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PHAEOCRYPTOPUS GAEUMANNII IN DOUGLAS-FIR STANDS IN SMOLARZ FOREST DISTRICT

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Abstract

The investigations were carried out in Douglas-fir stands in Smolarz Forest District (north-west Poland). Eleven stands were examined on the presence of Swiss needle cast. Only in three the disease was found. The crown defoliation degree was estimated for 200 trees in two stands. All disease symptoms have been observed on needles – ascomata on green, yellow and brown needles and crowns defoliation. In the highly infected stand, 90% of Douglas-firs had crown defoliated in more than 45%. The dying of trees was also observed. Only 5% crowns of Douglas-firs was defoliated in less than 25%. This study focused that the disease with low importance but appearing in the next few years, permanently might locally influenced the health conditions or even cause an important damage in trees foliage.

Key words: Swiss needle cast, *Phaeocryptopus gaeumannii,* Douglas-fir

Introduction

Phaeocryptopus gaeumannii, causal agent of the Douglas-fir (*Pseudotsuga menziesii*) foliar disease of Swiss needle cast, is the only known pathogenic species of the genus. Douglas-fir is its only known host. Disease tends to be more severe near the coast (Hansen et al. 2000).

The pathogen is native in North America. It was found to be widespread in western North America (Mańka 2005). Since 1990 a severe sustained epidemic of Swiss needle cast has been observed in dense stands of younger trees of Douglas-fir, especially in Christmas tree plantations (Hadfield and Douglas 1982). Currently, even mature forests of natural origin, particularly along the immediate coast are susceptible to severe infection (Michaels and Chastanger 1984 b). The disease severity in western North America is associated with abnormally high lev-

Phytopathologia 58: 43–52

ISSN 2081-1756

els of *P. gaeumannii* (Hansen et al. 2000, Manter et al. 2005). The epidemic continues to be most severe in Douglas-fir plantations established on former Sitka spruce, western hemlock or red alder forests (Hansen et al. 2000). In western Oregon and Washington the Swiss needle cast used to be found in 90% of Douglas-fir plantations on 84% of trees (Michaels and Chastanger (1984 a). Since 1996 the total area of symptomatic forest has been gradually increasing. Currently about 200 000 ha are classified as severely infected. In the last few years the disease has been recorded also in parks and gardens. *Pseudotsuga menziesii* vars. *galuca* and *caesia* are more susceptible than var. *viridis*. The former varieties shed the needles faster and more frequently (Mańka 2005).

Since its initial discovery Swiss needle cast has been reported in other locations where Douglas-fir has been cultivated outside of its native range. In Europe it was first found in Switzerland and Germany in 1925 (Gäumann 1930), next in Great Britain and Ireland in 1928. In contrast to the USA, in Europe it caused the severe defoliations. During the next three decades *P. gaeumannii* gradually spread eastwards across Europe. It was first found in Poland in 1947 (Dominik and Grzywacz 1998, Mańka 2005). Most recently it was found in New Zealand (Hood 1982), Turkey (Temel et al. 2003), Chile (Osorio 2007), Australia (Pederick and Marks 1975) and possible Japan.

Symptoms typically appear on one-year to three-year-old needles following infection which occurs shortly after needle formation. The oldest needles show symptoms first. Needles first become yellow-green, chlorotic, then mottled or entirely brown-discolored, then are cast. The primary mechanism of damage appears to be the production of fruit bodies (pseudothecia) in the stomatal apertures, occluding the stomata and interfering with gas exchange. *Phaeocryptopus gaeumannii* physically block stomata and reduce CO_2 assimilation (Manter et al. 2000). Defoliation is proportional to the number of stomata occluded by fungus, with needles being cast when about 50% of stomata are occupied, regardless of needle age. Trees have thin crowns. Prior to 1990, the disease was typically worse in lower and inner crowns, but now symptoms are worst in the upper crown, particularly on south slopes. Tree height and diameter growth (due to narrow wood increment) and total tree volume are reduced (Hansen et al. 2000, Maguire et al. 2002, Mańka 2005). Reduction is significantly correlated with degree of defoliation. The permanent and severe infections of younger (10–30-year-old) and older (80-year-old) Douglas-fir stands reduced the tree volume by 52% (Maguire et al. 2002) and diameter growth up by 85% (Black et al. 2010), respectively. The disease influences also the wood structure. Trees from severely infected stands (needle retention < two years) had higher wood elasticity, density, proportion of latewood and lower moisture content in sapwood than trees from healthier stands (Johnson et al. 2005). Infection by *P. gaeumannii* increases the susceptibility of trees to other pathogens or insects.

The presence of pseudothecia helps in diagnostic of the disease. They grow out from the stomata and appear as two parallel "sooty" bands along each side of the midrib on the undersides of the infected needles. They may be produced on green, one-year-old or older needles. They are produced in early winter. Ascospores are

produced and released in spring, particularly in March-July, until August. Massive spores production occurs at the end of June and beginning of July (Hood 1982, Michaels and Chastanger 1984 b, Rosso and Hansen 1999). Production, dissemination and activity of spores involved in the infection process are affected by lower temperature, higher humidity and strong winds.

The objective of this study was the evaluation of the severity of Swiss needle cast on trees of Douglas-fir in young deciduous-coniferous stands in North-western Poland. Temporal and spatial assessment of the disease is important for the research on ecology and epidemiology of the pathogen, susceptibility of the local provenances of Douglas-fir to pathogen and developing spatial models for predicting Swiss needle cast distribution and severity. Studies contribute to research on the increased disease spread and intensity in connection with the climate change. Results may be a decision support tool for forest managers dealing with Swiss needle cast.

Materials and methods

The investigations were made in 11 stands where Douglas-fir occurred at least in 10% in Smolarz Forest District (52°53'N, 15°45'E).

The detailed study was carried out in three Douglas-fir stands infected by *P. gaeumannii*: nine-year-old Douglas-fir plantation (compartment 340c, fresh deciduous stand – according to the Polish classification of typology, 20% of Douglas-fir, density 0.9, bonitation I), 17-year-old (compartment 469g, fresh mixed deciduous-coniferous stand, 20% of Douglas-fir, density 0.9, bonitation I) and 35-year-old (compartment 379b, fresh mixed deciduous-coniferous stand, 40% of Douglas-fir, density 1.0, bonitation I). In each of two older stands 200 alive trees, randomly chosen, were observed. The observations concerned the degree of crown defoliation. Each tree was classified to the defoliation range: 0–5%, 6–15%, 16–25%, 26–35%, 36–45%, 46–65%, 66–75%, 76–90%, 91–99%, 100% (dead tree). The classification was made with the aid of the atlas of foliage losses of forest trees (Borecki and Keczyński 1992). On the base of the defoliation degree according to the European classification (Jaszczak 1999), trees were assigned to the damage degree (Table 1). In plantation observations were limited to estimating of disease severity.

Table 1

Damage degrees of assessed trees

Damage degree	Needle lost (%)
0 – lack	0–10
1 – weak	11–25
2 – average	26–60
3 – high	61–99

Results

Swiss needle cast caused by *P. gaeumannii* was recorded in three out of 11 investigated stands.

The main symptoms of disease included the needle chlorosis followed by brown discoloration, dieback and cast. As dieback continued, crowns became defoliated and thin. Symptoms were observed throughout the crown with no apparent directional trend. Rare pseudothecia of *P. gaeumannii* were produced on the undersides of green or delicately chlorotic needles. Abundant pseudothecia were produced on needles with symptoms of yellow-brown discoloration and necrosis.

In the most cases trees had only current complement of needles. There were no trees without crown defoliation. In 17-year-old stand (464g) 90% of trees had only current complement of green needle, so the defoliation degree was estimated as a 60%. Crown of other trees were reduced in 40%. So all examined trees in this stand were assigned to the average damage degree. Slightly different situation was observed in the 35-year-old stand (379b). The stand was highly infected, because 90% of Douglas-firs had crown defoliated in more than 45%. The dying of trees was also observed. The most frequently (49%) trees lost 76–99% needles. Only 5% crowns of Douglas-firs was defoliated in less than 25% (Fig. 1).

Eighty four percent of assessment trees was highly damaged (3rd damage degree), what means that the loss of needles was higher than 61%. Only 2% trees was classified as trees without damage in crown. The average damage was observed in 11% and weak damage in 3% Douglas-firs (Fig. 2). The trees growing in vicinity had crown in different defoliation range, and were classified to different damage degrees (Phot. 1). Mortality occurred rarely, only on a few affected trees.

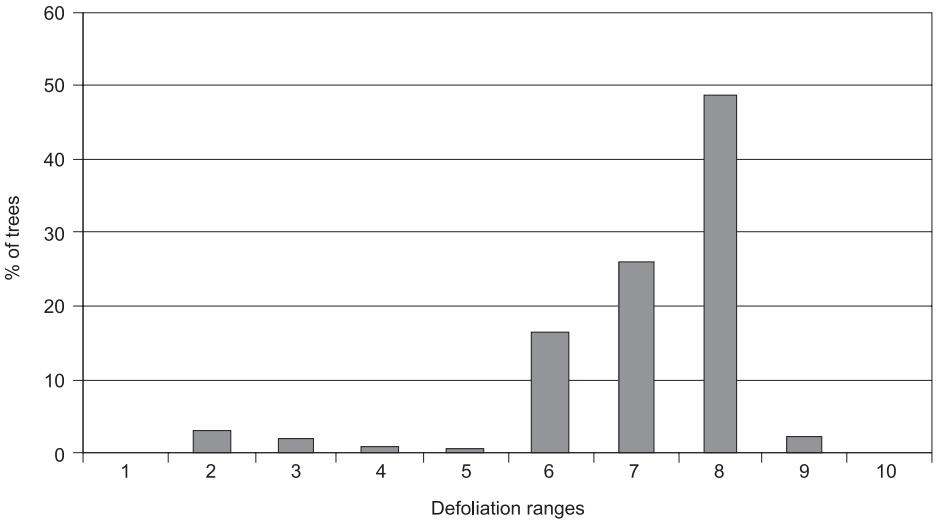

Fig. 1. Defoliation ranges of assessed Douglas-firs in 35-year-old stand: 1 – 0–5%, 2 – 6–15%, 3 – 16–25%, 4 – 26–35%, 5 – 36–45%, 6 – 46–65%, 7 – 66–75%, 8 – 76–90%, 9 – 91–99%, 10 – 100%

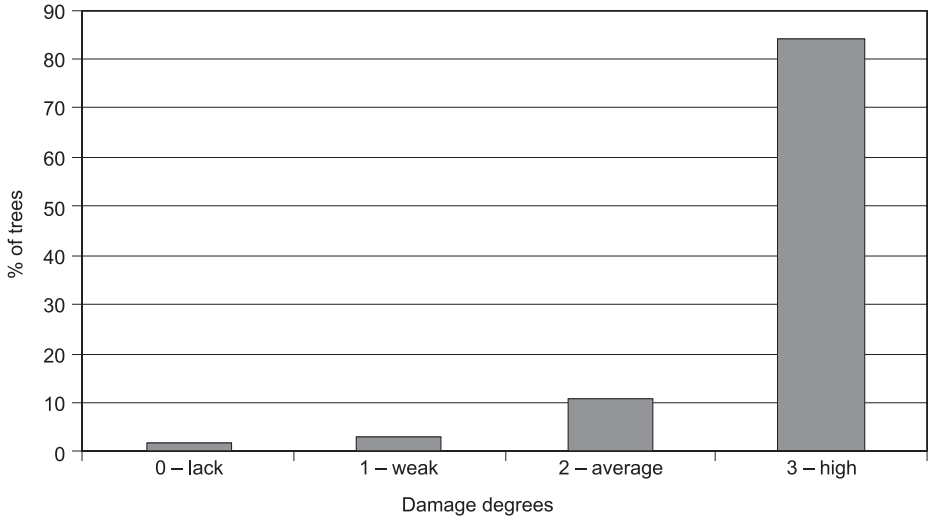

Fig. 2. Damage degrees of assessed Douglas-firs in 35-year-old stand

In the plantation (340c) only nine Douglas-firs had two complements of alive needles, and the average height was 5.5 m. Other trees were heavily infected. The current stem increment in length varied from 5 to 25 cm. The average height of trees was 1.5 m.

Phot. 1. Douglas-firs with the different disease severity (photo by P. Łakomy)

Discussion

Swiss needle cast caused by *P. gaeumannii* was not seen so far as a serious problem in Europe, except on certain sites. The disease however was observed in Douglas-fir plantation and stands in North-western Poland, 150 km inland from the sea coast.

Generally, currently the disease is of minor importance in Poland due to the small share of Douglas-fir. However, considering an increased severity of the disease in the USA where it became a significant forest health problem in last 30 years (Hansen et al. 2000) we report on its increased occurrence in Europe. Implications may range from increased tree mortality at the stand level to drastic consequences on a larger scale as the stand's resistance.

Climate (fog occurrence, precipitation, temperature) as well as topography (altitude, elevation), slope aspect (facing the sun), soil, forest stand structural attributes and physiographic features seem to affect the disease severity. Higher air moisture (determined by fog occurrence and precipitation, particularly in May-July, low and medium slope position, bigger exposition to summer drizzles resulted from the south-facing slope) and higher temperature (determined by warmer winters, particularly Novembers, lower altitude, warmer south-facing (western coast range) and north facing (eastern coast range) slopes) but not excessive heat (determined by colder summers, particularly in May-July) seem to correlate with higher disease severity in British Columbia and Oregon (Hood 1982, Rosso and Hansen 2003). However, results on the Swiss needle cast severity are sometimes contradictory.

In this study the examined stand was also heavily infected by pathogens. It could be resulted by permanent infections repeating at least for five years (on the base of Forest Service reports) and favourable climate conditions appeared in north-west Poland through last few years. Analysis of meteorological data shows that, in years 1994–2003, north-west Poland had 111–120% of its average rainfall and temperatures 0.5–1.0°C higher than the average (Bulletin... 2005).

The climatic and topographic conditions seem to have a strong effect on air moisture and leaf wetness, which are necessary for pathogen's spore germination and hyphal development in needles. The importance of the local conditions for disease severity results from physiology: (i) of pathogen which germinates and invades in late spring to summer and, (ii) of infected host which regulates the stomatal closure. Warm summer (July) combined with low moisture results in lower disease severity due to inhibition of the fungus growth and closure of stomata.

Other causes of the intensification of Swiss needle cast include increased amount and density of Douglas-fir, regeneration based on the off-site seed sources, host and pathogen physiology, pathogen diversity, pollution, change in tree nutrition, change in genetics of Douglas-fir resulted from management, planting of Douglas-fir in a spruce-hemlock zone, and forest management practices.

As far as the host physiology is concerned the Douglas-fir populations show significant, between- and within-provenances variation in tolerance and suscepti-

bility to *P. gaeumannii*. More susceptible provenances originate through natural selection, from locations with lower natural infection and lower rainfall and humidity and application of inland (not coastal) seed sources (Hood 1982, McDermott and Robinson 1989). Within the coastal varieties of Douglas-fir, susceptibility decreased as the seed source origin approached the coast, with lower elevation, and northward direction (Hood and Wilcox 1971, Pederick and Marks 1975).

In 35-year-old stand the severely and non-severely infected trees were growing in the close proximity what suggests the within-provenances, presumable heritable, variation in susceptibility.

As far as the pathogen characteristic is concerned, *P. gaeumannii* has much greater genetic diversity in epidemic areas (the Pacific Northwest) than in non-epidemic areas (eastern USA, New Zealand and Europe). The phylogenetic approach revealed that *P. gaeumannii* in Oregon is subdivided into two genetically differentiated groups that occur sympatrically (Winton et al. 2006). New epidemics in the Pacific Northwest are irrelevant to the appearance of the more virulent population or races.

Current impacts of Swiss needle cast has usually been evaluated in relatively young (< 35 years in age) Douglas-fir stands, often in plantation settings (Maguire et al. 2002). Studies in Poland were also done in young stands. Different methods and different parameters including foliage mass, ratios of crown measurements to sapwood area, sapwood moisture content, branch surface area and distribution, and tree basal area or growth measurements have been used to determine severity of disease and assess its impacts on trees (Maguire et al. 2002, Maguire and Kanaskie 2002). Needle retention is quantifiable symptom of Swiss needle cast and has been the primary assessment tool for foresters on the ground (Hansen et al. 2000, Johnson 2002, Maguire et al. 2002).

The magnitude of growth losses of Douglas-fir associated with varying intensities of damage is not usually known. To quantify retrospectively the relationship between severity of disease and growth losses the top height growth of the severely and non-severely infected trees was estimated in nine-year-old plantation. The healthy 10-year-old Douglas-fir trees growing in normal climatic and topographic conditions are usually 5–6 m high (Seneta 1987). The severely infected nine-year-old trees in Poland had their top height growth reduced by about 70%. In Oregon an average top height growth was reduced by up to 23–35% (–52%) and was also proportional to apparent foliage losses (Maguire et al. 2002).

Selection of improved genetic material is probably the best opportunity for correcting the impact of Swiss needle cast disease in the future Douglas-fir stands. In currently heavily infected stands silvicultural systems and operations include several regeneration methods, vegetation management techniques, fertilization, precommercial and commercial thinning, artificial branch pruning, partial cutting techniques and clearcutting (Filip et al. 2000). Bigger amounts of space, water, light and nutrients provided in early age and reduction of competition improve the habitat, help the tree to grow and tolerate the pathogen or defend it (Rose et al. 1999, Filip et al. 2000). Heavily infected stand should be clear-cut as soon as possible and replaced with a mixture of species with no more than 20% of Douglas-fir.

This study focused that the disease with low importance but appearing in the next few years, permanently might locally influenced the health conditions or even cause an important damage in trees foliage. The pathogen population might have increased enough to overwhelm natural mechanisms of the host tolerance or resistance.

Streszczenie

PHAEOCRYPTOPUS GAEUMANNII W DRZEWOSTANACH DAGLEZJOWYCH NADLEŚNICTWA SMOLARZ

Badania przeprowadzono na terenie Nadleśnictwa Smolarz w 11 drzewostanach, w których udział daglezji zielonej wynosił co najmniej 10%. Obserwacje dotyczyły występowania patogenu, stopnia defoliacji koron daglezji zielonej oraz nasilenia szwajcarskiej osutki daglezji. Stopnie defoliacji określano na podstawie „Atlasu ubytku aparatu asymilacyjnego drzew leśnych" (Borecki i Keczyński 1992), natomiast stopnie nasilenia choroby określono za pomocą klasyfikacji europejskiej. Tylko w trzech drzewostanach stwierdzono obecność *Phaeocryptopus gaeumannii*, przy czym szczegółowe badania przeprowadzono tylko w dwóch drzewostanach, ponieważ trzecim porażonym drzewostanem okazała się uprawa i ze względu na jej wiek nie można było zastosować metodyki oceny stopnia defoliacji koron. W każdym z dwóch pozostałych drzewostanów wybrano losowo 200 drzew, które poddano ocenie. W drzewostanie 17-letnim 95% drzew utraciło 60% aparatu asymilacyjnego (stwierdzono tylko jeden rocznik zielonych igieł na pędach), a pozostałe drzewa wykazywały 40-procentowe defoliacje. Drugi drzewostan (35-letni) był silniej porażony. 90% obserwowanych drzew wykazywało utratę aparatu asymilacyjnego w stopniu przekraczającym 45%. Tylko w 5% przypadków ubytek aparatu asymilacyjnego nie przekraczał 25%. Obserwowano także pojedyncze zamierające drzewa. W uprawie wszystkie drzewa były porażone w silnym stopniu. Długość przyrostu rocznego pędów głównych wynosiła od 5 do 25 cm, a wysokość drzew nie przekraczała 1,5 m. Wyjątkiem było dziewięć egzemplarzy rosnących na obrzeżu uprawy, które na pędach miały po dwa roczniki zielonych igieł, a ich wysokość sięgała 5,5 m. Przeprowadzone badania wykazały, że choroby o niewielkim dla gospodarki leśnej znaczeniu występujące w sposób ciągły przez kilka lat mogą się przyczyniać do powstawania strat gospodarczych.

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Accepted for publication: 30.11.2010