Current and Potential Phytopathological Problems of Silver Fir

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Abstract

In recent years, forest species with a small percentage of distribution are used more often than ever. Climate change and some serious biotic agents (especially bark beetles) are main reason why we can observe this phenomenon. The silver fir (Abies alba Mill.) is among the most valuable conifers in Europe for ecological and economic reasons. It has the largest distribution area of all the European species of fir. A lot of careful consideration and strategic adaptation within management practices of fir forests is necessary for succesfull establishment. It's quite common that fir stands are affected by the competitive pressure of beech. This may be due to climate change, as well as biotic factors such as plant diseases. Most important diseases are wood decay fungi like Armillaria spp. and Heterebasidion spp., needle cast Herpotrichia needle browning or Lirula nervisequia and needle rust especially Pucciniastrum epilobii. For some pathogens like Herpotrichia needle browning seems it's typical to be triggered by a complex disease resulting from synergistic interaction of several fungal pathogens. Climate change is intricately linked to the heightened prevalence of forest pathogens with significant damage potential in Europe.

Keywords: *fir, forest pathogens, needle cast, forest protection, drought*

1 Introduction

In recent years, tree species with a smaller percentage of distribution in forest stands have increasingly come to the foreground in forestry. One of the most commonly used species, especially in the so-called Hercynian mix, is the silver fir (*Abies alba*). However, cultivation can be impacted by several serious issues (Zúbrik *et al.*, 2017; Jarzyna, 2021). Drought-weakened stands are particularly susceptible to infestation by *Armillaria* spp. or mistletoe, while denser stands are more susceptible to infestation by agents of diseases of the needles like needle cast or rust. The most important pathogens affecting fir trees are listed below.

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2 Fungal Pathogens (Biology, Symptoms, Protection)

It is possible to encounter a number of pathogens limiting the cultivation of fir tree in Europe and especially in the Czech Republic. The most important category are wood-decay fungi. The most important representatives are *Armillaria* spp. and *Heterobasidion* spp., which pose a risk especially to former agricultural land (Jankovský, 2002; Soukup, 2005; Bledý *et al.*, 2024). *Stereum sanguinolentum* is often found as a wound parasite in areas of high wildlife pressure or after unsustainable logging. Other representatives are the *Phellinus hartigii* or the banded *Fomitopsis pinicola*. Canker is caused by fungi of the genus *Cytospora*, especially *C. pinastri* (syn. *C. pini, C. abietis*, anamorph *Valsa abietis*). The most common fungi on fir are the so-called Cytospora canker. Needle cast category are most often represented by *Herpotrichia* needle browning and *Lirula nervisequa* (syn. *Hypodermella nervisequa*), as well as *Lophodermium piceae* and *Rhizosphaera* spp. The most important rusts are fir broom rust (*Melampsorella caryophyllacearum*) and fir fireweed rust (*Pucciniastrum epilobii*), which require two hosts for a successful life cycle. For nurseries and forest restoration the greatest risk is posed by the agents of seedling drop and root rots, especially *Phytophthora* root rot (*Phytophthora cactorum*) and fungi of the genera *Pythium, Fusarium, Cylindrocarpon, Verticilium*. Other causal agents of seedling and seedling diseases are *Allantophomopsis lycopodina*, *Leptosphaeria* spp., *Phialocephala fortinii*, *Pseudaegerita* spp., *Scirrhia aspidiorum*, *Sydowia polyspora*, *Peyronellaea* spp., *Phomopsis* spp., *Varicosporium elodeae*, *Gyoerffyella rotula*. Last but not least parasite of silver fir in recent years is white mistletoe (*Viscum album*) which has been spreading throught Europe (Noetzli *et al.*, 2003).

3 Biology, Symptoms And Protection

Armillaria spp. are the most important pathogen of all coniferous trees. It is widespread and phytopathologically most important species of silver fir. Most known representatives of the genus is *A. ostoyae*, most commonly on spruce, but also on fir, and the *A. cepistipes* with the *A. gallica* infecting conifers rarely. *A. borealis* can occur on both conifers and deciduous trees but does not cause significant damage. They produce cap-shaped fruiting bodies with scales that emerge in autumn. The biggest damage is caused by the *Armillaria* in non-native stands on nutrient-rich habitats and newly afforested agricultural land (Jankovský, 2002; 2003). Symptoms of infestation include the focal nature of the infestation, resin eruption in infested individuals, white wood rot occurring most often in the roots and lower part of the trunk, bottle-shaped thickened bases of trunks, presence of fruiting bodies in the vicinity of infested trees, white blanched syrrocium under the bark and brown to black rope-like rhizomorphs on and around the roots (Soukup, 2005). Mature trees can live with developing blight for up to decades, whereas seedlings often die within the first year of infestation. The importance of *Armillaria* increases with high temperatures and low rainfall during the growing season. *Heterobasidion annosum sensu lato* includes several species, three of which are commonly found in Europe including the Czech Republic: *H. annosum sensu stricto* on conifers and deciduous trees, *H. parviporum* mainly on spruce and other conifers and more rarely on deciduous trees, and *H. abietinum* exclusively on conifers (Niemela et Korhonen, 1998; Klavina *et al.*, 2021). First representative is the most common species in the Czech Republic and causes significant damage mainly in forest stands on former agricultural land. The main symptoms of *Heterebasidion* spp. are root rot progressing to the trunk and subsequent thinning of the tree crown (Soukup, 2011). Trees in the stand are infested in clumps and are prone to breakage and uprooting. Fruiting bodies of *Heterobasidion* grow on stumps, roots, and dead trunks and are cork to woody, splayed to cap-shaped. *Stereum sanguinolentum* mainly attacks spruce and other conifers including fir, rarely also deciduous trees (live or dead).

It causes white rot of wood. Infection occurs at sites where whitewood is injured (e.g. by the bite of wildlife or mechanization). The growth of fruiting bodies on living trees occurs several years after infection, on dead wood earlier (Soukup, 2008). The fruiting bodies are relatively hard and have a smooth to bumpy spore coat (hymenium). Spore coat of *Stereum* turns blood red when injured. *Phellinus hartigii* causes white rot, typically spreading through the stem from the point of fruiting body growth. In the advanced stages of rot, trunk breakage may occur (usually in strong winds). The fruiting bodies on the trunk are perennial, rusty brown to brown. Young fruits are cup-shaped and typically hemispherical, hoof-shaped to obovate with a cracked surface when old. The wood in the last stage of infection is ochre-yellow in colour and quite brittle, soft and fibrous (Bledý *et al.*, 2024). Unlike all the previous species, *Fomitopsis pinicola* causes brown rot (blocky decay of the wood). In the advanced stage of rot, the trunk may also break. The fruiting bodies grow on the host trunk, are perennial, hemispherical to hoof-shaped, with hard bark. The flesh of the fruiting bodies is white to yellowish, the tubes ochre to yellowish, brown in age.

Some fungi of the genus *Cytospora* cause canker. *Cytospora* fungi overwinter in necrotic bark. Spores are spread mainly by water, but also by wind, insects and human activity. Infection usually occurs during spring (Jacobi, 2013). The main symptoms of infestation are colour changes and premature needle or leaf drop, branch dieback (usually progressing from the lower branches upwards), necrosis on stems and branches (often elongated, slightly sunken and different in colour from the surrounding healthy tissue) and severe resin rot, but trees rarely die (Trush *et al.* 2021). On or near necrotic trunks and branches, the pathogen forms entire clusters of fungal filaments which develop in the cambium of the host. The tips of the filaments later penetrate the bark surface and appear as black, grey, yellow-brown or white dots. It may contain both pycnidia and perithecia. The pycnidia of *Cytospora* fungi are characterised by conspicuous orange 'pentacles'. *Cytospora pinastri* forms asexual stage fruiting bodies (pycnidia) on fir needles that resemble bumps. In the pycnidia, they form tiny hyaline horn-like spores (conidiospores) that infect the youngest, newly emerging fir needles at the time of germination. Two-year-old and older needles and the unwounded bark of the branches are resistant to infestation. If infection has occurred, the mycelium spreads up to the trunk of the tree through the mycelium, but the infection does not spread to the trunk. Under the surface of the bark of freshly dead fir branches, sexual stage fruiting bodies (perithecia) form and burrow to the surface. Already weakened trees are particularly susceptible, most often due to drought, but also e.g. waterlogging, late frosts, heatstroke, mechanisation, improper use of pesticides, other pathogens or insects (especially insects).

According to the current knowledge, the browning of fir needles or *Herpotrichia* needle browning is caused by the co-action of several fungal pathogens, mainly of needle cast character (Pusz *et al.,* 2020). The pathogens pose a risk, especially for stands with high air humidity on poor soils. Infected needles turn grey-green to straw-brown, then fall off and show white tufts of mycelium. The shoot ends of heavily infected branches die. Needles and branches die mainly at the base of the crowns. Reduction of the aesthetic value of the trees is common, but mortality is rare. *Lirula nervisequa* is the causal agent of needle cast, closely related to the *L. mascorpora* which infects spruce trees (Čermák *et al.,* 2014). Both of these cankers cause browning and subsequent needle drop. On the reverse of the needles, longitudinal black fruiting bodies (hysterothecia) containing vesicles with sexual spores (ascospores) form around the main nerve. The disease mainly affects the lower branches. Confusion with other species causing needle drop cannot be ruled out in the early stages of infection.

Melampsorella caryophyllacearum as a two-host rust, attacks fir trees and herbs of the family *Caryophyllaceae* like *Cerastium* spp., *Stellaria* spp., *Arenaria* spp. and *Malachium* spp. This rust infects the cambium of fir trees through the bark of young branches. Infected fir trees form cancerous nodule or bump-shaped tumors that take up to several years to develop. When the tree is infected, the quality of the wood is degraded and resistance to wood-decay fungi

(especially *Phellinus hartigii*) is weakened. When the buds are infected, the buds form witch hazels, which have shortened and yellowish needles from which rust fruits (aecie) grow. The needles fall off in autumn. For its development, which is often conditioned by a 'wet' spring, the fir rust prefers stands at lower altitudes, close to water sources and in stands with more shrubs. *Pucciniastrum epilobii* attacks fir and willow herb *Epilobium* spp.. Infection of fir trees occurs in spring by basidiospores. During the summer, yellow fruiting bodies (aethecia) covered with a white tubular elongated blanks grow on the reverse of the youngest needles (Kunca *et al.,* 2020). Symptoms are typical during the period of aecia formation, outside this period confusion with other pathogens (e.g. *Rhizosphaera, Cytospora*) is possible. Infected needles curl, gradually turn yellow and brown and fall off the same year. Fir fireweed rust is an increased risk in nurseries and christmas tree plantations.

Phytophthora root rot damages mainly the root collar and is a major contributor to seedling dieback which occurs on almost all tree species. Pale spots appear on the hypocotyl and womb leaves during May–June, which later turn brown to black and grow into whitish like-spidery mycelium. Infestations are usually focal. Severely infested seedlings die. Annual seedlings are most at risk. Confusion is possible with other species involved in seedling drop from the genera *Pythium, Fusarium, Cylindrocarpon, Verticilium* (Pešková, 2005). These fungi are commonly found in the soil and on the surface of the seeds. Their spread occurs through the soil and growing medium. They can cause death of germinating seeds, rotting and smothering of roots and corms. The typical symptom is softening of the root collar, bending and falling to the ground. If the seedling becomes woody, the disease is manifested by root rot, where the seedlings remain standing after death.

White mistletoe is an evergreen branching semi-parasitic plant growing on the trunks and branches of trees, from which it draws water, inorganic and organic substances. Mistletoe usually flowers during February–April for 3–4 weeks. Pollination of the flowers is by insects, more rarely by wind (Baltazár, 2016; Cristini, 2018). The fruit is a sessile, white, false berry, ripening in November–January. The seeds with sticky pericarp are spread by birds (mainly *Turdidae*) on the surface of their bodies and through the digestive tract. The seeds begin to germinate at temperatures of 8–10 °C, and light is essential for germination. Vegetative spread of mistletoe rarely occurs. In the Czech Republic, fir trees are attacked by a subspecies of silver fir mistletoe (*Viscum album* subsp. *abietis*) with broad green leaves. Symptoms of mistletoe infestation include swollen trunks and branches, dieback of parts of the branches or the top above the infestation site, tubular corridors in the wood caused by root action and reduced growth. If parasitisation is very severe, mortality may occur. Mistletoe is particularly problematic in the dry season, as water drainage increases the hydric stress of the host and reduces resistance to attack by other biotic agents. In the Czech Republic, white mistletoe occurs mainly at lower and middle elevations and on older trees with a larger trunk diameter. In recent years, there has been a marked increase in the occurrence of all mistletoe subspecies in the Czech Republic, probably due to drought and high temperatures.

4 Prevention And Control

Typical control against wood-decay fungi include changing the species composition, removing infected material (especially trees with fresh symptoms) and practical changes in cuting. Biopreparations based on the fungi of the genus *Trichoderma* can be used against *Armillaria* spp. (Percival *et al.*, 2011), and *Phlebiopsis gigantea* (syn. *Phlebia gigantea*) against *Heterobasidon* spp. Water treatment on charred and intermittently waterlogged soils and loosening of the planting to reduce stumps (stumps are a source of infection) are also suitable against *Heterobasidion*. Prevention of infestations primarily based on avoiding injury to trees

is most important control against *Stereum* spp. and *Phelinus* spp. It is necessary protect roots, root flares and the bases of tree trunks with branches in exposed areas, harvesting and approaching timber during the dormant season, and treat wounds with a protective coating. At the same time, it is necessary to remove from stands fir trees with stem cankers caused by fir broom rust, which are often infected with *Phellinus hartigii*.

The key to controlling *Cytospora* spp. is avoid stress to trees: planting site-appropriate woody plants, pruning for air circulation (in dry weather to prevent the spread of spores and as close to the trunk as possible without damaging the collar), avoiding soil compaction and damage to trees, fertilising and watering adequately if there is a lack of nutrients in the soil (watering mature trees especially in summer and late autumn before the soil freezes). Control of planting material is also important. Larger wounds should be treated with an appropriate fungicide. Infested and dead parts of trees (including bark) should be removed and burned. It is not recommended to apply any coatings to wounds after removal of infected parts (only treat with fungicide) and allow the tissue to dry. Adherence to protective and defensive conrol against other pathogens will reduce the risk of combined tree stress. No effective chemical or biological defenses currently exist.

Defence against needle cast consists of thinning stands (reducing air humidity), avoiding long-term waterlogged sites and frost basins or removing heavily damaged individuals from the stand. Chemical intervention is appropriate in the case of heavier infestations in the previous season. It is carried out as a preventive control during the infection period (from the time of budburst to the end of bud growth) in nurseries and christmas tree plantations but is not necessary in forest stands.

Protection against fir broom rust consists of eliminating the second host and removing infested branches or heavily infested fir trees from the stand. To control fir fireweed rust, a second host is removed near nurseries, plantations and mature crop. In nurseries (and possibly also planting), preventive fungicides are carried out 3–4 times at intervals of 10–14 days from the beginning of May in the event of a stronger incidence of fir fireweed rust in the previous year. Spraying by fungicide must ensure perfect coverage of the treated trees, must be carried out on a dry surface and must not get wet before drying.

Prevention of seedling drop consists of deep and repeated loosening of the flower beds, ensuring sufficient air flow, avoiding waterlogging, disinfecting the substrate before sowing and pickling the seed. Fungicides are applied by watering at the first sign of infestation.

Prevention against white mistletoe involves growing ecotypes or cultivars more resistant to mistletoe infestation, high temperatures and drought, or trees on which mistletoe is virtually absent (e.g. beech, elms, oaks, larch). Due to the higher level of mistletoe infestation in older stands, a reduction in the practical cutting period may be considered. Removing mistletoe by cutting together with part of the host branch is only suitable for trees with a low degree of infestation, as pruning leads to weakening of the host and the mistletoe can regenerate (Lorenc, 2020; Lorenc et Véle, 2022). In stands, removal of infested trees is recommended, but felling will lighten the stand, creating favourable conditions for mistletoe development. Growth regulators can only be used on deciduous deciduous trees during dormancy, when they have no side effects on the host.

The current list of authorised products and other plant protection products can be found on the Plant Health Portal (ÚKZÚZ, 2014-2024), there is also a list for suitable products to forest protection (Zahradník et Zahradníková, 2024).

5 Summary

Silver fir has the potential to play a crucial role in the future composition of Central european forests. With ongoing climate change it is necessary to focus on abiotic and biotic factors more than ever. *Armillaria* spp. like the most important pathogen of all coniferous trees is widespread and phytopathologically most important species of silver fir. Wood-decay fungi is often accompanied by other fungal pathogens like *Heterobasidion* and needle cast or rusts. It's really important to use every part of preventive control of biotic agents and focus on IPM (integrated pest management). If we can find a right way how to cultivate silver fir at current weather condition and under phytopathological pressure, it's possible to fulfill both productive and non-productive functions in mountainous forests and water-influenced habitats at lowe altitudes. Adaptive management, which supports the establishment of mixed stands with silver fir, is essential for enhancing the stability and biodiversity of these ecosystems. The use of small-scale clear-cutting and selection-cutting methods that mimic natural processes is key to promoting structural differentiation within forest stands.

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