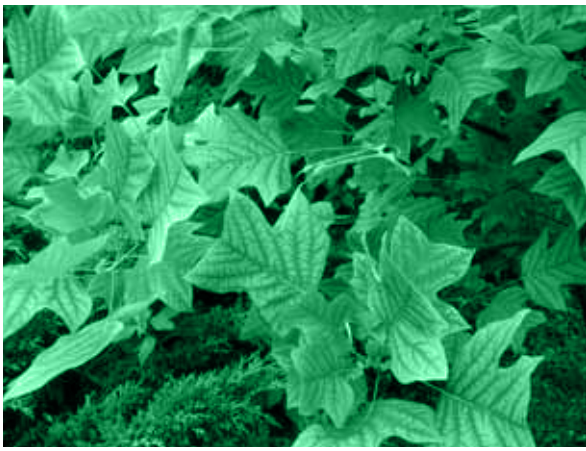
Pests and diseases of urban trees

Biosecurity recommendations

Janusz Mazurek, Katarzyna Nowik



www.drzewa.org.pl

Pests and diseases of urban trees. Biosecurity recommendations.

Fundacja EkoRozwoju, Wroclaw, pp. 40

Authors: Janusz Mazurek, Katarzyna Nowik

Editor: Piotr Łakomy

Editorial cooperation: Kamil Witkoś-Gnach, Piotr Tyszko-Chmielowiec

Consultation: Emilia Bylicka

Translation: Kamil Krzywicki

Editor of the english version: John Parker

Photographs and illustrations: Janusz Mazurek

Graphic design and layout: Bart-Studio, kontakt@bart-studio.pl

ISBN: 978-83-63573-23-2

Drzewa dla Zielonej Infrastruktury Europy

WFOŚiGW POZNAŃ
Wojewódzki Fundusz Ochrony Środowiska i Gospodarki Wodnej w Poznaniu

Life

The publication is a product of the LIFE15GIE / PL / 000959 project entitled „Trees for Europe's Green Infrastructure", co-financed by the European Union LIFE + Program and the Regional Fund for Environmental Protection and Water Management in Poznań.

www.drzewa.org.pl

Contents

The role of environmental conditions for the health of trees in urban habitats

Fig. 1. Wood cankers are often found on trees growing in urban conditions

An urban environment in the broad sense often does not provide trees and shrubs with conditions to enable their proper growth and development. Excessively compacted soils, the accompanying shortage of oxygen in the root system and problems with the availability of rainwater, as well as the insular character of vegetation, lead to special and very specific problems occurring to the health of plants. The opportunities for the development of both the plants and pathogens inhabiting them which occur in urban areas are not found in their natural habitats. Relationships between the plant (tree) and its urban environment are strongly disturbed and result in a situation that allows harmful organisms to develop on their weakened hosts due to unfavourable living conditions in urban areas. A classic example of these relationships is the frequent occurrence of tree cankers, *Nectria cinnabarina*, or the fungus *Sphaeropsis sapinea* causing the dieback of pine tops. In each of these cases one factor which significantly affects both the intensity and the scale of damage is the shortage of water caused by the excessive compaction of the soil, though this is not the only cause.

Soil drought and shortage of organic matter

Regardless of the actual source of the disorders they can be aggravated by the impact of climate change related to temperature increase and periodic drought. Ensuring the right amount of organic matter in the soil, which provides the most reliable natural water buffer, should be more carefully taken into consideration when designing future planting. The structure of vegetation in urban green areas is very diverse. Locally, in a small area, there are enclaves of vegetation with low species diversity while in larger areas, in parks or in suburban forests, natural self-regulating processes are greater and intervention in the form of special care treatments – for example spraying – is less necessary. A good example of this is Massaria, a fungus found recently on plane trees in Poland, whose phytosanitary significance is closely dependent on the tree location. The rapid dieback of branches, a consequence of Massaria, is usually perceived in greater intensity on older trees growing in dry places, in close proximity to street traffic and it may pose more threat in easily accessible places often used by pedestrians.

Massaria is a rather unusual example of a fungus which is not significant in terms of tree health but, depending on location, can pose a risk to human health. In such cases a long-term approach to the protection of trees, perhaps over decades and integrated with other areas of knowledge is required to protect trees against diseases in urban green areas. The methods of combating diseases and pests commonly used in production conditions can solely, and only in a small number of cases, complement these actions. However, it cannot be ruled out that where particularly reasonable, depending on many different factors, undertaking such treatments can often be the only alternative aimed at saving many valuable specimens of trees and shrubs.

The severity of individual tree diseases can depend on the conditions in which the trees grow in different habitats. Usually trees in parks or on large squares will require less pathogen protection treatment than those growing near streets, which are often surrounded by concrete. There is a paradox in this as the increased humidity in parks may contribute towards an increase in the number of diseases causing leaf spots. However, as a consequence they do not have such a high significance for the phytosanitary condition of trees, and often, by accelerating the decomposition of leaves, they affect the mineralisation process associated with the return of nutrients to the circulation and partly also the increase in the content of humus in the soil. Thus, the air-water relations improve. In the literature reviewed, one can find information that as a result of the mineralisation of fallen leaves, up to 30 kg N can be generated on an area of 1 ha. Both adequate water resources

Fig. 2. Dying back branches infected by Massaria may pose a threat to street traffic

and a sufficient self-regulating level of fertilization make the trees better prepared to defend against diseases important for their health. Thus the regular removal of leaves, which has long been considered a basic phytosanitary treatment, can be considered controversial in these situations. Sometimes such treatments will be reasonable, for example when removing leaves due to ash dieback (*Hymenoscyphus fraxineus*), some types of anthracnose, diseases causing spots on leaves or even horse-chestnut leaf miner. However this should be assessed on a case-by-case basis with due consideration of all potential advantages and disadvantages. Whenever one cannot rely on the natural processes of mineralisation and humification, it is worth carrying out correct mulching. To this end it is necessary to use mainly organic material in the form of fermented mulch composed of coniferous bark and sawdust, preferably with wood chips. The primary role of materials used for mulching under trees and shrubs is to collect water and reduce soil compaction while maintaining biodegradability. Sawdust and wood chips, due to the lack of suberin (a substance of strong hydrophobic properties located in the bark) are characterised by greater ability to absorb and store water than bark mulch. In this case it is mainly activities taking into account the improvement of air-water relations, and not aesthetic considerations, that should be the fundamental factor in the selection of the material used for mulching.

For trees growing in cities an additional problem, especially for species with smooth bark, can be the harmful effect of scorching. As a result of strong sunlight exposure, often accompanied by high temperatures, widespread elongated cracks on the bark can appear. Whether and how the trees will react to these cracks in the form of the formation of a wound-healing seal depends on their condition. For trees in a weak phytosanitary condition their defensive response may be inadequate and the wounds can be colonised by various pathogens, in turn leading to the initiation of successive dieback. However, regardless of the consequences of this disadvantageous effect, many researchers point out that the effect of soil drought is a factor with a much higher potential for harm than sunlight exposure or high temperatures.

Effects of tree care treatment and construction works on tree health

Street traffic, pedestrian traffic, some care treatment works or any construction works can lead to unfavourable conditions for tree development. In phytosanitary terms this is all the more important because weakened trees defend themselves poorly against diseases. In addition any mechanical damage creates favourable conditions for fungal spore settlement in fresh wounds. This is the infection method by fungi of the genera *Leucostoma*, *Valsa*, *Phomopsis* or *Botryosphaeria*, leading to the development of wood cankers. Sometimes the first unambiguous signs of their occurrence are evident only after many years of infection. Protection of trees from mechanical damage is one of the basic methods of preventing many

Fig. 3. Symptoms of iron chlorosis

tree diseases in urban conditions. All care treatment work on such trees should be carried out with due attention, while any tools, in particular those used for cutting, should be disinfected. It is also worth carefully considering the date of pruning operations so that they do not correlate with dates when the most numerous fungal spores are dispersed. After pruning, large, flat wounds remain in trees, which increases the likelihood of being colonised by many types of pathogenic fungi. Signs of infection can only be seen after a few years, which makes it difficult to properly diagnose them at the point of infection. The degree of harmfulness of pathogenic organisms infesting the wounds depends often on the condition of the trees being infected. In such a situation an excessive number of large wounds in trees can lead to a disturbance of the relationship between the crown and the root system. This compromises the ability of the tree to defend itself against any pathogens infecting its wounds. In this situation, the correct way of pruning and appropriate decontamination of tools should be considered very important elements of tree disease prevention.

Very often, mechanical damage occurs during the transport of trees from nurseries, which also contributes to the activation of some diffused cankers. Nursery material can also be the basic source for the introduction of specific species of pathogenic fungi into urban vegetation. A classic example of this is the „passing on" of fungi of the genus *Verticillium* along with infected material. The increased activity of wood cankers is often observed on trees originating from avenue trees nurseries, especially when the plants have long been „in shock" associated with replanting. Depending on the quality of young tree maintenance, and in particular on appropriate and well-timed watering, the defensive reactions of freshly-planted trees may be sufficient to inhibit the development of pathogens responsible for both the initiation and development of wood cankers. In the case of improper care the fate of many trees is, however, sealed.

Excessive soil compaction

In urban soils transformed by urbanisation processes the soil structure can deteriorate very quickly and to a large extent. Most often this is caused by excessive compaction of the soil in the area of the largest activity of the root systems of trees and shrubs. It is assumed that strong compaction in the upper layer of soil, close to the surface, is one of the basic elements of the deterioration of the phytosanitary condition of vegetation in urban environment. The consequence of this phenomenon is an oxygen deficiency which directly contributes to the disappearance of mycorrhizal fungi and limits the development of the root system. This causes the root system to begin to lose its functions and means it cannot properly nourish the above-ground parts of the tree. A typical example of such disorders is the occurrence of classic dieback, which are almost always a manifestation of root problems. When planting trees in cities it is therefore necessary to take into account solutions that will at least partially compensate for the limited possibilities of root development in urban soils. The consequences of disorders related to soil compaction affect water absorption capacity and thus also absorption of nutrients.

Nutrient absorption disturbance

Improperly nourished plants have worse defences against many diseases. A classic example of the lack of a sufficient amount of oxygen in the soil is the relatively common phenomenon of iron chlorosis, which can be observed in the youngest leaves in the form of interveinal chlorosis.

Under conditions of oxygen deprivation, iron deficiency is caused by the reduction of Fe to soluble forms that cause its elution. Iron chlorosis may be a contributing factor to the limited development of annual growth rings.

Soil compaction and the associated lack of oxygen can also interrupt the supply of one of the most important nutrients: nitrogen. Research has shown that even with regular fertilizer application the amount of nitrogen in the soil and the plants may not change significantly.

Nitrogen deficiency in plants significantly affects their immunity to diseases. Nitrogen converted into amino acids is the basis for the construction of proteins, including many defensive proteins. One of the most important amino acids associated with immune processes is arginine, which in time can transform into phenylalanine. In turn, phenylalanine, under the influence of plant enzymes, is transformed into tannins, lignin or anthocyanins, which are important links in the defensive response of trees. Nitrogen deficiency, followed by the deficiency of arginine and phenylalanine, causes trees to be more easily infected by pathogens. Sometimes the form of nitrogen is also of significance. One of the methods facilitating the functioning of trees despite being infected by fungi of the *Verticillium* genus is the administration of nitrogen in springtime, primarily in the ammonium form. On the other hand, excess nitrogen is important for increasing the susceptibility of trees to the infection by *Sphaeropsis sapinea*.

As we can see, the issue of tree health in the urban environment is very complex, and commonly used methods of protection diverge in a fundamental way from those found in other branches of horticulture and forestry. Very often, it is impossible to „heal" a tree once it is infected, although sometimes a mere improvement in living conditions allows for its longer life span despite the disease developing. In the vast majority of cases trees are infected because their living conditions differ significantly from the optimum. Protection of trees against diseases should therefore first take into account a programme of maintenance works that minimises the negative impact of adverse environmental conditions. Sometimes this can be relatively straightforward things such as preparing the proper soil structure, ensuring proper irrigation and protecting against damage. Although this is certainly not always possible, the more such factors are properly considered, the better.

We wanted to present herein some of the most significant urban tree diseases and to draw attention to the whole set of factors leading to their occurrence and spread, taking into account the ways in which they can be prevented.

Fig. 4. Symptoms of nitrogen deficiency in the Japanese cherry under conditions of excessive soil compaction

Best practice

Currently, as never before, we are dealing with mass and often poorly controlled trade of plant material between continents, which generates a considerable risk of transmission and spread of tree diseases of major threat to their health. The mass production of plants, with shortened production cycles, also affects the spread of many diseases in asymptomatic form. The proper protection of trees requires the introduction of phytosanitary procedures to both limit the spread of disease and minimised the damage when infection occurs. The scope of such measures should cover prevention from the introduction of pathogens along with newly planted material, to inhibit the spread of diseases through appropriate care treatment procedures, to reduce tree infections by improving their conditions and reducing the proliferation of new diseases of particular risk to tree health. Some of these activities are the responsibility of the Main Inspectorate of Plant Health and Seed Inspection in Poland, although there is still a strong need to develop national biosafety procedures and to extend educational activities to raise awareness about the need to also reduce the spread of tree pathogens in non -forest areas. Thus, the approach to care treatment work should be changed through successful implementation of BEST PRACTICE.

1. Health quality of nursery material

Material intended for planting in an urban environment must be free of diseases and meet the parameters set out in the qualitative recommendations for decorative nursery material.

Detecting the presence of many asymptomatic tree diseases (*Verticillium*, *Fusarium*) is virtually impossible. In these cases, nurseries which sell this material for planting in cities should be subject to regular inspection as to the health quality of the material produced.

Trees intended for planting should be free from any symptoms indicating the presence of infections caused by fungi and bacteria. Particularly alarming symptoms may include:

- extensive vertical bark fractures
- wedge-shaped infiltrations on the bark, especially near branches and twigs removal sites
- local „collapse" in the bark with visible traces of wood discolouration
- extensive cankers on the bark with a wound seal, whether visible or not
- wounds with traces of resin leakage
- visible deep wounds after nursery fastenings that are too tight
- symptoms of rotting of the root system and symptoms of the root collar turning grey, brown or red.

Plants with small canker areas can be planted with the prior removal of the shoots 10 cm below the edges of the wound.

Regarding the uncontrolled shipping of plants from other countries for hobbyist purposes, the option of replanting plants from home gardens to urban green areas must be restricted. There is an urgent need to raise public awareness about the risks posed by such practice as regards the transmission of diseases of major importance to tree health.

2. Transport of material for planting

When transporting nursery material intended for planting in cities, care should be taken to ensure that it is carried out in such a way as to guarantee the absence of any mechanical damage which could constitute a site of infection. The root system must also not be allowed to be excessively dry out during transport.

3. Preparation of the land for planting

Both the land preparation and the planting itself should be carried out in accordance with generally accepted horticultural procedures in such a way as to allow optimum growth and development of the plants. Proper development of the root system and appropriate air-water relations in soil significantly affect the health of trees and shrubs and thereby improve their resistance to diseases. Proper preparation of the soil often requires nutrient replenishment in the form of organic or mineral fertilisation. Therefore, before the trees are planted, it is advisable to perform basic soil testing at a Chemical and Agricultural Research Laboratory, taking into account primarily soil and salinity tests, and tests on the content of micro- and macronutrients, and the granulometric composition. In special cases it is worth extending the scope of these tests to include the content of humus and/or mineral nitrogen. Later, as these trees grow, a chemical analysis of the leaves can also be performed to assess the ability of the tree to extract nutrients from the soil.

To improve the growth of newly planted trees, it is recommended to perform mycorrhization. As the appropriate species of mycorrhizal fungi changes with the age of the tree, a set of mycorrhizal fungi should be adapted to the requirements for the given tree species, typical for the tree in that particular age clas

To improve the growth of newly planted trees, it is recommended to perform mycorrhization. As species of mycorrhizal fungi change with the age of the tree, a set of mycorrhizal fungi should be adapted to the requirements for the given tree species, typical for the tree in that particular age class.

4. Regular inspection of plants for the presence of diseases

Trees in an urban environment should be inspected regularly for the presence of diseases. Where diseases of particular severity are found, such places should be described and assessed in the context of the risks posed by them.

5. Risk assessment

A risk assessment should take into account the degree of risk posed by the disease to human safety, the health of the tree and the rate of spread of the disease. In the risk assessment, the effect of the disease on the health of trees in a human safety context must be the highest priority. A risk assessment diagram is shown in fig. 1.

6. Preparation for care treatment procedures related to low- and high-risk diseases

It should be assumed that those who are professionally involved in urban vegetation matters are at a high risk of disease transmission and therefore should comply with appropriate procedures to reduce the spread of diseases, in line with the previously performed risk assessment. The proper preparation for a specific location is included in Diagram 2.

7. Special requirements for work related to low- and high-risk diseases

The scope of specific operations related to low or high risk is shown in Table 1.

8. Restricting the development of tree diseases through proper maintenance

Proper maintenance helps reduce the consequences, and sometimes also the development. of many pathogens. In this context it is important both to care about the structure and health of tree crowns, and to consider „soil health". These most important elements include:

- correct crown formation according to arboricultural and phytosanitary rules;
- protection of trunks and crowns against mechanical damage;
- protection of tree butt swells from damage;
- pest protection;
- reducing excessive compaction of the soil under the trees;
- caring for the right amount of organic matter;
- protecting biological life in the soil.

9. Direct action

In particularly justified cases, which must be taken into account in a risk assessment, it is possible to use chemical and biological plant protection products to protect the trees from diseases. When choosing the method, it is preferable to use effective biological agents or other „soft" insecticides. The use of chemical agents must comply with applicable laws, and there is a need to properly assess both the benefits and the negative environmental effects, taking into account the specificities of the urban environment.

Table 1.

"LOW" risk work	"HIGH" risk work
– Routine activities, such as inspection of nurseries or green areas, where contact with diseases of major severity is less probable.	Activities where there is a suspicion of a risk of contact with diseases of major severity. This relates to areas already covered by specific supervision, suspected of high-risk disease and activities leading to sampling of soil, plant material and other work at and near infected plants.
Cleaning of personal clothing	
– Routine cleaning of footwear and clothing by removing visible residues of soil and plants.	– Regular cleaning of footwear and clothing by removing visible residues of soil and plants each time when changing locations (e.g. different places in the same park). – Spraying footwear and clothing using disinfectants. Shoes should be soaked in a disinfectant.
Cleaning of machines	
– Machines should be cleaned regularly from residual soil and organic remains. Special attention should be paid to the cleaning of tyres, wheels and wheel bays.	– Avoid vehicles entering areas at risk of transmitting high risk diseases. – Otherwise, try to use available paved roads. – Due to the possibility of transmission of diseases along with soil and organic remains from soil and organic residues, clean machines every time you leave the endangered site. – Disinfect tyres and wheels.
Cleaning tools for maintenance work	
– Limit the number of tools only to those strictly necessary for a particular activity. – All effort should be taken to ensure that equipment used is clean, efficient and free from organic residues.	– Tools must be cleaned and disinfected before each new sample is taken for testing. – Pruning tools must be first thoroughly cleaned and then disinfected. – All tools being used must be cleaned and disinfected before leaving the location. – Each plant and/or soil sample must be kept separatly in a closed container. – In cases with a high risk, ropes used for arboricultural work should be cleaned and dried before the next use.
Special safety rules	
– As a routine, maintain clean pathways free of soil and organic debris.	– In specific cases, consideration should be given to have a warning information sign in a prominent place indicating that after any activity has been completed near the affected trees, any traces of soil must be removed after leaving the location, and organic residues must be removed from shoes, clothes, bicycles and children's bikes on rubber wheels, etc. – All paths located nearby should be kept extremely clean. Asphalt and other paved paths should be kept clean of soil and organic residues. – Unless there are appropriate procedures, it is prohibited to collect plants or cuttings for further propagation, according to the principle that any wood should remain in the given location.

Diagram 1. Risk assessment related to diseases of trees and shrubs.

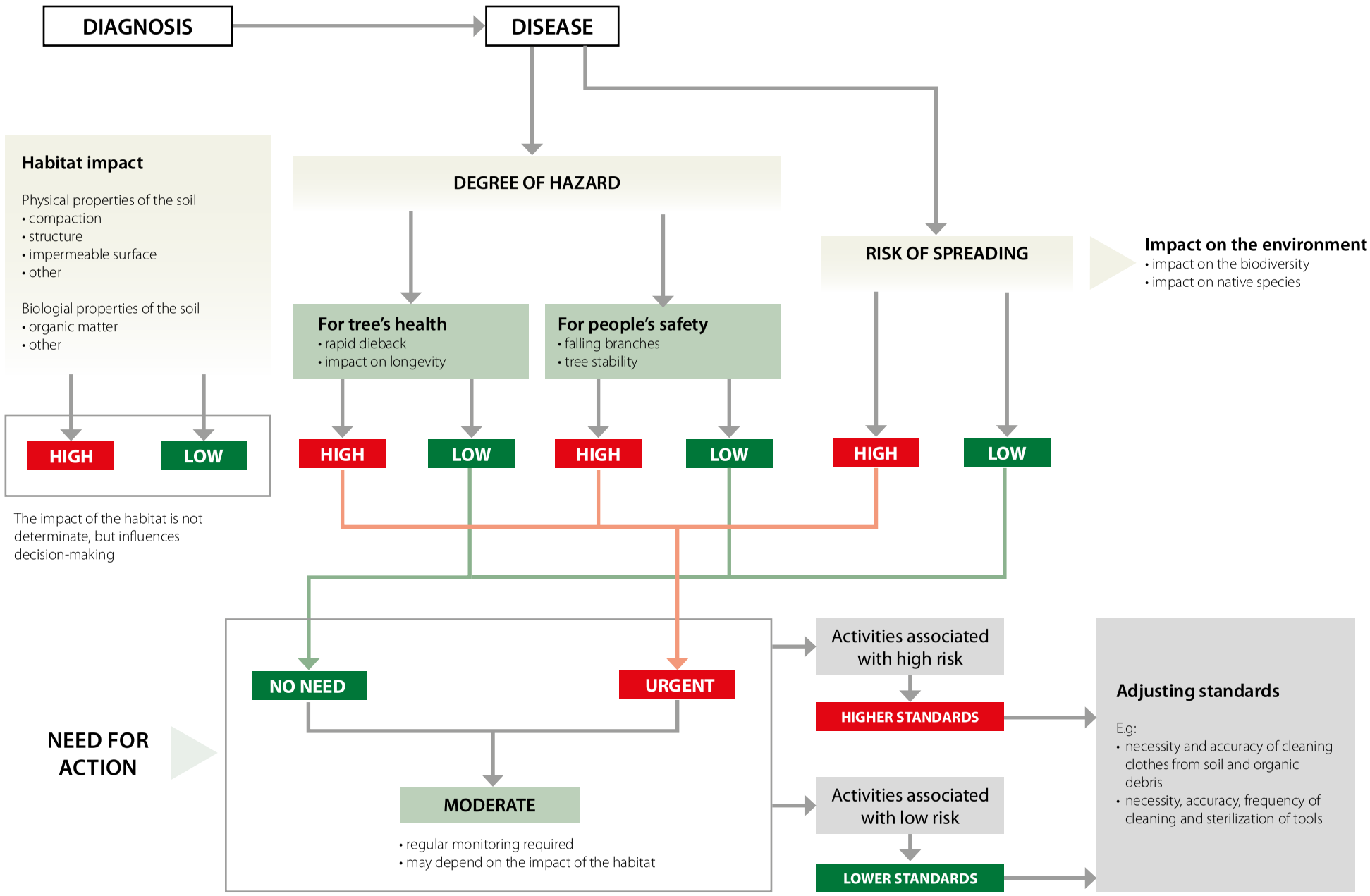
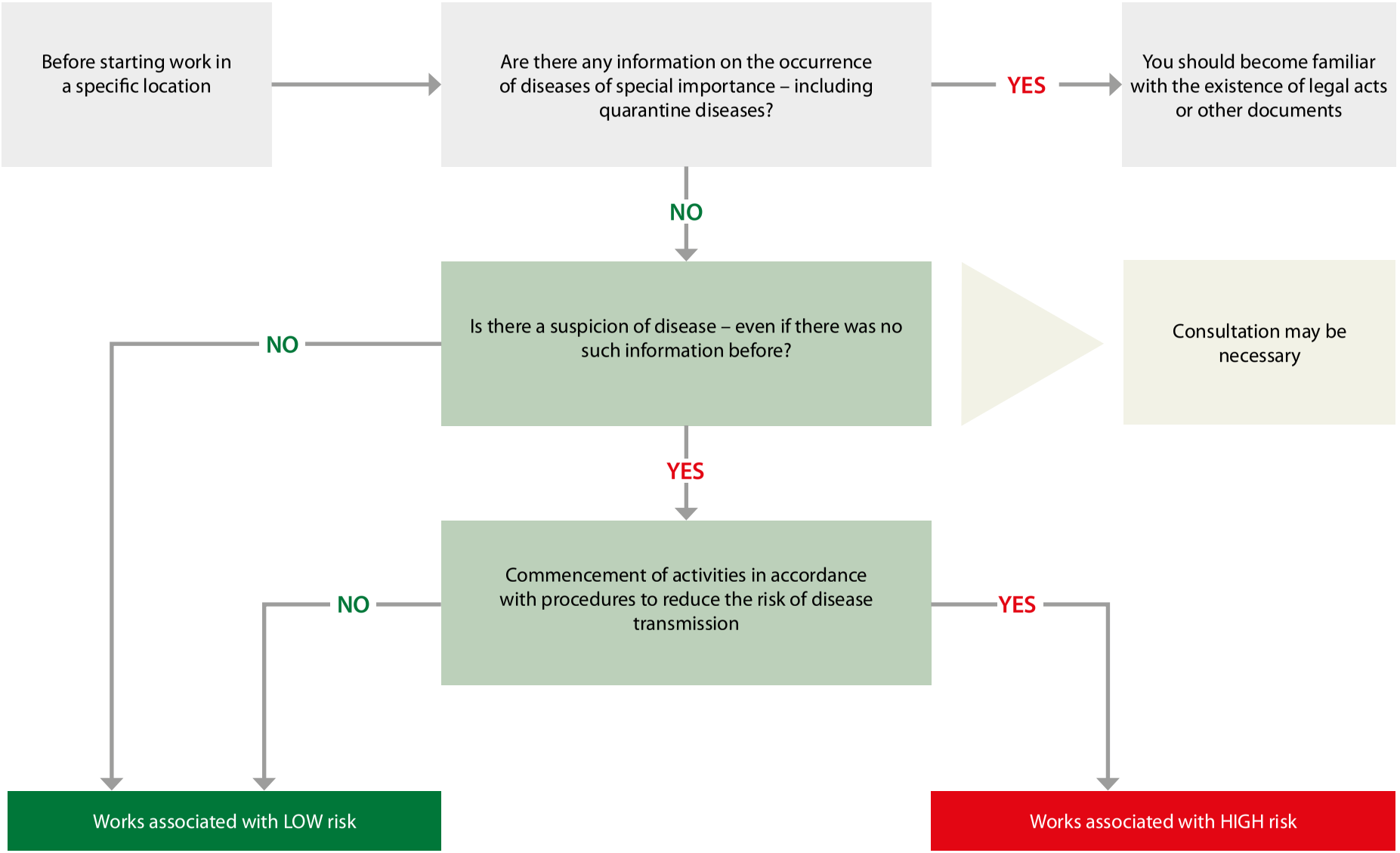


Diagram 2. Scheme of activities required for care work related to low and high risk tree diseases.



Diseases

List of the most important disease symptoms included in this publication

Symptoms	**Diseases accompanying the described symptoms**	**Additional remarks**
Rapid wilting of branches and twigs, often on one side of the crown of trees and shrubs. Possible premature leaf fall	- Verticilium Wilt - Dutch elm disease - fungi of the genus Fusarium	In the cross-section of shoots, more or less visible browning in vascular system, in the form of regular rings, or dashed strokes or dots.
Wounds in the form of concentrically arranged rings. Dark red lumps form within the wounds	- Long-term cancers caused by species of the genus Nectria - Poplar Canker/Poplar Dieback	The fungus causing Colar spot quickly colonizes tissues, hence it is not observed - as in the case of multifarious cancers - concentrically arranged rings.
Withering and wrinkling of leaves. On the bark, which is slightly sunken, dark red lumps are visible.	- Nectaria Cinnabarina	
On the bark visible necrosis (brown, red, orange) within which the tissue collapses and then crumbles. The edges of the necrosis are often wedged- shaped, sharply cut off from healthy tissue.	- Gangrene wounds caused by fungi Leucostoma, Valsa, Cytospora, Phomopsis, Botryosphaeria, - Ash Dieback Chalara - Plane Tree Anthracnose (apiognomnia errabudna)	Within the necrosis, for some types of pathogens, vesicular elevations (blisters) formed by fungi fruiting bodies can be clearly seen
Wedge-shaped cyanosis, tapering sharply towards the core, visible in the cross-section of infected trunks or branches.	- Phomopsis and Botryosphaeria species - Plane Tree Anthracnose (apiognomnia errabudna)	Symptoms are clearly visible primarily in the initial period of infection.
In the middle of summer, a violent withering in the oldest branches of plane trees. The visible cyanosis of the outer parts of the decaying branches. Under the bark of fallen branches are visible dark, small fruiting bodies	- *Massaria disease*	Plane trees growing in the city are characterized by a greater predisposition to the occurrence of the disease, especially in such habitats where they are exposed to strong water stress.
Stains on the leaves that cover the nerves and even petioles	- Tree anthracnose - Ash Dieback Chalara	Anthracnose leads to brittleness in shoots of plane trees.
Small, brown spots on leaves of hawthorn. Strong, premature leaf fall, especially in midland hawthorn.	- Leaf spot caused by the entomosporium mespilli	Fungi is most active in "humid„years
Extensive red spots on chestnut leaves often surrounded with a yellow rim	- Chocolate leaf spot in chestnut trees	Symptoms of the disease may be confused with the appearance of the horse-chestnut leaf minor.
Browning and decaying in the tops of pines	- *Sphaeropsis sapinea* - *Gremmeniella abietyna*	*S. sapine is particularly harmful for double/triple-needled pine species.*

Symptoms	Diseases accompanying the described symptoms	Additional remarks
Needle dropping of in older growths of coniferous trees	- Needle Cast Disease caused by various fungi - Scots Pine Needle Cast - Rhizosphaera kalkhoffii in spruces	Yellowing and descent of needles in older growths is often caused by natural physiological precipitation. These plants regularly exchange the „suit" of needles; hence this phenomenon may be confused with the cast diseases.
A white, powdery coating on the leaves of many species of trees and shrubs	- Various species of powdery mildew	The spores of powdery mildew do not require wetting of the leaves to initiate the infection. They can develop even in „dry" years
Rusty or yellow-orange "cushions" are visible on the surface of the leaves. Strongly infected leaves fall off	- Various species of rust powdery mildew – especially in poplars and willows	Rust of pear and juniper may be indicated with extensive yellows spots on pear tree leaves.
Swollen bark with yellow or orange blisters occurs in pear tree and juniper. Stems and shoots above the infected places dry up.	- Rust of pine bark - Pear and juniper rust	In the case of pear and juniper rust, jelly-like orange creations in the shape of tongues are clearly visible over time.
Rapid yellowing and browning in needles. Under the bark of infected trees, visible fan-dome- shaped patches of white mycelium and dark mycelium cords (rhizomorphs)	- Honey fungi	On the trunks or around the trunks of infected trees can be seen numerous hat-friutbodies of various species of honey fungi.
Cyanosis, browning, rottenness in roots and root collar. Extensive, wet spots on trunks. Tree dying with time.	- Phytophthora diseases of trees - different species	Symptoms of phytophthora occurrence in trees and shrubs are not very specific and difficult to be easily spotted. The correct assessment requires laboratory diagnostics
Characteristic, crosier-shaped bendings in infected shoots. Plants look like burnt with the fire. Wedge-shaped drips in the cross-section of infected shoots. During wet and warm weather sticky white-cream bacterial exudates in infected tissues can be visible.	- Fire blight	The disease infects trees and shrubs from the rosaceae family. In urban conditions, the symptoms are most commonly found in pears, hawthorn, rowans and cotoneaster.
Symptoms are: - Rapid browning and blackening in flowers, - oval, small spots on the leaves in the place where the tissue may break off leaving regular holes, - discolouration and often darkening in nerves and petioles, - decaying in the tops of shoots, - Cancerous state, accompanied with rubber spills	- Bacterial cancer	Symptoms are often correlated with the occurrence of frost, due to bacterium ability to ice crystallization, which leads to bursts in the tissues of sensitive organs. In decorative cherries, the disease may be confused with the symptoms of fungal disease – Brown Rot Blossom Blight (Monilinia laxa)

Vascular diseases

Vascular diseases include those disorders in the functioning of trees which are caused by the excessive growth of fungi and bacteria in vascular bundles, or by the immunological response of the tree to infection, which consequently leads to disturbances in the conduction of water and nutrients in plants and quite often results in dieback of trees and shrubs.

Verticillium wilt in trees

Fungi of the genus *Verticillium* are commonly occurring soil organisms capable of infecting many host plants, including many species of tree. The disease caused by them is referred to as Verticillium wilt. The greatest damage is observed in maple trees, especially *Acer platanoides*, however other trees such as ash, elm, catalpa and many others can be infected. The main species that causes the disease in trees and shrubs is *Verticillium dahliae*.

The symptoms may appear in an acute form, manifested by the sudden wilting of leaves which turn brown and remain on the tree, or in a chronic form. The chronic symptom of the disease is typically seen as the progressive discolouration of leaves starting from their edges; this is particularly difficult to interpret correctly because these symptoms may accompany many physiological disorders. A feature that allows disease diagnosis to a very large extent is the characteristic browning of the inner rings of wood, particularly visible on the cross-section of shoots. The discolouration, depending on the type of plant, may concern one or more layers of wood, vary in colour and occur in the form of a regular ring, or only radially spaced points.

The main sources of infection are microsclerotia, i.e. spore organisms that are able to reside in the soil to a depth of up to 1m, surviving for up to 12-15 years, which reach the ground under trees when they grow on the dying-back and falling

Fig. 5. Dieback of magnolia as a result of an infection by *V. dahliae*

Fig. 7. The infection can sometimes be seen in the form of intermittent dark bands after removal of the bark

Fig. 6. Browning of wood rings is a very characteristic symptom of verticillium wilt

parts of plants. Microsclerotia germinate in response to root excretion products. The hyphae penetrate the bark of young roots and the fungus grows into the vessels; as a consequence there is a comprehensive disruption in the conduction of water and nutrients. As the mycelium of *V. dahliae* has limited ability to develop across vessels produced in subsequent years, its growth in the vascular lumen of the xylem produced annually is usually the result of new root infections made annually by the mycelium from microsclerotia germinating in soil.

A one-year-old infection in trees does not always result in their dieback. In this situation, it is possible to remove the infected soil around the trees to a depth of 20–30 cm and replace it with new soil. Sometimes, for weaker infections, additional springtime watering and fertilisation with fertilizers composed of N: P: K 10:10:10 with nitrogen in the ammonium form may be helpful. However, the most important element in the fight against Verticillium wilt is the health quality of nursery material. Studies clearly showed that the introduction of the *V. dahliae* fungus to nursery material is the basic source of the entry of the pathogen into urban green areas.

Dutch elm disease

Dutch elm disease, caused by two species of fungi: *Ophiostoma ulmi* and *Ophiostoma novo-ulmi*, is one of the best-known serious tree diseases.

A characteristic symptom of the disease is sudden wilting and premature fall of leaves. Very often this wilting of shoots is observed initially on only one side of the tree.

Plants can sometimes completely die back as early as in the first year of infection. Occasionally the chronic course of the disease is seen and then successive thinning of the leaves in the entire crown can be observed. As in the case of Verticillium wilt, the browning of the vessels can be seen on the cross-section, in the form of regular rings, dashes or dots.

On the longitudinal section, dark dashed bands appear under the bark.

The symptoms of the disease may be confused with verticillosis, which also infects elms, and with *Candidatus Phytoplasma ulmi* caused by phytoplasmas. The infection in elms by a phytoplasma leads to rapid yellowing and thinning of the leaves and their characteristic curling along the main vein.

The fungi responsible for causing Dutch elm disease are spread by elm bark beetles *Scotylus scotylus* and *Scotylus multistriatus*. These insects develop under the bark of weakened or felled, but not completely died back trees. The infection occurs in the spring, during supplemental feeding, which takes place on thin twigs, most often in their forks. The spores germinate in a wound made by foraging by elm bark beetles and germinate into a hypha that penetrates the vessels. Soon, the pathogen is systematically transported to distant parts of the crown.

Fig. 8. Wilting and browning of leaves are the first symptoms of Dutch elm disease

Fig. 9. Browning of wood rings visible on the cross-section

Fig. 10. Dark dashed bands visible on the longitudinal section

Fig. 11. Dieback of an elm as a result of infection with yellows caused by phytoplasmas

The fungus spreads, starting from young parts of the tree to the older parts, and goes through the trunks even to the roots. In the case when elms grow close to each other, the infection can occur by root grafts, without the participation of elm bark beetles.

As the mycelium of the pathogen survives for no more than one year in an infected tree, the disease progresses mainly due to annually occurring infections. The penetration of mycelium from last year's ring into the new one occurs less frequently, and is mainly in older trees. Each new infection is, therefore, determined by a sufficient number of elm bark beetles hatching near to (within a radius of 150m) a given tree. Tree protection against Dutch elm disease is aimed primarily at limiting the spread of the disease. The treatment of already infected trees in the form of prompt cutting out infested branches and/or fungicide injections into trunks is possible, but very expensive and does not guarantee their complete cure.

The basic phytosanitary treatments include the removal of any elm wood (until April 15) with the bark intact, which has been damaged as a result of: mechanical damage, wind, snow or

Fot. 12. Zrosty korzeniowe umożliwiają infekcję wiązów rosnących w bliskiej odległości

Fot. 13. Żerowisko ogłodków na zainfekowanym wiązie

Fig. 14. Symptoms of infection in Norway maples with fungi of the genus *Fusarium*

Fig. 15. Sporodochia visible on the bark of infected trees

drought, infection by other diseases, and damage by pests. All elm wood with intact bark – such as stumps, damaged and dying-back branches, trees damaged by drought and wind – constitute perfect conditions for breeding beetles.

All fragments or whole plants should be removed and burned, or at least stripped of the bark. All fragments with a diameter larger than 1.5cm need to be destroyed, and the main sanitary effort should be concentrated on older wood. It is also necessary to conduct regular inspections (once every two years) of trees for the presence of elm bark beetles, the first in June and the second in late July or early August. Infested trees should be removed within 14 days and in exceptional cases this can be done by May of the following year. Any stumps that are to be left on site should be completely stripped of their bark. Limiting root growth may, however, be required if the trees grow less than 15m from each other. To this end, the thinning of weaker trees is to be carried out, or a ditch around the infested tree with a depth of 60 cm should be dug out to prevent any possible root grafts.

In Europe, hybrid varieties of elms with high or at least increased resistance to the disease are also offered, although their suitability for planting in cities is often limited by other requirements. The best-known varieties are: 'New Horizon', 'Regal', 'Sapporo Autumn Gold', 'Independence', 'Accolade', 'Cathedral', 'Frontier', 'Homestead', 'Patriot', 'Pioneer', 'Prospector'. Their production and dissemination are covered by varietal protection. Alternatively, instead of elms, the Japanese elm (*Zelkova serrata*) can be introduced, a species closely related to elms, but with much greater resistance to the disease, which is deemed a „substitute" for endangered elms.

Fusariosis of trees and fusarium cankers

Apart from fungi of the genera *Ophiostoma* and *Verticillium* vascular diseases in trees may also be caused by various species of the genus *Fusarium*. The infection is most often made by *Fusarium oxysporum*. There is a strict specialisation between this fungus species and its hosts, associated with the occurrence of local special varieties. There are cases of infection in staghorn sumac, ailanthus, as well as pine and Douglas fir.

Fungi of the genus *Fusarium* is more often associated with the possibility of causing wood cankers. Some species, such as *F. solani*, or *F. lateritium* commonly occur in the soil, and even on the bark of trees, hence the presence of spores of these fungi is common in the environment.

Spores are easily spread by water, wind and insects. The production of cankers occurs primarily via wounds or other damage. As a result of the infection, collapsed wounds appear over time, and the tissue beneath them turns brown and even black. On the bark of infected trees, characteristic spore clusters (sporodochia) are clearly visible, which are easily identified under a microscope.

In turn, on the cross-section of infected trees, the discolouration of wood takes the shape of the letter T.

The presence of fungi of the genus *Fusarium* does not clearly indicate that they cause disease, as many species are secondary fungi inhabiting tissues that were previously destroyed by other factors. Tests of pathogenic character are always required to confirm the disease.

Wood cankers

Within the broad concept of wood cankers, three basic types should be considered:

Annual cankers – are caused by fungi (also bacteria) that normally do not cause infection, but can inhabit tissues under severe stress. The infection usually takes place during dormancy of trees.

Perennial cankers – they rarely lead to the dieback of trees, but they weaken their structure, which significantly affects appearance.

Diffuse cankers – developing in the absence or weak presence of callus tissue. A quick invasion of the fungus and the decomposition of adjacent tissues occurs. These cankers can cover the entire perimeter of the branch and even tree in one season. **They often lead to the dieback of trees.**

Cankers caused by the genus *Cryptodiaporthe*

Wood cankers caused by fungi of the genus *Cryptodiaporthe* can infect the willow, Cornelian cherry, maple and alder. In particular, the species *Cryptodiaporthe* populea is the cause of dieback of poplar, and is one of the most important poplar diseases. Poplar dieback is common and is particularly acute for trees weakened during replanting, or as a result of frost, drought or, at the other extreme, excessive watering. Its presence is also favoured by inappropriate amounts of nutrients, as well as various types of trunk and root damage. The very high harmfulness of the disease is noted in urban conditions for the black poplar, in particular the ‚Italica' variety, which can be destroyed even at an early age.

The sensitivity of poplars is very diverse. Particularly severe damage occurs primarily among the varieties and species from the *Aigeiros* and *Tamahaca*. The most sensitive are: silver poplar, balsam poplar, black poplar and Chinese poplar. Relatively little damage or even no major damage is noted for species and/or varieties: California poplar, Berlin poplar, Canadian poplar, gray poplar, American poplar and *P. deltoides spp. monilifera*, *P. fremontii*, Maximowicz' poplar. On the other hand, other species from the *Populus* classification are considered resistant.

As a result of infection, wood cankers develop which can be found most often on twigs and smaller branches usually in their forks. Three types of symptoms occur:

- oval patches at the bases of lateral branches;
- spots on main shoots usually at pruning sites or breaking off side shoots;
- patches around buds, new shoots from which, if there are any, would die back.

At the site of infection the bark may look intact, while the tissue under the bark turns brown, grey-brown and even darkens depending on the species of the tree. On young trees, the disease quickly covers the whole perimeter of the trunk and the tree dies. In older trees, periodic formation and destruction of the scar occurs, which leads to the growth of the canker. After some time, the disease may fade at the place of infection, but soon appears in other places, usually at a higher location. Over time the fruiting bodies of the fungus appear in the form of black spheres (pycnidia) on the discoloured parts of the bark. As the pycnidia that form under the bark initially lift the skin, characteristic blisters can be observed on the bark.

Conidia spores produced in pycnidia are responsible for the majority of new infections. They occur in springtime through buds

Fig. 16. Symptoms of poplar dieback (picture not available at the moment)

Fig. 17. Blisters on the bark may indicate the presence of *Cryptodiaporthae* fruiting bodies

and scars on buds, while in autumn – as a result of germination of spores – in leaf scars, lenticels and various wounds. In Europe, it was observed that the epiphytose of the poplar rust pandemic leading to the widespread fall of leaves allowed a massive infection in leaf scars by *C. populea*.

Protection against poplar dieback requires that only healthy and well-developed cuttings should be used for production of material for planting.

Coral spot

Coral spot is caused by the *Nectria cinnabarina* fungus and does not cause typical wood cankers, which is explained by its very rapid ability to overgrow tissues. This organism poses a significant problem, primarily to maple trees although it can infect many different species. As a result of the infection, first the leaves wilt and wrinkle, and then younger and older shoots die back. Dark red lumps appear on the bark, especially during late-autumn and humid winter months.

The bark is slightly collapsed at infection sites. The infection is most often caused by fungal spores, primarily entering the tree through wounds, and the infections can occur even during mild winters. There is also the possibility of infection via soil when the root of a healthy tree contacts infected deciduous wood (old roots, branch fragments). Infection is facilitated by all factors that typically weaken a tree such as: drought (in hydrated shoots the fungus grows 10 times shorter than in dehydrated ones) poor water and air conditions (soil compaction), excessive temperature drops and mechanical damage to the tree including that caused by foraging insects. A very important factor leading to an extensive spread of the disease is maintenance work, including pruning with tools that were not decontaminated. In this way the pathogen easily colonises the next trees that are pruned using the same tools. The basic treatments leading to the reduction of the fungus spreading include:

- cutting and destroying infected parts of the tree;
- avoiding damaging the plants;
- fighting insects;
- protection of fresh wounds;
- spraying the wounds after hail and pruning;
- providing favourable conditions for the development of the tree;
- destroying infected roots, and disinfecting soil if necessary.

Perennial cankers

Perennial canker is a common disease found on many deciduous trees including oaks, maples, ash, alder, apple, poplar, magnolia, willows and rowan. It can be caused by several fungi species such as *Peyronellaea obtusa* (syn. *Nectria ditissima*), *Neonectria ditissima* (syn. *Nectria galligena*) or *Fusarium lateritium* (syn. *Nectria coccinea*). In the latter case, beech trees are particularly susceptible. Within the species *N. ditissima*, it is assumed that there are two more special forms of this fungus: *fraxini* on ash (there is an increased occurrence in recent years) and *mali* on apple.

The first clearly visible symptom of infection is the presence of brown necrosis on the bark, within which the tissue collapses and then crumbles. Over time an open wound is formed, the edges of which swell rapidly and strongly. Sometimes the tissue forming on the edge of the wound allows it to be completely sealed but usually it dies out and crumbles so that the edges of the wounds move further apart. Thus the wound is enlarging and characteristic concentric rings are formed. Leaves located above wounds are usually smaller and chlorotic. On thinner shoots, infected places are locally thicker, opening on one side over time. Within the wounds, small, creamy-white clumps of mycelium and dark red clumps that are the fruiting bodies of the fungus may be observed.

The infection is most often caused through pruning wounds, various types of damage (including leaf scars and lenticels), and the mycelium destroying tissues adjacent to it, mainly by toxins. The fungus is active primarily in the winter, however the reactions of wound sealing prevail in vegetative season.

The development of the disease is facilitated by all factors that reduce the lifespan of trees, such as frost or drought. In order to limit the development of cankers the infected shoots should be removed as soon as possible, preferably during the dormant period of the plants.

Fig. 18. Typical symptoms of infection by Nectria cinnabarina

Fig. 19. Symptoms of perennial canker (temporary lack of a photo)

Cankers caused by the genera *Leucostoma* and *Valsa* (*Cytospora*)

The particularly common fungi that lead to the formation of diffuse cankers include species of the genera *Leucostoma* (which cause the so-called Leucostoma canker) and Valsa. These fungi form characteristic fruiting bodies embedded in the tree tissue in the places affected by the cankers.

However, in the *Cytospora* genus the conidal stage is much more frequently observed. This type produces spherical sporocarps embedded in the tissue, from which the spores emerge in the form of slimy, easily visible, leaks.

Leucostoma canker can occur on many commonly found tree species including apple, birch, ash, oaks, poplar and rowan. The fungi hibernate in tree cankers in the form of mycelium with fruiting bodies. Spores can be produced throughout the year but are predominantly distributed during cold and humid periods at the end of autumn and in early spring. The infection always occurs when the humidity and temperature are suitable for the fungal growth and where there is tissue vulnerable to infection. The probability of infection depends on the long-lasting high humidity and high temperatures, within the range of 10–15°C.

Spores that are transmitted by the wind, insects and non-decontaminated tools most often infect leaf scars, pruning wounds, buds and twigs damaged by frost and areas which have been subjected to insect damage. Infestation may also occur in places where recently-planted trees have suffered wounds caused by nursery bindings or stake and ties which have either been attached too tightly or not removed at the appropriate time (author's observations). This should be taken into account when inspecting the material to be planted. The fungus develops quickly in the bark and phloem and then grows into the wood, which as a result of the toxin influence turns brown, even at a considerable distance from the place of infection.

Increased sensitivity of trees is observed where there is water shortage and after tissue damage has been caused by frost. No completely effective methods of chemical protection against diffuse cankers are currently known. Limiting their development requires, above all, applying the right maintenance methods. Trees should be kept in the best condition and one should avoid pruning during wet weather, especially from mid-August, until the leaves fall. All correct pruning rules should be observed. Strongly infected trees should be removed as soon as possible, and any fragments destroyed by frost should be properly pruned. It is very important to reduce these fungi because infection often occurs in unsealed wounds after incorrectly performed pruning. It is also important to correct the forks, as spores are also often sprouted in cracks.

Fig. 20. Sporocarps of fungi of the genera *Leucostoma* and *Valsa* can be observed after slight bark unveiling

Fig. 21. Slimy red seeding of *Cytospora* spores on a poplar trunk

Fig. 22. Fastenings that are too strong tree may activate some wood cankers

Fig. 23. Typical diffuse cankers on a rowan tree caused by infection with *Cytospora* fungi

The dieback of individual branches on spruce is most often caused by the fungi of the genus Cytospora, sometimes contributing to the loss of the aesthetic value of the infected trees. In Europe, the fungus occurs mainly as a saprophyte on shoots that die back for various reasons; it also leads to the formation of small cankers covered with resin. Within infected shoots, needles may die back and fall from the tree. It is these light-brown, and more often white, resin spills appearing in wounds formed at the base of the shoot which are the most characteristic symptom of the disease. Initially, older shoots are susceptible to infection, hence the disease most often develops on branches in the lower part of the crown. Blue spruces are quite often infected, especially when they grow outside of their natural area of occurrence. In the course of disease control no chemical treatments are carried out on spruces and typical preventive recommendations, aimed primarily at limiting water stress and other stress factors, constitute an important part of all treatments related to improving the health of these trees.

Cankers caused by the genus *Phomopsis*

Numerous species of fungi of the genus *Diaporthae* are associated with the symptoms that accompany leaf blotches, wood cankers and tree dieback. Unambiguous determination of their harmfulness is often difficult, because within the genus some of them are very strong pathogens, while others are saprobionts and inhabit only dying back tree fragments. Some species may also infect trees, but only if these had been damaged or weakened due to the shock of transplantation or subjected to other stress factors such as drought, frost or the presence of other pests and diseases.

On infected tissues, fungi of the genus *Diaporthae* form sexual fruit bodies (perithecia), in the shape of almost circular bottles with an elongated neck; these are an important diagnostic feature. The fungi also produce fruiting bodies that are the result of asexual reproduction, so-called pycnidia, that belong to the genus *Phomopsis*. These are also diagnostically important. The presence of pycnidia can be a very important diagnostic feature because they produce two types of unicellular spores: ellipsoid (alpha spores) and spindle-shaped (beta spores). The spores grow outside the fruiting bodies in the form of characteristic slimy, filamentous spills, which are sometimes visible to the naked eye or may be observed using a regular magnifying glass. During observation under a microscope, the shape of spores makes it possible to distinguish the fungi of the *Phomopsis* genus from those of *Leukostoma* or *Valsa*.

These fungi hibernate in the form of mycelium on decaying bark, and less often on leaves and fruit. Infection occurs as a result of spraying, raindrops and wind; sexual spores produ-

Fig. 24. Dieback of a young plane tree as a result of infection by *Phomopsis obscura*

Fig. 25. Symptoms of infection by *Phomopsis obscura* on the trunk of a plane tree

ced in perithecia and asexual (conidial) in pycnidia. In most cases fresh wounds are infected, including natural ones such as leaf scars. However there are also species that can infect trees due to direct, active, penetration of tissues of leaves and even shoots. Fungi of the genera *Diaporthae* and *Phomopsis* infect many species of both deciduous and coniferous trees. They are found quite often on plane, birch, species of the genus *Prunus*, chestnut, maple, pine, yew and Douglas fir. These pathogens should be controlled in a similar way as wood cankers of the genera *Leucostoma* and *Valsa*.

Cankers caused by the genus *Botryosphaeria*

Fungi of the *Botryosphaeria* genus are an opportunistic species that contribute to the formation of wood cankers that can lead to death of entire trees. They often inhabit twigs and branches that have died back as a consequence of other factors. Particularly strong damage caused by their activity is observed on plants damaged or affected by drought, frost and strong or violent defoliation. The disease is found more frequently on plants grown outside their natural habitat.

Symptoms of the disease may vary significantly depending on the host plant. Nevertheless, the most common are small or elongated spots on the bark. The spots can be elongated without the swelling at the edges typical for many wounds, but they well may be large collapsed tree cankers. Infected twigs tend to die back, but trunks and large-diameter branches are more resistant, limiting the development of fungi to small canker areas, often found in the central part of the branch. The bark stops growing in the damaged area while the surrounding healthy tissue continues to grow. As a consequence, the bark becomes rough, darkens and finally cracks due to the growth of the mycelium.

Sometimes the first sign of the disease is wilting of leaves on one or more branches. In turn, under the bark where shoots are dying back, on the cross-section, one can observe a chestnut-red discolouration, often occurring only on one side of the trunk. This discolouration can also take the shape of a wedge, directed with the sharp end towards the centre of the shoot.

These symptoms are visible primarily in the initial period of infection. After removal of the bark it is also possible to see browning of the wood a few centimetres below and above the canker area. On older plants, shoots often die back above the canker area resulting from a previous infection. In conditions of high humidity, dark fruit bodies (pycnidia) form tissues are infected, which are a good identification feature of these fun-

Fig. 26. Wedge-shaped infiltrations visible on the trunk cross-section are a typical symptom of *Botryosphaeria* spp. (also *Phomopsis* spp.)

gi. In pycnidia, spores are produced that are the most basic, but not the only, source of spreading the disease. Fruit bodies are often seen in crevices formed as a result of bark cracking. The disease can be significantly spread by contaminated pruning tools.

Initially, tree protection requires minimising any stress resulting from water shortage and high temperatures. In the event of a confirmed diagnosis it is also recommended to remove any branches which are dying back and on which the fungus may produce spores to spread the disease.

Massaria Disease of Plane

Massaria, or *Splanchonema platani* = *Massaria platani* (*anamorph. Macrodiplodiopsis desmazieresii*) is a fungus from the group of sac fungi (*Ascomycota*) infesting plane trees, which for some time now has been infamous in Europe due to its role in the process of quick dieback of branches of these trees and the associated increase in risk to public safety.

Splanchonema platani is usually considered a weak pathogen, and typically causes minor damage. It can cause significant damage only in special situations, such as long-term drought. Plane trees growing in urban areas are more vulnerable to the disease, especially in such habitats where they are exposed to high water stress.

Identification of symptoms is not simple and should be done in a purposeful manner, preferably in good light conditions, often using a magnifier. There is no single characteristic that guarantees clear diagnosis of the fungus, and correct identification requires the analysis of several characteristic symptoms. Research already conducted in Europe demonstrates that most of them (95%) are observed on branches with a diameter of <20 cm, and 63% of symptoms on branches with a diameter of <10 cm. Usually, shoots growing in the lower parts of the crown are infected.

First, pinkish, sometimes orange-coloured, stripes, are noticed on the surface of infected branches, or are often located near branches. They are often wider near forks, and tapering, or sometimes banded on a certain section along the branch. Infected tree fragments get darker over time, and fruiting bodies of the fungus can be seen on their surface. Symptoms on the upper part of the branches can be difficult to see from the ground, although the symptoms of infection observed in summertime are characterised by a certain specific pattern. The dieback of shoots begins from their tops and progresses towards the inside. The withering of infected branches clearly contrasts with uninfected branches.

Although Massaria does not pose a great threat to the health of plane trees, it can be important for safety in public spaces. In these situations, appropriate procedures should be implemented to standardise maintenance work and develop appropriate arboricultural practices. Such actions must consider how regular inspections are carried out, as well as risk assessment and prioritisation as to the need to remove infected branches. This requires the development of a „ground level" inspection system that takes into account the observation, recording and mapping the risk-posing trees. In many cases confirmation of the disease is not possible until the affected branches have been removed and observed using a microscope. Since the removal of branches also affects the condition of trees in low-risk circumstances, where Massaria does not pose a significant problem for public traffic, consideration should be given to retaining dying-back branches in the tree, provided they are regularly monitored. However, branches that present unambiguous symptoms and at the same time pose a risk to people should always be removed. The development of such a system must also include monitoring the environmental conditions in which the plane trees grow which might affect the development of the disease and which, to a greater or lesser extent, can be controlled. These include soil compaction, root damage, water availability and biological and physical soil conditions. The disease usually occurs in greater intensity on older trees which grow close to each other, often along avenues, in close proximity to street and pedestrian traffic. These areas should be considered as places of high risk.

Fig. 27. The presence of dark fruit bodies visible on withered branches and microscopic observation of spores is the most reliable method to identify Massaria

Fot. 28. Charakterystyczny obraz przekroju konaru opanowanego przez *Massarię*

Ash dieback disease

Ash dieback disease is caused by the fungus *Hymenoscyphus fraxineus*, whose pathogenity was confirmed for the first time in 1990 in north-western Poland. Symptoms of its occurrence are quite unspecific and often difficult to interpret unambiguously. The most common are wilting, discolouration and local or total necrosis of the leaves and premature defoliation, leading to thinning of the crown. On leaves, necrosis is often located along the veins in the form of brown-black spots. Infected leaves wilt and dry up. Over time extensive necrosis occurs, which covers the entire perimeter of the trunk or branch and leads to the dieback of tissues located above it. During the development of the disease, the dieback of whole branches or their tops is observed, as well as the dieback of the tops of trees. However, these types of symptoms may also be accompanied by many other species of fungi inhabiting ash tissues that are often weakened by various factors.

The infection takes place through the leaves, after which the mycelium permeates through the main vein to the shoots in a way similar to some anthracnoses. Within the trunk it grows upwards and downwards through the sapwood. Strongly infected trees die back. If the fungus is found then it is necessary to remove the fallen leaves on which the cup-shaped fruit bodies form with spores, creating the source of infection in the following year. It is also necessary to remove all trees with extensive visible wounds on the trunks.

The European ash is considered very sensitive to the disease, including the ‚Pendula' variety, narrow-leaved ash and black ash. The particularly vulnerable varieties of European ash are ‚Jaspidea' and ‚Atlas', while ‚Diversiolia' and ‚Wetshof', ‚Glorie' are considered to be medium sensitive. Less susceptibility was demonstrated by the ‚Geeskink' and ‚Altea' varieties. The manna ash and green ash are, on the other hand, species considered to be moderately sensitive, while the American ash and Manchurian ash are not very sensitive.

Dieback of tops in coniferous trees

The dieback of tops in pines is a disease that has been known for a long time, although it has only recently appeared in great intensity. It is caused by the fungus Sphaeropsis sapinea (Fr.) Dyko & B.Sutton, which can infect many species of conifers such as fir, cypress, cedar, larch, spruce, Douglas fir and thuja. However, it is most crucial for pines, especially for two-needle and three-needle species. More damage is caused to plants growing in unfavourable conditions, especially those under water stress and in high temperatures, and those with high levels of soil compaction. The susceptibility of pines increases when species are outside of their natural range. In the case of conifers other than pines the disease is usually activated on trees growing in adverse environmental conditions, especially if there are severely infected pines in the vicinity.

The main symptom of its occurrence is the dieback of shoot tips. The infection usually occurs in spring and summer, resulting in the current year's shoots turning brown. Over time, especially in wet weather conditions, sporocarps of the fungus (pycnidia) can be seen on the dead bark and the base of the needles. The tops of the shoots, together with the apical bud, die back and curve, and the needles that hang down are often glued together with resin.

Spores infect current year's increments most often at wound sites. Cones are also infected, which are then a source of infection in subsequent years. In conditions where water is sufficient, fungus activity is usually limited only to the short section of the tip of the current year's shoots. Fully-formed needles and shoots from previous years are not usually infected, but mycelium may develop on their surface or inside as an asymptomatic form. The pathogen has the ability to penetrate older shoots, but mostly when they are exposed to water stress. In this situation, the mycelium develops onto older branches and shoots, and then, through tracheids, reaches the sapwood and bark. Under natural conditions the disease may disappear along with a change in unfavourable weather conditions, while in urban conditions S. sapinea often leads to the dieback of whole trees.

The basic method of limiting the development of the disease is to provide the right amount of water for the trees. The tops of infected trees can be pruned, mainly to improve their appearance. However, this does not completely rule out the possibility of infection because the fungus is able to infect even by spores produced in sporocarps on cones.

Fig. 29. Necrosis on the trunks of ash trees, caused by infection by *H. fraxineus*

Fot. 30. Przebarwienie drewna widoczne na zainfekowanym pniaku

Fig. 31. Symptoms of infection by *Sphaeropsis sapinea*

Fig. 32. Spores of *S. sapinea* visible on infected shoots

The symptoms caused by *S. sapinea* can be confused with another common fungus, *Gremmeniella abietina*, which leads to the dieback of pine shoots. This pathogen also occurs in the Norway spruce. In the case of this disease, the needles in the top part of pines turn grey-and-green, and sometimes they turn brown and wither. In autumn, fungus sporocarps in the form of dark dots are also visible on the needles that are subject to dieback. Apical buds are covered with resin, and in springtime they either do not produce increments or these increments are shortened. Over time, shoots without needles can be seen on the tops of crowns, which is a characteristic symptom of the disease. The most reliable way to distinguish *S. sapinea* from *G. abietina* is through microscopic observation of spores produced in sporocarps. *G. abietina* usually infects the Scots pine, although it can also occur on firs, spruces, larches, Douglas firs and tsuga. Active biological control with the use of *Pseudomonas fluorescens* is possible.

The dieback of pine shoots can sometimes be caused by the fungus *Cenangium ferruginosum,* which can be distinguished from other species by bowl-shaped sporocarps (apothecia).

The infection of spruce tops, in the middle and upper parts of the crown, can also be caused by the fungus *Sirococcus conigenus*. Blue spruce and Sitka spruce are most susceptable. As a result of infection redness and falling of needles is observed on the young spring increments,. Over time, shoots stripped of needles begin to bend in a characteristic manner.

There are dark spherical sporocarps (pycnidia) of the fungus on the dead needles and shoots. The easiest way to spot them is in places where needles have fallen. Preventive treatments include the removal of infected shoots at a time when the plants are dry, so as not to create conditions allowing the spread of the disease. The infected material cannot be used for mulching.

Fig. 33. Symptoms of blue spruce infection caused by *Sirococcus conigeus*

Leaf and needlecast diseases

Leaf anthracnose and leaf blotches

The term anthracnose should be understood as a group of diseases caused by morphologically similar fungi. In most cases, these are fungi belonging to the genus Apiognomonia such as: *Apiognomonia veneta* – on plane trees, *A. errabunda* – on beech trees, *A. quercina* – on oaks and many more. In Poland, the occurrence of the disease on plane, hornbeam, beech, linden, ash, maple, wild privet and magnolia. The most common symptom of anthracnose is the emergence of brown-to-black spots on the leaves and petioles.

Fig. 34. Typical symptoms of anthracnose on leaves

Fig. 35. Symptoms of plane tree anthracnose

Fig. 36. Symptoms of the *Entomosporium mespili* on the hawthorn

Fot. 37. Symptoms of *Phyllosticta paviae* on horse chestnut

The spots may cover the veins of leaves (in plane trees) and petioles. In some cases the mycelium grows through the veins to the petioles and further to the shoots, leading to the formation of small canker areas.

Strong anthracnose often occurs during a cool and wet spring, when there is a delay in leaf development. The disease is particularly dangerous under such conditions. In an urban environment anthracnose of plane (*Apiognomonia veneta*) is of great importance and is a problem even for older trees. The fungus can penetrate from spots on the leaves, through the veins and petioles to the shoots, which results in their fragility. On other genera of trees anthracnose is important only in special situations and mainly for younger specimens.

Combating anthracnose involves removing and destroying fallen leaves (to reduce the primary infection), and removing and destroying thin twigs which have died back and shoots with canker areas, preferably away from the infected trees. However, this should be done before the fungus develops to such an extent that the infected shoots become fragile and brittle. Sometimes whole infected shoots must be cut out. For anthracnose of plane a method of cutting trees for short shoots has been developed, which consists in removing all the shoots but leaving the main branch at the end of its current-year growth. Cutting performed regularly over subsequent years eliminates the formation of shoots older than one year, which stimulates the growth of leaves directly from the branch and reduces the occurrence of the disease. The London plane varieties ‚Bloodgood', ‚Liberty' and ‚Columbia' are considered anthracnose-resistant. The latter two also demonstrate little sensitivity to powdery mildew (*Erysiphe platani*).

In wet summers in the whole of Poland, and regularly in coastal and mountainous areas, leaf spots caused by the fungus *Entomosporium mespili* may have great importance. The pathogen infects over 60 species of plants from the Rosaceae family including apple, rowan, cotoneaster, pyracantha and quince. The most significant damage is caused to midland hawthorn, leading to premature leaf fall.

Horse chestnut trees are sometimes strongly infected by chocolate leaf patches (*Phyllosticta paviae*). As a result of infection large red spots appear on the leaves, often surrounded by a yellow border. The disease is important primarily for the horse chestnut and red horse chestnut. On the horse chestnut its presence is sometimes confused with the symptoms caused by horse chestnut leaf miner moth foraging and often occurs together with this pest. Just like horse chestnut leaf miner moth it can lead to premature leaf fall.

Needlecast diseases

Needle cast diseases are when coniferous trees have a mass needle fall caused by a complex set of factors, usually of a pathogenic nature. The most common needle cast diseases include spring pine needle cast caused by fungi of the genus *Lophodermium* and autumn pine needle cast caused by Cyclaneusma minus, *Lophodermium pinastri* and *Sydowia polyspora*. Increasingly pine needle cast diseases are also caused by *Micosphaerella pini*. In urban conditions occasionally one can observe the symptoms of Douglas fir needle cast (*Rhabdocline pseudotsugae*). In this situation the symptoms may be particularly spectacular; this is because the current year's growth looks healthy while needles fall from last year's growth and only bare shoots remain.

Yellowing and falling of needles on older growth is not particularly unusual for conifers. These plants regularly exchange their „set" of needles, hence the phenomenon is often confused with needle cast diseases, On the other hand a physiological needle fall, when larger than usual, may also indicate problems related to nutrient deficiency or lack or excess of water. Thujas, junipers and cypresses also cast older twigs in the autumn period.

Needle cast disease symptoms may also be manifested by yellowing needle tips on new growth produced by trees in a given year. Although the symptoms may be visible in the autumn, the first clear symptoms appear in March and April. From this point on the disease rapidly exacerbates, until finally a large proportion of the needles begins to fall before summer.

In the meantime, around April and May, very small black spots appear on yellowed needles growing on the trees, forming fruiting forms of the fungus. However, the formation of new spores capable of infection takes place primarily on fallen needles, which can then be clearly visible in the form of black spots and

Fig. 38. Symptoms of needlecast infection on Douglas fir needles

Fig. 39. Natural physiological yellowing of needles (no picture available at the moment)

Fig. 40. Typical symptoms of *Lophodermium* infection on needles

Fig. 42. Needles falling as a result of infection remain on shoots in the lower parts of the trees

Fig. 41. *R. kalkhoffii* sporocarps visible on the underside of the needles

may or may not be accompanied by dashes running transverse to the length of the needle.

Needle cast diseases can also appear on spruce, of which the fungus Rhizosphaera kalkhoffii, usually found on the blue spruce, becomes more and more important. As a result of infection, tiny, barely visible (0.1mm in diameter) spherical sporocarps, regularly arranged in rows, appear on the lower part of the needles.

Falling needles that remain on the lower part of the tree are the source of infection in the following years. In spring, with the development of new shoots, annual needles are infected, which fall only in the summer and autumn of the next year after 12–15 months of incubation. Initially the symptoms occur in the lower parts of the trees, but higher parts may also be affected in the case of a strong infection.

Increased infections are often a consequence of trees having been weakened as a result of periodically repeated infestations by green spruce aphid (*Elatobium abietinum*). In special situations annual chemical or biological protection of young growth performed twice, when they are 2–3 cm long and again, 3 weeks later, for three years in a row, strongly limits the development of the disease. It is also possible to shake off the needles accumulating in the lower part of the trees as well as to thoroughly remove those fallen on the ground.

In urban conditions, needle cast diseases rarely pose a problem requiring special phytosanitary treatment.

Powdery mildew

Powdery mildew (*Erysiphales*) is one of the common causes of plant diseases. Quite unambiguous symptoms in the form of a white powdery coating on infected plants make identification relatively easy. The impact of the urbanised environment on the growth and development of these fungi is a complex issue. In some powdery mildew species, an increased sensitivity to the accumulation of urban pollution was found, manifested by the shortening of the development cycle and the lower degree of plant infection. On the other hand, plants growing in unfavourable urban conditions are weakened and therefore more susceptible to infection by various pathogens, including by the *Erysiphales* fungi. To initiate infection, the spores of powdery mildew do not need the leaves to be wet, hence their development in „dry" urban conditions is better than for many other types of fungi. It is assumed, however, that their stronger occurrence in such habitats is caused not so much by the favourable conditions for their development, but rather by the weaker condition of trees, which, when struggling with environmental stress, are not able to actively use their immune mechanism. In these situations the creation of optimal development conditions for plants plays a primary role in combating the fungi. The control of powdery mildew by spraying is technically difficult for large trees, although can be possible with the use of more environmentally friendly biological preparations.

In cities, symptoms of powdery mildew caused by two species are particularly visible: *Erysiphe alphitoides* and *Erysiphe hypophylla*, the first of which is observed much more frequently.

The fungus is commonly found on the leaves of the native Polish species of oaks: pedunculate oak and sessile oak. It is observed on trees in all age classes. As a result of strong infections the leaves can wrinkle, darken and even die back. The pathogen is also capable of damaging buds and tissues of apical shoots, causing them to die back. The disease causes a reduction in the growth of young oaks, and even their dieback when it occurs for a whole year. The shoots infested by powdery mildew usually do not gain the so-called winter maturity (they do not develop wood) and suffer from early frosts. Trees are also sometimes subject to secondary infections by fungi that cause gangrene (inclu-

Fig. 43. Symptoms of powdery mildew on oak leaves

Fig. 44. Symptoms of powdery mildew on plane trees

ding *Fusicoccum quercus*, *Phomopsis* spp.), leading to increased damage. Both species are considered urbanophilic and develop perfectly in urban conditions, as well as in gardens and parks located within or near to cities.

In urban conditions in Poland, many new and previously unknown species of powdery mildew have been confirmed recently, such as the horse chestnut powdery mildew (*Erysiphe flexuosa*), catalpa powdery mildew (*Erysiphe catalpae*), plane tree powdery mildew (*Erysiphe platani*) and others.

Rusts

Pine bark rust

Pine bark rust attacks mainly Scots pine but it can also be found on other species of two-needle pines such as mountain pine, maritime pine, Aleppo pine or black pine. Infections can be caused by one of two species of fungi: *Endocronartium pini* or *Cronartium flaccidum*. It is a heteroecious rust, meaning it changes host during its development cycle. In the case of *E. pini*, infection usually occurs without an intermediate host; infection of pines with *C. flaccidium* requires infection of intermediate hosts, which include swallow wort or peonies.

The first clearly-visible symptom of the disease is dieback of the tops or individual branches of the trees. The dying-back fragments are covered by rough changes in bark with wounds through which resin leaks. In the case of *E. pini* the most characteristic symptoms are seen in conjunction with swelling in spring, containing yellow-orange, fading blisters appearing in

Fig. 45. Symptoms of *Cronartium falaccidum* on peonies as an intermediate host

Fig. 46. Symptoms of infection in pine shoots caused by infection by pine bark rust

Fig. 47. Rust symptoms in a willow

the period from May to July. Walls of the blisters burst and yellow powder pours out of them; the mass of the fungal spores. Over time this leads to bark crumbling at the site of infection and can contribute to the formation of cankers on older trees. Above the infection site the tree tissue darkens and then dies back; needles are lost and dry tips appear. The degree of harmfulness depends on where the infection occurred.

Not every infection leads to the dieback of trees. The development of the disease is inhibited when the lateral branches are quickly settled and destroyed by various secondary fungi or die back due to natural causes. If there is no infection on the trunk, it may prove sufficient to remove individual branches. It is recommended to do this in spring, after visible blisters have appeared on the bark (aecia) but before they burst and start spreading spores. Removal of whole trees is, however, sometimes required. When planning tree planting one should avoid putting sensitive species of pine trees together in one place and avoid obtaining all plants from the same source. Pines should be planted in a mix with deciduous species.

Pear and juniper rust (*Gymnosporangium sabinae*) is a very similar species to pine bark rust. It has been spreading across a vast area in Poland for several years. This disease, until recently associated mainly with symptoms appearing on pears, is becoming increasingly important for the juniper. Even if it does not lead to the loss of whole shrubs, it contributes to the strong dieback of shoots. The initial symptoms on the juniper are very reminiscent of those encountered during the formation of aecia of rust pine bark. In this case, the bark also swells in the springtime, and then rusty-orange blisters appear in its cracks. Distinctive, tongue-shaped gelatinous formations appear over time, distributing spores that infect the leaves on pear and rowan trees. The disease on the juniper is not subject to treatment, while the protection of pear trees relies on preventive spraying of the leaves as long as spores are spread from junipers. The first treatments start early, when the pear trees are in the white bud stage.

Gymnosporangium sabinae primarily infects the savin juniper, Virginian juniper, prickly juniper and Phoenician juniper.

Rusts of poplars and willows

The most common fungi that cause rusts of tree leaves are of the *Melampsora genus*. There are over a dozen species and the symptoms they cause are very similar to one another; it is difficult to clearly distinguish between them. These fungi can cause heavy infections in trees, mainly on poplars and willows. Leaf rusts in poplar and willow is of great importance in Europe due to the widespread use of poplars in the construction industry and willows as an energy material. Strong infections lead to premature fall of leaves which contributes to limiting the growth of trees the following year. Consistent perennial defoliation can lead to the weakening of trees that are susceptible to infections by other pathogens. The influence of severe defoliation on an increased amount of sick poplars as a result of infection of leaf scar tissue by canker of poplar bark (*Cryptodiaporthae populea*) has been documented. Weakened trees are also more susceptible to blight of poplars (*Valsa sordida*).

Symptoms of infection are very identifiable. Rusty or yellow -orange cushions appear on the surface of the leaves. Initially few, they occupy more and more large areas of the leaf leading to a strong limitation of assimilation.

These pillows are clusters of so-called uredinospores, by which the fungus spreads during vegetation. On the fallen leaves the pathogen hibernates in the form of so-called telia, which in the spring produces spores (teliospores) which infect intermediate hosts. Depending on the fungi species of the genus *Melampsora*, these can be conifers (like pines or larches), as well as herbaceous plants. On intermediate hosts the fungus produces spermogonia and aecia, and spores produced in the aecia (aeciospores) go on to infest poplar and willow leaves.

The basic method of protection is obtaining and planting resistant maples nearby. This is the only real method of limiting the population of these fungi. The introduction of varieties with different degrees of their sensitivity to rusts may also be of great importance. As the disease is of a comprehensive nature, and the infection can be made by several similar species of the genus *Melampsora*, the resistance of the variety to one of them does not provide a guarantee of resistance to all others.

Diseases caused by fungi infecting from the soil

Phytophthora diseases in trees

Algae-like organisms of the genus *Phytophtora* are among the most economically important plant pathogens. They show very high adaptability and it is supposed that it was mainly mass worldwide shipping of plants that allowed these organisms, coming often from the tropics, to invade so successfully. *Phytophthora* diseases usually cause the dieback of small tree roots at a depth of 10–20cm. They are rarely found in more shallow layers of soil due to the presence of many antagonistic organisms that proliferate during the decomposition of organic matter. This is further evidence of the important role of organic matter in limiting the development of tree diseases. As these organisms are closely dependent on moisture, the presence of water in the form of dew, precipitation and water used for sprinkling irrigation is conducive to their occurrence. Some species of the genus *Phytophtora* has also been found in the water used for irrigating plants, which certainly does not help protect plants against these pathogens. This sometimes may even lead to plant producers installing special sand filters. In Poland, phytophthora diseases come to various tree stands, usually from domestic nurseries, as well as in the form of large trees transported from abroad. They may not show any symptoms at first, but when they are noticed it is usually too late to intervene. The biggest problem in protecting trees against phytophthora is the correct diagnosis, which is even more complicated for trees than other plants. In particular the symptoms of infection in the root system, including the root collar, are very difficult in a simple visual inspection. Traditionally-occurring symptoms – in the form of blue discolorations, browning or rot of underground organs – although easy to notice, do not always guarantee correct interpretation. The symptoms often resemble various physiological disorders which are manifested by such responses as growth arrest, change in leaf colour, wilting and consequent dieback of trees and shrubs.

The basic protection against phytophthora diseases is the introduction of healthy nursery material for planting. It is also recommended to avoid heavy soils with low amounts of air, and to reduce the effect of potential waterlogging of roots. In the case of young trees, in the initial period of infection it is possible to apply systemic fungicides to the soil around the crown, watering with various antagonistic organisms and even injecting the agents (e.g. using phosphites) directly into the trunks. It is also important to keep the right amount of organic matter to as much depth as possible.

Armillaria mellea complex

Within the armillaria mellea complex, several species of the *Armillaria* genus are strongly aggressive primary pathogens, while others infect trees weakened under the influence of various adverse environmental factors. Armillaria also tends to be found more frequently on plants with a shallow root system or those too shallowly planted. The first signal that may indicate infection is rapid growth reduction. In the case of conifers, the yellowing, reddening and sudden fall of needles may occur.

Armillaria fungi are not typical soil pathogens because although they infect plant roots they may survive in the soil solely on lignified material. They can infect over 500 species of plants

Fig. 48. Symptoms of phytophtora diseases in alders in nursery production conditions

and are made by special formations called rhizomorphs, visible to the naked eye in the form of dark mycelial cords.

The fungus spreads from one plant to another mainly through the roots that have contact with each other in the soil. Sometimes long mycelial cords can infest the plants over long distances. If the fungus infects only the roots the damage is usually small, but sometimes the mycelium grows higher and surrounds the entire trunk and contributes to the dieback of trees. The most reliable method to determine the species is the presence of sporocarps, but the symptoms of settlement by the armillaria mellea complex can be noticed earlier by observing, under the bark, white mycelium patches and slightly less frequent dark rhizomorphs of the fungus.

Opportunities for combating the armillaria are very limited and focus mainly on treatments aimed at improving the living conditions of trees. In addition, infected trees should be removed as soon as possible, preferably by grubbing up. Just leaving a stump may not be sufficient. There is an option to settle the stumps with commercially available microorganisms antagonistic to the fungus. For coniferous tree stumps they will be *Phlebiopsis gigantea*; for deciduous trees *Pleurotus ostreatus* and *Hypholoma fasciculare*. Before this, infected trees can be separated from healthy ones by digging a thick PVC plate or a plate of another similar material to a depth of at least 45cm into the ground. When digging up it should be kept in mind that the rhizomorphs are able to grow radially from the infection site, and larger, strong-growing roots located under the barrier can also be a source of infection. It is also worthwhile to dig separation ditches as deep as possible; they will need to be corrected several times a year until the trunk of the infected tree is completely removed. This treatment can be difficult to implement on sandy soils.

Fot. 49. Ryzomorfy opieniek mogą być dobrze widoczne pod korą

Fot. 50. Wachlarzowato-dłoniaste płaty grzybniowe opieńki widoczne pod korą zainfekowanych drzew

Bacterial diseases

Fire blight

Fire blight (*Erwinia amylovora*) is still the most well-known and dangerous disease for trees from the Rosaceae family, which, in addition to the apple tree, is a threat primarily to the hawthorn and rowan. The most characteristic sign of its occurrence is crosier-shaped bending of infected shoots, which also look as if they have been burnt by fire.

The infection usually occurs during blooming, although bacteria can also get into the tissues through various natural openings. The disease spreads from the places of infection along the shoots, which can be seen in cross section in the form of wedge-shaped infiltrations.

This is an important feature, because combating fire blight involves primarily cutting out infected shoots with a certain margin below the visible infection edge, and then spraying the plants. Occasionally, sticky, creamy bacterial exudates appear on infected tissues. Wounds should be protected with emulsion paint with the addition of copper agents or biological agents based on antagonistic bacteria and/or fungi after the removal of shoots. For spraying during the budding period, copper agents are usually used, but their effectiveness is limited to preventive action only. According to the research by Professor Sobiczewski, *Erwinia amylovora* is a necrotroph, which means that the organism can survive on dead plant tissue on leaves and fallen shoots for up to eight months. Infected fragments of plants, when left, may be a source of infection in the spring of the next year; all infected and cut fragments of plants should therefore be thoroughly destroyed.

Bacterial canker

A very well-known bacterial pathogen which can lead to the dieback of the cherry, sour cherry, apricot, peach and, more rarely, apple or pear shoots, is the bacterium *Pseudomonas syringae* pv. *syringae*. Among the known hosts of this species are trees such as silver birch, magnolia (including magnolia grandiflora), *Populus trichocarpa*, black poplar, aspen, willow, linden

Fig. 51. Bending of a tip of rowan shoot as a result of *E. amylovora* infection

Fig. 53. Darkening and dieback of leaves as a result of *Pseudomonas syringae* infection

Fig. 52. An infection of petioles of stranvaesia davidiana, one of the hosts of fire blight

Fig. 54. Cankers on the trunk caused by *P. syringae* infection. The characteristic rubber spills are visible.

and others. The bacterium can also infect Amur maples. P. syringae has the ability to create ice crystallization nuclei on and within the plants which, after frost disrupts and damages tissues of sensitive organs.

The most common symptoms of tree infestation with this species include:

– rapid browning and blackening of flowers;
– necrotic spots on the leaves;
– small, oval spots located where the tissue may break off, leaving regular holes;
– discolouration and often darkening of nerves and petioles;
– dieback of tips of shoots;
– cankers accompanied by rubber leaks.

Protective treatment requires spraying the trees with copper agents at the time of leaf fall and again in springtime, during bud burst. The basic method of treatment is cutting out the infected shoots and, if necessary, removing the whole trees.

In the case of some trees, such as ornamental cherries, the symptoms of bacterial canker may be confused with the symptoms of brown rot of stone fruits (*Monilinia laxa*).

Multifactorial dieback of trees

The progressive process of weakening the life expectancy of trees until their dieback often arises as a result of many years of influence from various biotic and abiotic factors. Sometimes this is caused by the long-term effect of one factor; this may be related to infection by viruses, phytoplasmas, and even some fungi, or damage caused by insects. Most often, however, this process results from the synergistic effect of primary damage caused by water stress, mechanical damage and insect damage, creating suitable places for infection by the many organisms colonising the previously damaged tissues. Unfavourable environmental conditions for the tree such as air pollution, salt stress and excessive soil compaction etc. are also conducive to the colonisation and development of harmful organisms.

In urban conditions this phenomenon has been described in detail for maple trees. It is assumed that the process of progressive deterioration of the condition of these trees in cities is determined by the simultaneous occurrence of many different factors, which include, above all:

– water shortage;
– disturbances in the uptake of nutrients in a shallow soil layer with a low content of organic matter;
– root girdling;
– too little space for the free development of the root system;
– occurrence of excessive number of wood cankers and algae -like organisms of the *Phytophtora* genus;
– excessive compaction of the soil under the trees;
– chronic form of infection caused by *Verticillium dahliae*;
– severe mechanical damage to the trunks;
– damage to the roots during earthworks;
– secondary damage to weakened trees by the following fungi: *Nectria cinnabarina*, *Ganoderma* spp., *Botryosphaeria* spp.

The process of tree weakening is affected not only by local disturbances related to the urban environment but also by global ones such as the droughts experienced in 2015 and 2018. According to Koehler („Zarys hylopatologii", 1981), 1981, the impact of drought on the occurrence of adverse disturbances in the health of trees and shrubs does not disappear with the disappearance of drought. There appears to be a set of long-term reactions which are hard to clearly interpret, and trees may require additional protection at this time.

Multifactorial dieback of trees in forests was described mostly for maple trees but also for elms, firs, spruces, oaks, beeches, birches, ash, poplars and alders.

New threats

Canker stain of plane

Ceratocystis platani, sometimes called the Canker stain of plane, caused by the fungus *Ceratocystis fimbriata f. platani*, is responsible for the dieback of plane trees within three to seven years of infection. In Europe, it is already responsible for removal of almost 100,000 trees. All kinds of plane trees can be infested, of which the London plane is the most sensitive. The oriental plane is also very vulnerable, and the American sycamore is only slightly less vulnerable. This pathogen has been passed on to Europe from North America in infected wood packaging crates.

The presence of the fungus is usually suspected only at the moment of strong yellowing and thinning of foliage of trees and wilting of shoots. In the initial period of infection, symptoms are not very specific and hardly noticeable. The first visible symptom is the presence of elongated, multi-coloured – from red-brown to blue-black expanding spots. Initially, discolouration of the sapwood is found and then also of the cambium and phloem. Young plane trees may die back as soon as after two years from infection, while in older trees the disease takes longer to develop. Over time, infected internal layers of wood and phloem turns from reddish to almost black.

In the first phase, the development of wood cankers on the smooth bark of plane trees is barely perceptible. There are dark spots with barely marked raised edges, and the formation of cankers is observed practically only at the moment when the tissue in the central part begins to collapse.

However, on the cross-section of trunks or branches, discolourations of the wood can be seen, initially lenticular, with time wedge-shaped, directed with a sharp end towards the core. The fungus, when growing into the vessels, leads to their dysfunction. As a consequence, the tissues above the infected sites initially show wilt symptoms and eventually die back completely. A weaker growth of twigs and thinning, dwarfing and premature yellowing of leaves are found. The dieback is accompanied by infection with various secondary pathogens, for which C. fimbriata facilitates the colonisation of trees.

Within days of infection the fungus produces spore groups in grey colonies on infected tissues. Soon the sporocarps of the fungus appear – dark coloured, visible using a magnifying glass as bottles with a very long neck, so-called perithecia. Under conditions of high humidity, spores (ascospores) flow out from the inside of these sporocarps, through their necks, in the form of a small drop of sticky substance, which sticks to insects and other animals and can be transported over long distances. The fungus in the infested wood still produces resting spores, so-called chlamydospores visible in infected tree vessels for up to two years after infection. The presence of each type of these spores is a very important diagnostic feature enabling the diagnosis of the disease, especially as the fungus can produce them all on infected wood or under the bark of cut trunks or branches.

Canker stain of plane infection is of paramount importance in urban conditions. This is most often caused through fresh wounds colonised by spores characterised by a long lifespan on un-sterilised tools. The fungus grows to the infected branch, covering ever larger parts of the crown, hence disinfection and decontamination of tools used to work on infected trees is an essential factor limiting the transmission of the disease. Spores can also contaminate the soil under trees, so it may sometimes be necessary to remove it. The fungus is also transmitted as a result of contact between the roots of the infected and healthy trees. In these situations, the disease progresses very quickly.

Pierce's disease

More and more attention has recently been devoted to the new threat from pathogenic bacteria, namely *Xylella fastidiosa*. The Pierce's disease it causes was described for the first time in 1987. The bacterium is able to infect over 300 species of plants. The first outbreak in Europe was confirmed in Kosovo in 1996. In 2013, the disease appeared in Italy, and a year later in France. Thus, *X. fastidiosa* began to also pose a real threat to the cultivation of various plants in Poland. According to EU legislation, this organism is subject to the **OBLIGATION OF COMBATING**. So far, large variations have been identified within the species, and there are several physiological species that differ in terms of the range of hosts. The particular importance for trees may be the **Xylella fastidiosa sub-species multiplex**, which probably has the widest ability to infect various plants, including some tree species such as the pedunculate oak, Scots elm, American planetree or northern red oak.

Unfortunately, the symptoms of occurrence on trees are not very specific. The most common is the drying of leaf edges, sometimes accompanied by the dieback of twigs and larger branches. The most characteristic symptoms are visible in the summer, usually in the form of browning and drying the edges of the leaves. The browning of the edges of leaves is often accompanied by a characteristic yellow border.

In the conditions of its natural occurrence *X. fastidiosa* can be transmitted only by insects fed by wood juices, which include local species of leafhoppers and spittlebugs. The species with the highest potential for spreading the disease in Poland include such species as European alder spittle bug, willow spittlebug, meadow spittlebug, black-and-red froghopper and green leafhopper, which can forage on many species of trees. Bacteria that get into the vessels as a result of insect foraging causes the formation of tyloses and gummoses. These block the trans-

port of water and nutrients which consequently leads to plant death. In addition, the bacterium produces toxins, the presence of which exacerbates the disease.

Fusarium circinatum

A new threat to pines is infection caused by ***Fusarium circinatum***, from the species of the genus *Fusarium*. This leads to the formation of resin spots surrounding twigs and larger branches, expanding with time in the form of cankers on the trunk. Badly infected trees may die back. The infestation usually occurs in places of mechanical damage or damage caused by insects. The fungus spreads with the wind or by insects. The resistance of individual pine species to the disease is diverse. The following species are considered vulnerable: *P. echinata*, Monterey pine, Virginia pine and slash pine. In turn, Canary Island pine, Aleppo pine, stone pine and Japanese black pine are considered resistant.

Phytophtora lateralis and *Phytophtora ramorum*

In Europe there is a growing threat to Lawson cypress from a new species of the genus *Phytophtora*: ***Phytophtora lateralis***. It can also affect Japanese cypress, Sawara cypress and western yew, and the first reports recently appeared about the possibility of occasional infections in northern white-cedar and western redcedar. The organism first infects the roots, after which it spreads along the trunk, leading to the dieback of trees. The infection occurs as a result of contact between trees and spores in the soil, hence the source of the disease may be infected cuttings and infected soil.

In Poland there have been real threats for some time from ***Phytophtora ramorum*** not only to oaks, but also to other species. This is one of the most important species for trees within the genus *Phytophthora*, which may be the cause of their dieback. Globally, it is responsible for the sudden dieback of oaks in California and Oregon. In Poland it has been detected in nurseries for ornamental and forest plants for some time, although it is not yet too significant a problem. In addition to oaks (northern red oak, Austrian oak, evergreen oak), it can infect birches, beech, sweet chestnut, horse chestnut, Douglas fir, Japanese larch and Sitka spruce. Its hosts include many species of Ericaceae, including rhododendrons. On some hosts the pathogen does not cause death, and instead is manifested by the presence of little specific spots or, at most, the dieback of shoot tips or individual branches. However, infected leaves are considered the main source of the disease spreading; spores are formed, so-called sporangia, in the area where spots are seen. These can spread the infection to other hosts, including trees. It has recently been confirmed that P. ramorum is able to pass on from oaks to larches, and that the European ash can also act as a host to the disease. However in the case of ash only the leaves are infected, and the tree is not sensitive to infection in branches.

Literature

Baule H., Fricker C. 1971. Nawożenie drzew leśnych. PWRiL Warszawa.

Bell J.N.B., Treshow M. 2002. Zanieczyszczenie powietrza a życie roślin. Wydawnictwa Naukowo-Techniczne Warszawa.

Bhat, R. G., Subbarao, K. V. 1999. Host range specificity in *Verticillium dahliae*. Phytopathology, 89: 1218–1225.

Biggerstaff C., Iles K.J., Gleason M.L. 1999. Dutch Elm Diseases and Diseases – Resistant Elms. Iowa State University, Univesity Extension, Sul-4.

Blanchard R.O., Tattar T.A. Field and Laboratory Guide to Tree Pathology. Second Ediotion. Academic Press Ltd., London.

Borecki i inni.1983. Szkodniki i choroby roślin sadowniczych. Praca zbiorowa, PWRiL Warszawa.

Brasier C.M., Buck K.W. 2001. Rapid evolutionary changes in a globally invading fungal pathogen (Dutch elm disease). Biological Invasions 3: 223–233.Carter J.C. 1975. Diseases of Midwest trees. Special Publication 35, Uniwersity of Illinois at Urbana – Champaign College of Agriculture in Cooperation with Illinois Natural History Survey.

Chaney W.R. 1985. Anatomy and physiology releated to chemical movement in Trees, Presented at the annual conference of the International Society of Arboriculture in Milwaukee in August 1985.

Coder K.D. 2007. Soil Compaction Stress & Trees. Symptoms, Measures, Tretments. Warnell School Outreach Monograph University of Georgia.

Engelhard A.W. 1957. Host index of *Verticillium albo-atrum* Reinke & Berthold (including *Verticillium dahliae* Kleb.). Pl. Dis. Reptr. Supplement 244: 23–49.

Goud J.C., Termoschuizen A.J. 2003. Quality of methods to quantify mikrosklerocja of *Verticillium dahliae* in soil. European Journal of Plant Pathology, 109: 523–534.

Goud J.C., Termoschuizen 2002. Pathogenicity and virulence of the Dutch VCGs of *Verticillium dahliae* to woody ornamentals. European Journal of Plant Pathology, 108: 771–782.

Goud J.C., Termoschuizen A.J., Gams W. 2003. Morphology of *Verticillium dahliae* and *V. tricorpus* on Semi-Selective Media used for the Detection of *V. dahliae* in Soil. Mycological Research, 101: 822–830.

Goud, J.C. 2003. Verticillium wilt in trees. Detection, prediction and disease anagement. PhD Thesis Wageningen Universiteit, Wageningen, The Netherlands With references . With summary in English and Dutch. xii + 98 pp

Greig B.J.W, Gregory S.C., Strout R.G. 1991. Honey Fungus. Foresty Commision Leaflet 6, London. Bulletin 100.

Hammerbacher A. 2005. Biology and Epidemiology of *Fusarium circinatum*. Dissertation. University of Pretoria.

Hansen E.M., Lewis J.K. 2005. Compendium of Conifer Diseases. Second printing. The American Phytophatological Society.

Harris D.C. 1998. In: J.A. Hiemstra, D.C. Harris (eds.). A Compendium of Verticillium Wilts in Tree Species, CPRO-DLO, Wageningen, The Netherlands/HRI-East Malling, West Malling, UK.

Hart J.J., Kennedy K.M. 1981. Management of Dutch Elm Diseases. Michigan State University. Cooperative Extension Service. Extension Bulletin E-506. File 27.31.

Hiemlick E.B. 1969. Trees and shrubs hosts of *Verticillium albo-atrum*. Biological Notes, Illinois Natural History Survey, Urbana Illinois, 66.

Hiemstra J.A., Harris D.C. 2015. A Compendium Of Verticillium Wilts In Trees. Commision of the European Comunities under grant CT 96 2015.

Hillel D. 2012. Gleba w środowisku. Wydawnictwo Naukowe PWN.

Horst R.K. 2008. Westcott's Plant Diseases Handbook. XIV.Springer.1318 p. Hardcover Johansson, A. 2006. *Verticillium longisporum*, infection, host range, prevalence and plant defence responses. Licentiate thesis. ISBN 91-576-7153-2

Keefer R.F. 2000. Handbook of Soils for Landscape Architects. Oxford University Press, Inc.

Koehler W. 1977. Zarys hylopatologii. PWN Warszawa.

Kosmala M. 2000. Pielęgnowanie drzew i krzewów ozdobnych. PWRiL Warszawa. Lopes – Escudero F.J., Mwanza C., Blanco – Lopez M.A. 2006. Production of Homogenous and Viable *Verticillium dahliae* Microsclerotia Effective for Verticillium Wilt Studies. Biotechnology, 5(4): 421–428.

Łabanowski G., Orlikowski L., Soika G., Wojdyła A. 2001. Ochrona drzew i krzewów iglastych. Wydawnictwo Plantpress Sp. z o.o.

Łukasiewicz S. 2012. Struktura fizyczna gruntu, zawartość substancji organicznej oraz skład chemiczny gleb w podłożach 21 stanowisk zieleni miejskiej na terenie Poznania. Część I. Struktura fizyczna gruntu. Badania fizjogeograficzne: Seria A. Geografia fizyczna. Tom 62: 87–103.

Mańka K. 1998. Fitopatologia leśna. PWRiL Warszawa.

Mańka M. 2011. Choroby drzew leśnych. Poradnik leśnika. PWRiL Warszawa.

Mazurek J. 2018. Najważniejsze choroby drzew alejowych (cz. II). Szkółkarstwo, 4.

Mazurek J. 2018. Najważniejsze choroby drzew alejowych (cz. II). Szkółkarstwo, 5: 20–27.

Młynik A.W. 1990. Grzyby niszczące stare drzewa – sprawcy zgnilizn drewna. Zarząd Ochrony i Konserwacji Zespołów Pałacowo-Ogrodowych. Komunikaty Dendrologiczne, 15: 3–35.

Morehart A. L., Donohue III F.M., Melchior G.L. 1980. Verticillium wilt of yellow poplar. Phytopathology 70: 756–770.

Neubauer C., Heitmann B., Vogel C. 2009. Morphology, vegetative compatibility and pathogenicity of *Verticillium dahliae* isolates from woody ornamentals in Germany. Journal of Plant Diseases and Protection, 116 (3): 109–114.

Orlikowski L.B., Oszako T. 2009. Fytoftorozy w szkółkach i drzewostanach leśnych. Centrum Informacyjne Lasów Państwowych.

Oszako T. 2005. Zagrożenie szkółek i drzewostanów, ze szczególnym uwzględnieniem olszy przez gatunki z rodzaju *Phytophtora*. Sylwan, 6: 55–61.

Oszako T., Nowakowska J.A. 2011. Na wojnę z fytoftorozą. Echa leśne, 11: 13–15.

Oszako T., Sawicki A. 2009. Fytoftoroza atakuje. Las Polski, 21: 16–18.

Pataky. N. 1996. Cytospora or Leucostoma Cancer of Spruce. Report of Plant Diseases No. 604. Departament of Crop Science University of Illinois at Urbana-Champain

Phillips D.H., Burdekin D.A.1982. Diseases of Forest and Ornamental Trees. Scientific and Medical Division THE MACMILLAN PRESS LTD. London.

Pląskowska E. i in. 2010. Miejskie Tereny Zielone – Zagrożenia. Wydawnictwo Uniwersytetu Przyrodniczego we Wrocławiu.

Pląskowska E., Mazurek J., Gębarowska E., Grzeszczuk J. 2015. *Phomopsis scabra,* jako groźny patogen platana klonolistnego. Zeszyty naukowe Uniwersytetu Przyrodniczego we Wrocławiu. Rolnictwo, 612: 57–66.

Seneta W., Dolatowski J. 1997. Dendrologia. Wydawnictwo Naukowe PWN.

Shmidt O. 2006. Wood and Tree Fungi. Biology, Damage, Protection and Use. Springer-Verlag Berlin Heidelberg, Germany.

Sierota Z. 2001. Choroby Lasu. Warszawa: Dyrekcja Generalna Lasów Państwowych.

Sinclar W.A., Howard H.L. 2005. Diseases of Trees and Shrubs. Second Edition. Cornell University Press

Smith I.M., McNamara D.G., Scott R.R., Harris K.M. 1994. Kwarantannowe Agrofagi Europy. Inspektorat Kwarantanny Roślin, Warszawa.

Sobiczewski P., Schollenberger M. 2002. Bakteryjne Choroby Roślin Ogrodniczych. PWRiL Warszawa.

Starck J. R. 1997. Uprawa roli i nawożenie roślin ogrodniczych. PWRiL Warszawa.

Struve K. 2002. A Review of Shade Tree Nitrogen Fertilization Research in the United States. Journal of Arboriculture, 28(6).

Szczepanowska B. 2001. Drzewa w mieście. Hortpress Sp. z o.o.

Szulc A. 2013. Zielone Miasto. Zieleń przy ulicach. Agencja Promocji Zieleni Sp. z o.o.

Szwałkiewicz J. 2009. Uszkodzenia drzew leśnych. PWRiL Warszawa.

Tjosvold S.A., Buermeyer K.R., Blomquist C., Frankel S. 2005. Nursery Guide for Diseases Caused by *Phytophtora ramorum* on Ornamentals: Diagnosis and Management. Regents of the University of California, Division of Agriculture and Natural Resources. Publication 8156.

Wójcik, P. 2009. Nawozy i nawożenie drzew owocowych. Warszawa: Hortpress Sp. z o.o.

Zawadzki S i in. 1999. Gleboznawstwo. Wydanie IV poprawione i uzupełnione. Praca zbiorowa. PWRiL Inowrocław.

Żółciak A. 2005. Opieńki. Centrum Informacyjne Lasów Państwowych.

Biosecurity Good working practice for those involved in forestry
https://naturalresources.wales/media/2638/forest-industry-standard-practice.pdf
https://www.forestresearch.gov.uk/research/tree-pest-and-disease-alerts-and-advisory-notes/

Massaria Diseases of Plane
https://www.ltoa.org.uk/massaria-disease-of-plane/193-massaria-disease-of-plane-practical-management-guidance

Practical Guidance. Wodwise: Tree Pest and diseases: Presen and Future Threats. Summer 2013. Woodland Trust
http://www.woodlandtrust.org.uk/mediafile/100263370/pg-wt-2014-woodwise-2013-summer.pdf?cb=113e4ffea9f44458b037aa43af664708

Problems on plane trees. Forest Research. Pathology Advisory Note (No. 7)
https://www.forestresearch.gov.uk/research/tree-pest-and-disease-alerts-and-advisory-notes/