Progress of spreading *Stereum sanguinolentum* (Alb. et Schw.: Fr.) Fr. wound rot and its impact on the stability of spruce stands

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ABSTRACT: In 2002–2003, we conducted a detailed inventory of bark stripping damage in Forest District (FD) Mořkov (Forest Enterprise Frýdek-Místek) and in Forest Range (FR) Proklest (Training Forest Enterprise Křtiny). In total, 3,988 trees were examined in FD Mořkov and 1,512 trees in FR Proklest; in detail, 52 and 38 sample trees in FD Mořkov and FR Proklest, respectively. The rot spread in stems in the Proklest RD by an average rate of 15.6 cm/year, in FD Mořkov by an average rate of 23.8 cm/year. The rate of the rot spread decreases with the increasing period of parasitizing. The stem length affected by the rot ranged most frequently between 2.5 and 4.5 m (Proklest) or 2 and 3 m (Mořkov). The rot damaged on average 38.8 and 42.4% of the sample tree volume in RD Proklest and FD Mořkov, respectively. The proportion of trees affected by the rot decreased with the stand age. The observed extent of wound rot significantly decreases mechanical stability of stands and their adaptation potential.

Keywords: *Stereum sanguinolentum*; bark stripping; stand stability; Norway spruce

The wound rot of Bleeding Stereum *Stereum sanguinolentum* (Alb. et Schw.: Fr.) Fr., syn. *Haematostereum sanguinolentum* (Alb. et Schw.: Fr.) Pouz. is a serious result of bark stripping and browsing of spruce stands in the Czech Republic. Stripping damage affects a great part of stands in areas of deer *Cervus elaphus* (L.) and *Cervus nippon* (L.) management. Considerable damage has been found in the area of the Slavkov Forest and in the whole zone of boundary mountains from the Krušné hory Mts. to the Jeseníky Mts. The damage occurs also in the Brdy Upland and in the SE part of the Bohemian-Moravian Highland (ANONYMOUS 1996). Forests in the Carpathian region of Moravia are less damaged, e.g. the Beskids and the Jeseníky Mts., although significant damage can be noticed also there as given in the paper. As early as in 1970, it was found through inventories that about 70 thousand ha of the reduced area of spruce stands (ČERNÝ 2001) were damaged by browsing, bark stripping and subsequent rot. The same author gives damage to 80 thousand ha of spruce stands in mountain areas at the end of the 90s of the last century. In the extensive whole-area single statistical inventory of damage caused by game carried out by the Institute for Forest Ecosystem Research (IFER) and Institute for Forest Management Planning (ÚHÚL) in 1995, the proportion of trees damaged by game amounted on average to 19.2% not differentiating tree age and species. In medium-aged stands (15–60 years), bark stripping and browsing affected on average 21% of trees. Although slight damage predominated, more than 30% of trees were damaged in 10.2% of monitored stands (in % of timber land) (ANONYMOUS 1996).

Stereum sanguinolentum attacks most frequently more than 50% of damaged trees as stated by a number of authors, e.g. FRANZ et al. (1991) or SZUKIEL (1986) and its rot relatively rapidly spreads through attacked stems. Thus, impacts on forest management economics and stability and resistance of spruce stands become an important factor the extent of which and the rate of impact have to be carefully monitored.

In 2002–2003, we carried out a detailed inventory of stripping damage in FD Mořkov – Forest Enterprise Frýdek-Místek (ČERMÁK et al. 2004) and RD Proklest – Training Forest Enterprise (TFE) Křtiny. In addition to the extent of damage to forest stands, a lot of information was obtained on spreading the rot and the rate of its occurrence in trees.

MATERIAL AND METHODS

Monitoring methods

On the basis of preliminary monitoring, representative plots were placed in both regions for detailed monitoring. These plots of an area of 50 × 50 m were situated in

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spruce stands or in stands dominated by spruce at an age of 22–93 years. In total, in FD Mořkov 16 representative plots were selected (6 in stands of the 2nd age class, 4 in the 3rd, 3 in the 4th and 3 in the 5th age class), in RD Proklest 7 plots (2 in the 2nd age class, 3 in the 3rd and 2 in the 4th age class). In each of the plots, spruce trees were classified into the following categories: healthy tree, damaged tree and damaged tree with rot (gaping wounds, oozy occluded wounds, wounds of large extent). In total, 3,988 trees were examined in FD Mořkov and 1,512 trees in RD Proklest. For particular plots, the proportion of damaged trees was expressed (% of damaged trees of all monitored trees) and the proportion of trees with rot (% of damaged trees with rot of all monitored trees). Moreover, sample trees were selected with mensurational quantities approaching the values of a mean stem. In each of the plots, 5–10 sample trees were chosen which were felled and studied in detail. In total, 52 sample trees were felled in FD Mořkov and 38 sample trees in RD Proklest. The sample trees were measured (total length, mid-diameter) and then cross-cut to 1-meter sections up to a height of the encroachment of *Stereum sanguinolentum.* If the rot was no more evident at the end of the stem section, the section was further divided into halves. By means of calculations, volumes were determined of particular sections, of sound wood and of rot in the sections (according to the formulae of Huber and Smalian). The percentage of wood loss was determined (the proportion of wood of the stem part with the occurrence of rot out of the whole volume of a sample tree) and the time was found of the origin of damage by bark stripping. The rate of the rot progress in cm/year was determined as the stem length affected by rot divided by the number of years elapsed from the year of the damage origin. For all ends of particular sections of sample trees in RD Proklest digital images were made (with a respective scale and number of sample tree/section). Based on the images, biometrical measurements were carried out using LUCIA program – rot area and total area of the section end.

Characteristics of studied areas

Forest District Mořkov in the Frenštát pod Radhoštěm Forest Enterprise belongs to the working-plan area Frenštát pod Radhoštěm being situated in the area of the Beskid Foothills and the Moravian-Silesian Beskids geomorphological units. The area belongs to the flysch zone formed by sandstone and claystone beds. On predominantly mesotrophic brown forest soils at an altitude of about 450–850 m, Norway spruce *Picea abies* (L.) Karst. monocultures predominate and spruce stands with a broadleaved admixture particularly of beech *Fagus sylvatica* L. The biota ranks among the 3rd oak/beech, 4th beech and 5th fir/beech forest vegetation zones. *Fageta typica* and *Abieti-fageta typica g*eobiocoene type groups dominate. The forest district area is a part of a hunting district included in the 3rd quality class for red deer with the standardized spring stock of game amounting to 17 head (10 head/1,000 ha) and coefficient of expected production 0.8.

RD Proklest, TFE Křtiny is situated 15 km NE of Brno in the area of the Drahany Upland geomorphological unit, on culm monotonous sediments. The ranger district (RD) is situated N of Bukovina at 490–574 m altitude (peak Proklest). The biota belongs to the 3rd oak/beech (S and W of the RD) and 4th beech forest vegetation zones, potential vegetation would be composed of beech forests of *Luzula* type, in broken topography of herb-rich beech forests. The geobiocoenosis type group (GTG) of *Fageta typica* predominates being completed particularly by GTG *Querci-fageta typica*. Nevertheless, spruce stands predominate in the region (about 60%). The area of the Křtiny TFE forms a hunting district included into the 4th quality class for red deer with the standardized spring standing crop of 25 heads (5 heads/1,000 ha) and coefficient of expected production 0.8.

RESULTS AND DISCUSSION

The rot caused by *Stereum sanguinolentum* penetrates into living stems through mechanical wounds. In the forest ecosystem its role as a saprophyte predominates. The fungus decomposes dead wood, viz. smallwood in particular.

In the areas under study, stripping damage occurred with the subsequent penetration of rot in the majority of trees during the period when their age ranged between 15 and 30 years. In RD Proklest, the rot spread in stems at an average rate of 15.6 cm/year (from 1 to 36.4 cm/year), in FD Mořkov at an average rate of 23.8 cm/year (from 1 to 70 cm/year). The rate of the rot spread decreases with the increasing period of infection (Fig. 1). Correlation between the period of infection and the annual progress of rot is higher in stems with the period of infection < 10 years (FD Mořkov $r = -0.653$, $P < 0.05$) as compared with sets of all stems (FD Mořkov $r = -0.509$, RD Proklest $r = -0.495$, $P < 0.05$). The observed progress of the rot is lower than that mentioned by ČERNÝ (1989), viz. 30–80 cm/year being also lower than data obtained from an extensive survey of the progress of colonization of stems damaged by fungi in northern Europe (Sweden, Lithuania and Finland) where the rot affected on average 291.5 cm stem within 7 years. Thus, its annual progress amounted to 42.6 cm/year (VASILIAUSKAS 1998b).

In the majority of stands, damage originated in the period when their age ranged between 15 and 30 years. Within this age, stems begin to clean from drying lower

Table 1. The stem volume proportion debased by the rot in particular age classes

Age class	Age	RD Proklest (%)	FD Mořkov (%)
II	20–39	40	60
III	40–59	33	30
IV	60–79	26	28
V	80–99	–	10

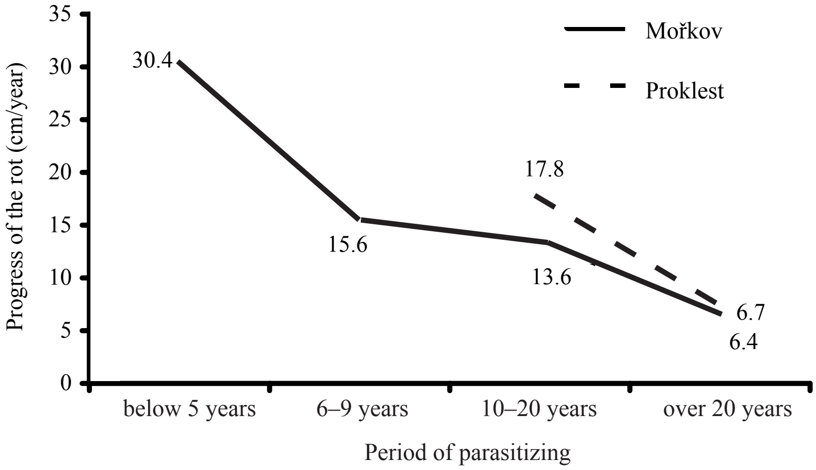

Fig. 1. Average progress of the rot in relation to the period of parasitizing

branches showing smooth bark yet which suits best for bark stripping. Therefore, a number of other authors, e.g. Eckmüllner (1985) or Záruba and Šnajdr (1966) found that stands about 20 years old were preferred in bark stripping. Infection of a tree took place at the point of the wound occurring at a height of 1–1.5 m above ground. The stem length affected by the rot most frequently ranged from 2.5 to 4.5 m (RD Proklest) or from 2 to 3 m (FD Mořkov). The maximum length of the rot-affected stem was 5.5 m (RD Proklest). In RD Proklest, the rot debased on average 38.8% of the volume of sample trees affected by the rot (maximum 67%), in FD Mořkov 42.4 % of the volume (maximum 83%). The proportion of the volume debased due to the rot decreases with tree age (Table 1). A reason consists in the slower progress of the rot (as mentioned above) within the longer period of infection; the volume of the stem increases more quickly than the rot spread.

The proportion of the area affected by the rot at the stem section end is logically highest at the end that is nearest to the point of the rot penetration (Fig. 2). A significant relationship has been found between the percentage of the area affected by the rot at the end of the second section (1 m from a stump) and the stem length affected by the rot ($r = 0.810$, $P < 0.05$). Thus, the horizontal rate of the rot spreading in a stem corresponds to the rate of vertical spreading. Correlations also exist between the percentage of the area affected by the rot at the end of the second section (1 m from the stump) and the stem volume proportion debased by the rot ($r = 0.709$, $P < 0.05$) given by regularities of the rot spreading and stem geometry. The data obtained correspond to conclusions of Vasiliauskas (1998b) from northern Europe where the average proportion of rot-affected area at the point of the wound amounted to 36.8%.

The proportion of trees with the rot (out of the total number of trees damaged by bark stripping) in representative plots decreased with the stand age, viz. from 86% (RD Proklest) or 59% (FD Mořkov) in the 2nd age class to 81% (RD Proklest) or 54% (FD Mořkov) in the 3rd age class and to 72% (RD Proklest) or 43% (FD Mořkov) in the 4th age class. In total, it applied to 82% (RD Proklest) or 49% (FD Mořkov) of all trees with wounds. The observed decreasing trend of the proportion of trees with the rot is caused above all by sanitation felling aimed primarily at the most damaged trees (with open dry wounds of large extent or oozy occlusions). In newly originated wounds occurring at the older age, it often applies to small wounds that need not result in the penetration of a pathogen or spread of a rot. Data on the proportion of trees affected

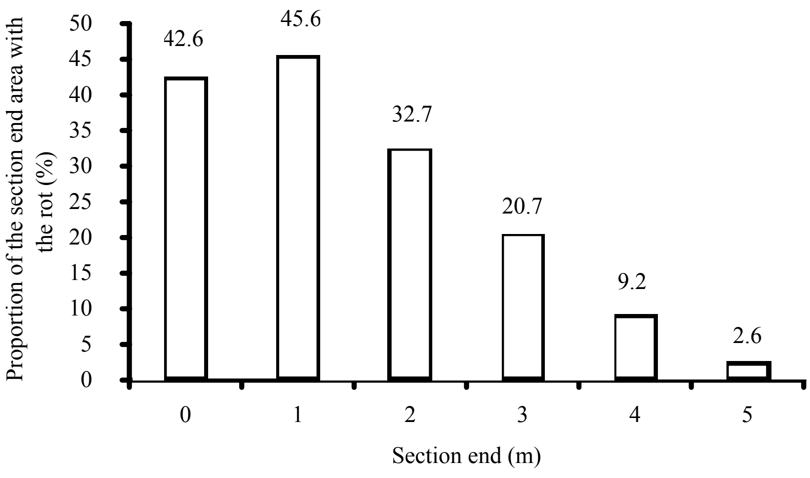

Fig. 2. Average area of the section end affected by the rot in % (mean of all sample trees), RD Proklest

by *Stereum sanguinolentum* fluctuated in similar surveys in a very broad range of values. For example, VEIBERG and SOLHEIM (2000) detected the occurrence of *Stereum sanguinolentum* in 27% of damaged trees in Norway, ATTA and HAYES (1987) in 47% and 54% trees, PECHMANN and AUFSESS (1971) in 60% of trees in Bavaria, SMIRNOV (1981) in 82% stripped spruce trees in southern taiga, ROEDER (1971) reported even 99.7% of attacked trees from northern Germany. VASILIAUSKAS (1998b) mentioned that infection occurred rather in winter than in summer wounds of stems. The rate of damage is also dependent on the character of wounds to a great extent. PAWSEY and STANKOVICOVA (1974) proved significantly higher occurrence of *S. sanguinolentum* in stems where also wood was disturbed as compared with stems where only simple peeling off the bark occurred.

In addition to the dominant occurrence of *Stereum sanguinolentum*, the rot caused by *Heterobasidion annosum* (Fr.) Bref. was also noticed in tree stems of FD Mořkov (7 sample trees together with *S. sanguinolentum)* and *Coniophora piceae* Černý (1 sample tree). The dominance of *Stereum sanguinolentum* among the fungi of the class *Basidiomycetes* was also found in other studies aimed at the spectrum of fungal pathogens occurring in stems damaged by bark stripping, e.g. in Sweden and Lithuania (VASILIAUSKAS et al. 1996; VASILIAUSKAS, STENLID 1998; VASILIAUSKAS 1998a).

Trees affected by rot at a rate found in monitored stands (i.e. on average about 40% of the stem volume and about 45% of the cross-sectional area at the point of damage) show markedly decreased mechanical stability. In *Stereum sanguinolentum,* spreading around the stem girth from the wound point, the decreased tree stability is markedly related to the direction of wind. If the wind acts at right angle to the direction of the rot spread, the tree is less endangered than in the case of parallel action. If the rot affected a half of the cross-sectional area, the cross-section carrying capacity was only about 50% or even about 24% as against the original carrying capacity (VICENA 2002). All this results in the higher rate of damage (given by decreased carrying capacity) and its higher frequency (given by the smaller wind speed necessary for the origin of wind breakage). In extreme cases, early disintegration of stands occurs.

Of course, the consequences of the rot spread do not consist only in the decreased mechanical stability of a tree but also its adaptability is significantly decreased. The disturbance of physiological processes, general decrease in the vitality of a tree, all this appears to be a predisposition for the origin of other damage, for example due to unfavourable climatic conditions (water stress). Predisposition due to rot results in the faster exhaustion of the adaptation potential of stands to synergetic effects of natural and anthropogenic stress factors. Under situations when it is possible to expect an increased load of stands in connection with the supposed course of a climatic change, markedly damaged stands (due to bark stripping and the rot caused by *Stereum sanguinolentum*) can soon occur in the stage of exhaustion resulting in their disintegration even without effects of gale.

CONCLUSIONS

The inventory of stripping damage and subsequent wound rot caused by *Stereum sanguinolentum* in the area of Forest District Mořkov (the Beskids Protected Landscape Area) and Ranger District Proklest, Training Forest Enterprise Masaryk Forest Křtiny (the Drahany Upland) proved the high rate of the wounds colonized by *Stereum sanguinolentum* and its relatively rapid spread through the tree stem. The rot affected on average about 40% of the stem volume and about 45% of the cross-section area at the point of damage and significantly decreased mechanical stability of trees and their adaptation potential. In spruce stands markedly damaged by bark stripping, there is at present an important risk of the early disintegration of stands.

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Postup šíření hniloby pevníku krvavějícího *Stereum sanguinolentum* (Alb. et Schw.: Fr.) Fr. a její důsledky pro stabilitu smrkových lesů

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ABSTRAKT: V letech 2002–2003 jsme prováděli podrobnou inventarizaci škod loupáním na revíru Mořkov (LS Frýdek-Místek) a na LÚ Proklest (ŠLP Masarykův les Křtiny). Celkem bylo vyšetřeno 3 988 stromů v revíru Mořkov a 1 512 stromů na LÚ Proklest, detailně potom 52 vzorníků v revíru Mořkov a 38 na LÚ Proklest. Hniloba se v kmeni šířila na LÚ Proklest průměrnou rychlostí 15,6 cm/rok, v revíru Mořkov potom průměrnou rychlostí 23,8 cm/rok. Rychlost šíření hniloby klesá se vzrůstající dobou parazitace. Délka kmene zasaženého hnilobou se nejčastěji pohybovala v rozmezí 2,5–4,5 m (Proklest), resp. 2–3 m (Mořkov). Hniloba znehodnotila průměrně na LÚ Proklest 38,8 % hmoty vzorníků zasažených hnilobou, v revíru Mořkov potom 42,4 % hmoty. Podíl stromů s hnilobou na reprezentativních plochách klesal s věkem porostu. Zjištěný rozsah hniloby významně snižuje mechanickou stabilitu porostů i jejich schopnost adaptace.

Klíčová slova: hniloba *Stereum sanguinolentum*; loupání; stabilita porostu; smrk

Na základě předběžného monitoringu byly na obou územích umístěny reprezentativní plochy pro podrobný monitoring. Zkusné plochy o velikosti 50 × 50 m byly situovány do smrkových porostů nebo porostů s převahou smrku ve stáří 22–93 let. Celkem bylo na revíru Mořkov vybráno 16 reprezentativních ploch (6 v porostech II. věkové třídy, 4 ve III., 3 ve IV. a 3 v V. věkové třídě), na LÚ Proklest potom 7 ploch (2 ve II. věkové třídě, 3 ve III. a 2 ve IV. věkové třídě). Na každé ploše byly smrky zařazeny do kategorií: zdravý strom, poškozený strom a poškozený strom s hnilobou (otevřené rány, mokvavé zavalené rány, rány velkého rozsahu).

Hniloba se v kmeni šířila na LÚ Proklest průměrnou rychlostí 15,6 cm/rok, v revíru Mořkov potom průměrnou rychlostí 23,8 cm/rok. Rychlost šíření hniloby klesá se vzrůstající dobou parazitace. Korelační vztah mezi dobou parazitace a ročním postupem hniloby je silnější u kmenů s dobou parazitace do 10 let (revír Mořkov $r = -0{,}653$, $P < 0{,}05$) ve srovnání se soubory všech kmenů. Délka kmene zasaženého hnilobou se nejčastěji pohybovala v rozmezí 2,5–4,5 m (Proklest), resp. 2 až 3 m (Mořkov). Hniloba znehodnotila průměrně na LÚ Proklest 38,8 % hmoty vzorníků zasažených hnilobou, v revíru Mořkov potom 42,4 % hmoty. Horizontální rychlost šíření hniloby v kmeni tedy odpovídá rychlosti vertikálního šíření ($r = 0{,}810$, $P < 0{,}05$). Podíl stromů s hnilobou na reprezentativních plochách klesal s věkem porostu – od 86 % (Proklest), resp. 59 % (Mořkov) ve II. třídě přes 81 % (Proklest), resp. 54 % (Mořkov) ve III. třídě k 72 % (Proklest), resp. 43 % (Mořkov) ve IV. třídě. Celkově šlo o 82 % (Proklest), resp. 49 % (Mořkov) všech stromů s poraněním. Kromě dominující hniloby pevníku krvavějícího *Stereum sanguinolentum* byla v kmenech v revíru Mořkov zaznamenána hniloba kořenovníku vrstevnatého *Heterobasidion annosum* a poprašky smrkové *Coniophora piceae*.

Stromy zasažené hnilobou v míře zjištěné v monitorovaných porostech (tj. v průměru 40 % hmoty kmene a 45 % plochy průřezu v místě poškození) mají výrazně sníženou mechanickou stabilitu. Výsledkem rozšíření hniloby ovšem není jen snížení mechanické stability stromu, významně je snížena i jeho adaptabilita. Narušení fyziologických procesů, celkové snížení vitality stromu, to vše je predispozicí pro vznik dalších poškození – například v důsledku nepříznivých klimatických podmínek (vodní stres).

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