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The role of root system in silver birch (*Betula pendula* Roth) dieback in the air-polluted area of Krušné hory Mts.

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ABSTRACT: 120 root systems and trunks of 20 years old birch trees and 60 root systems and trunks of 15 years old birch trees affected by defoliation and with no visual symptoms of damage were analyzed in the air-polluted area of Krušné hory Mts. In the given area, birch develops a superficial or anchoring root system of circular shape. A greater effect of defoliation was recorded in trees with the superficial root system. The defoliation was in correlation with the extent of bole rot, root system rot and rooting depth. The proportion of root system branches infested by rot increased with increasing defoliation. Dominating fungi on roots were *Armillaria gallica* and *Armillaria ostoyae*. The degree of defoliation was directly proportional to the extent of bole rot induced by *Trametes confragosa* and *Armillaria gallica*, infecting frost ribs in the trunks. Extensive defoliation was recorded if more than 25% of peripheral tissues of the trunk and over 15% of root system branches were infected by rot. The defoliated trees showed a marked loss of fine roots, impaired longevity of fine roots and a change of ectomycorrhiza into ectendomycorrhiza.

Keywords: *Betula pendula* Roth; root system; air pollution; bole rot; root rot; mycorrhiza

Its natural range being rather extensive, the birch does not rank with commercially important tree species in Central Europe. It was long considered to be a weed species in commercial forests, and it is the most likely reason why there are only a few records to be found about the species in Central-European forestry literature. Data on the root system are quite exceptional.

Under normal conditions, birch develops a heart-shaped root system (Köstler et al. 1968; Mayer 1977; Polomski, Kuhn 1998). A typical feature of the entire root system of birch is its strong branching tendency. Shooting out directly from the stump in an inclined direction, the main lateral roots rapidly branch into thinner horizontal roots and aslant downwards running heart-shaped roots of large diameters. Heart-shaped roots resembling anchors shoot from the lower part of the stump, and they also branch near to the point of their origin. This is how a sizeable and voluminous root system develops particularly in soils well supplied with nutrients.

Köstler et al. (1968) informed that unlike nearly all the other tree species, birch develops the heart-shaped root system already at a very young age. Birch trees grown from sowing and studied by these authors exhibited typical heart-shaped root systems reaching as deep as to 7–9 (max. 11) dm at the age of 10–12 years. However, according to Amann (1967), at the beginning birch has a tap root that later changes into a root system with lateral roots. Similarly, Kavka (1995) reported that the tap root of birch develops at a young age but soon branches and develops long-reaching lateral roots near the soil surface. Laitakari (1935 in Köstler et al. 1968) detected the tap root in young plants only sporadically.

Assessment of birch root systems at the age of 18 to 20 years made by Starikov (1969), who revealed that a great majority of roots (88.7%) occurred at a depth of 0–40 cm and from the depth of 40 cm their amount was rapidly decreasing. Vertical roots penetrated into a depth of 80 cm. According to Hoffmann (1966), birch roots very intensively through the upper 50 cm of soil. Svoboda (1957) described the birch root system as branching but relatively shallow and assumed that this is why birch often suffers from windthrows on wet and loamy soils in particular. A superficial and far reaching root system of birch was also mentioned by Melzer (1964). Kreutzer (1961), Válek (1977) and Mayer (1977) ranked birch with the species characterized by a deep reaching root system (to 100 cm). Having analyzed trees old 20 to 40 years Kreutzer (1961) detected the regular depth of root penetration to range from 60 to 120 cm. Trees analyzed by this author had several large-diameter main

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lateral roots of typical curved growth, running closely under the soil surface. The rooting density continually decreased from 30 cm downward.

Rooting depth is considerably influenced by the soil character. ERTELD (1942 in KÖSTLER et al. 1968) described the depth reach of 6–17 years old birch trees growing on the poorest sands in northern Germany to range between 4.5 and 26 dm with 43% of studied trees reaching with their roots into a depth of 15 dm. In the irregular vertical root system the greatest depth was reached by so called elbow roots developing at a different distance from the stump. Rooting density reflects the changing conditions of moisture and nutrition to a considerable extent. On pseudogleys, soils poor in nutrients and rich in skeleton, the lower soil layers are only weakly engaged by roots and birch develops a root system similar to that of spruce. The vertical root system exhibits a dieback as early as at the age of 80–100 years due to infestation by red and heart rots with increasing danger of windthrows (KÖSTLER et al. 1968; MAYER 1977). Older birch trees at problematic sites (pseudogleys) usually have some dead parts of the vertical root system.

The horizontal reach of roots can be considerable. LAITAKARI (1934 in KONŠEL 1936) detected extreme lengths of horizontal roots in some cases (20, 25, 26 m). The root diameter rapidly decreased but the cross-section of main roots remained oval-shaped with a narrowing lower part. The poorer the site, the greater the root length. A similar finding was reported by SVOBODA (1957), who stated that the root system breadth fluctuated according to soil quality. VÁLEK (1977) ranked birch in the group of tree species with roots of medium length, reaching up to 6 m.

As to the amount of fine roots, birch takes a middle position among the tree species; oak, black alder and elm have a lower amount of fine roots, and beech and particularly maple and lime have a larger amount of them than birch (KÖSTLER et al. 1968). The authors reported that birch preferably fills the uppermost humus soil layer with its fine roots in which an extremely dense and sometimes even felt-resembling and floccose system of fine roots develops posing significant root competition for other species (so called disc effect of birch). Similarly, KAVKA (1995) reported birch to be very strongly rooting through the upper soil horizons with fine roots. RACHTEJENKO (1952 in KÖSTLER et al. 1968) measured the highest concentration of fine roots in the upper decimeters of the soil with 70% of these roots to be found at a depth of 5–6 dm.

Roots of the last order (root tips) are often transformed into mycorrhizas. According to a number of authors (MEYER 1973 in POLOMSKI, KUHN 1998; KOZLOWSKI, PALLARDY 1997 and other), members of the *Betulaceae* family develop ectomycorrhiza. KLÁN (1989) ranked birch among species with the most developed mycorrhiza. The mycorrhizal symbiosis can be affected by many factors. KOWALSKI (1987) made some measurements of mycorrhiza in common birch (*Betula verrucosa* Ehrh.) on three plots in an air-pollution area. The percentage of live mycorrhizas decreased with the increasing amount of depositions.

Birch is very sensitive to mechanical obstacles in the soil such as high skeleton percentage or soil compaction. Roots that are smooth and stretched flat in homogeneous soils get curved at even a slight soil compaction and the regular root system arrangement becomes confused (ERTELD 1942; RACHTEJENKO 1952; both in KÖSTLER et al. 1968). The birch root system architecture can also be modified by anthropogenic substrate. Being grown on spoil banks of power-plant flue ash birch was observed to develop exclusively superficial roots that did not penetrate into a depth (HARABIN 1970). The same author (HARABIN 1971) observed a similar fact on spoil heaps with toxic materials where birch developed an entirely superficial and very low branching root system.

Air pollution and ecological situation in the Krušné hory Mts. claimed the establishment of stands with substitute tree species whose area is over 30 thousand hectares. The proportion of birch in these stands is significant (40%). Birch was used mainly as an admixed species but there is a number of stands with birch forming monocultures. It is to be pointed out that – with the exception of damage caused by game, snow and rime, the species grew successfully, fulfilling all functions anticipated from the stands of substitute species until the mid-1990s. This situation markedly changed in 1997, when birch trees did not flush on extensive areas, many of them died or have been observed declining since that time – with the symptoms of drying out crowns and general defoliation. Therefore the goal of the paper was to analyze and assess the response of root system to defoliation in this tree species, possibly to find out whether defoliation occurred as a consequence of root system damage.

MATERIAL AND METHODS

Material

Characteristics of stands under study

Trees of silver birch (*Betula pendula* Roth) were studied in the air-polluted area of the Krušné hory Mts. in 2000. The analyses were made in seven significantly exposed and damaged stands and in two sheltered stands in which the defoliation and dieback did not occur (control).

Characteristics of damaged stands:

- LČR (Forests of the Czech Republic) Forest District Červený Hrádek, Stand 72B2, age 18 years, pollution risk zone A, forest type 7K3, altitude 750 m, typical podzol – moderate, anthropogenic, stand established by planting after site preparation by a bulldozer, tree height – 5.7 m; $d_{1.3}$ – 63 mm.
- LČR Forest District Červený Hrádek, Stand 86B2b, age 21 years, pollution risk zone A, forest type 7K3, altitude 820 m, podzolic cultizem – slightly gleyed, stand established by sowing after site preparation by a bulldozer, tree height – 4.7 m, $d_{1.3}$ – 63 mm.

– LČR Forest District Červený Hrádek, Stand 90A2b, age 14 years, pollution risk zone A, forest type 7K3, altitude 860 m, podzolic cultizem, stand established by planting after site preparation by a bulldozer, tree height – 3.9 m, $d_{1.3}$ – 66 mm.
– Jirkov Municipal Forests, Stand 220C3a, age 23 years, pollution risk zone A, forest type 7K3, altitude 760 m, organic podzolic soil – moderate, stand established by sowing after soil surface scarification, tree height – 6.1 m, $d_{1.3}$ – 69 mm.
– Jirkov Municipal Forests, Stand 220A2e, age 18 years, pollution risk zone A, forest type 7K3, altitude 900 m, organic podzolic soil – moderate, anthropogenic, stand established by sowing after site preparation by a bulldozer, tree height – 4.9 m, $d_{1.3}$ – 68 mm.
– Staré Hamry Forests, Stand 114F1, age 23 years, pollution risk zone A, forest type 6S1, altitude 910 m, stand established by sowing after soil surface scarification, tree height – 6.2 m, $d_{1.3}$ – 75 mm.
– Staré Hamry Forests, Stand 113A2z, age 19 years, pollution risk zone A, forest type 6S1, altitude 890 m, stand established by sowing after soil surface scarification, tree height – 7.1 m, $d_{1.3}$ – 77 mm.

Characteristics of control stands:

– LČR Forest District Červený Hrádek, Stand 71D3, age 24 years, pollution risk zone A, forest type 7K3, altitude 710 m, organic podzolic soil – moderate, stand established by sowing after soil surface scarification, tree height – 7.3 m, $d_{1.3}$ – 68 mm.
– LČR Forest District Červený Hrádek, Stand 74A2, age 16 years, pollution risk zone A, forest type 7K3, altitude 700 m, stand established by planting after site preparation by a bulldozer, tree height – 7.5 m, $d_{1.3}$ – 67 mm.

As the stand damage was not homogeneous – in the stands there were always trees with hardly any damage, trees with different degrees of defoliation and dead trees (intact and dead trees growing next to each other), it was necessary to analyze separately for each stand the trees with defoliation from 0 to 20%, from 40 to 50%, from 80 to 90%, and dead trees. Trees chosen for measurements were only those at the main stand level at all times.

Methods of partial analyses

Root system analyses

Root systems of trees to be analyzed were lifted by hand (archaeological method), which made it possible to measure the rooting depth in dependence on the soil horizons. After the lifting, all root systems were subjected to biometric assessments according to the methodology described by MAUER (1989). Longitudinal sections of all roots were assessed visually for the occurrence of rots, symptoms of infestation by fungi and biotic pests. Parameters of fine roots (diameter below 1 mm) ensuring the main portion of nutrition were measured in the most exposed stands and in the control stands as follows:

– Type of mycorrhiza – visually – morphological structure of fine roots (under a stereo-magnifying glass);
– Anatomic structure of mycorrhizas (under a microscope after staining the sections with aniline blue);
– Mycorrhizal infection – by the method of quantitative assessment of glucosamine as the basic element of the fungus body structure (VIGNON et al. 1986) after acidic hydrolysis of chitin (PLASSARD et al. 1982);
– Viability of fine roots – by the method of 2,3,5 triphenyltetrazolium-chloride reduction (JOSLIN, HENDERSON 1984).

Analyses of aboveground parts

All lifted trees were measured to determine biometric indicators of aboveground parts. Each trunk was cut from the tree foot into about 15cm sections and subjected to assessment of the rot surface area on the trunk cross-section and of the extent of rot affecting the peripheral tissues of the trunk at a place of the severest rot infection. The rot surface area was expressed as follows: 0–25%, 25–50%, 50–75%, and over 75%.

In order to identify fungal pathogens, the roots and trunks with rot were subjected to microscopic examinations and cultivation in the wet chamber and on nutrient media in laboratories of the Department of Forest Protection, Mendel University of Agriculture and Forestry, Faculty of Forestry and Wood Technology in Brno.

Mathematical and statistical evaluation

The results of measurements were processed by common mathematical and statistical methods. Tables comprise arithmetic means and standard deviations. Significance of the results was assessed by *t*-test at a level of significance of 95%; the results of the root system architecture were compared with those obtained from trees with defoliation of 0–20%. Results of the test are marked in the tables as follows: + statistically significant value; – statistically insignificant value.

RESULTS

– No statistically significant differences in tree height and stem diameter were found in trees with different degrees of defoliation (evaluated for each analyzed stand separately);
– The degree of defoliation has a direct relation with the extent of trunk and root rots and with the root system "size". Furthermore, the two factors mutually affect each other.

Root system architecture and size (Table 1)

– Defoliation affected trees with the superficial root system to a larger extent than trees with the anchor root system.

Table 1. Root system architecture

Parameter	Control		0–20%		40–50%		80–90%		Dead	
	Anchor root system	Superficial root system	Anchor root system	Superficial root system	Anchor root system	Superficial root system	Anchor root system	Superficial root system	Anchor root system	Superficial root system
Number of analyzed trees (pcs)	8	4	38	4	9	3	16	26	3	9
HSR[1] (pcs)	19.8 ± 5.4–	21.6 ± 5.0–	17.7 ± 5.9	18.8 ± 4.8	15.0 ± 4.3–	16.3 ± 2.6–	10.1 ± 2.6–	10.0 ± 3.0+	9.7 ± 3.4+	10.9 ± 2.9+
Diameter of HSR[1] (mm)	14.2 ± 3.5–	14.6 ± 1.4–	15.5 ± 3.9	14.2 ± 2.2	14.9 ± 4.4–	15.1 ± 2.9–	13.7 ± 3.2–	12.8 ± 2.7–	10.8 ± 2.8–	12.3 ± 1.8–
Max. diameter of HSR[1] (mm)	28.5 ± 8.4–	32.0 ± 6.8–	36.8 ± 10.7	24.0 ± 3.2	26.5 ± 8.3+	25.7 ± 3.2–	15.1 ± 5.7+	22.5 ± 9.7–	11.2 ± 3.0+	17.6 ± 3.8+
Number of anchors (pcs)	14.1 ± 3.6–	–	12.0 ± 6.0	–	6.8 ± 4.8+	–	3.7 ± 2.5+	–	4.0 ± 1.4+	–
Diameter of anchors (mm)	15.3 ± 4.5–	–	15.3 ± 3.1	–	14.4 ± 4.2–	–	12.4 ± 3.1+	–	11.3 ± 2.6+	–
Max. diameter of anchors (mm)	25.1 ± 5.5–	–	29.5 ± 6.9	–	23.3 ± 10.4+	–	16.6 ± 4.9+	–	14.5 ± 2.1+	–
Average rooting depth (cm)	43.2 ± 9.5–	–	46.1 ± 8.8	–	30.3 ± 7.9+	–	24.1 ± 6.8+	–	17.6 ± 3.5+	–
Maximum rooting depth (cm)	56.8 ± 12.4–	–	57.2 ± 18.6	–	37.3 ± 13.9+	–	35.7 ± 12.8+	–	27.6 ± 3.1+	–
Number of non-skeletal roots (pcs)	24.5 ± 7.5–	23.5 ± 7.8–	24.0 ± 13	19.9 ± 7.6	7.8 ± 3.6+	6.3 ± 1.6+	4.1 ± 1.7+	4.3 ± 1.9+	2.7 ± 0.6+	2.0 ± 0.8+
Maximum angle between HSR[1] above 90 degrees (in % of trees)	41	0	5	0	0	0	6	8	0	2

Defoliation: Control, 0–20%, 40–50%, 80–90%, Dead

[1]HSR – horizontal skeletal roots

– No significant differences in superficial root lengths were detected in trees with different degrees of defoliation. Both the undefoliated and the most defoliated trees develop circular or elliptic root systems (in dependence on the terrain slope) with central positioning of the stem. The longest superficial roots do not exceed the length of 3.0 m.
– Trees with the superficial root system (the root system can be found only in humus and humus-enriched horizons with rooting depth not exceeding 15 cm): statistically significant differences between the control and trees with 0–20% defoliation were found in none of the parameters under study. No dependence was detected between the average diameter of horizontal skeletal roots and the degree of defoliation. However, the number of both horizontal skeletal and non-skeletal roots was observed to decrease with increasing defoliation; it was also recorded that the increasing defoliation results in the decreasing maximum diameter of horizontal skeletal roots.
– Trees with the anchor root system: statistically significant differences between the control and trees with 0–20% defoliation were found in none of the parameters under study. No dependence was detected between the average diameter of horizontal skeletal roots and the degree of tree defoliation. The magnitude of all other studied parameters (number and maximum diameter of horizontal skeletal roots, number of non-skeletal roots, number of anchors, both average and maximum diameter of anchors, both average and maximum rooting depth) was observed to decrease with increasing defoliation.

Bole rot (Table 2)

– It is possible to make a clear statement that the incidence of rots has a direct relation to the occurrence of frost cracks (ribs) on the trunk. However, all frost cracks need not necessarily induce the incidence of rot.
– It was found in trees with the superficial and anchor root systems that bole rot unambiguously spread with increasing defoliation. The effect of defoliation appeared to be higher in trees with the rot-infected peripheral tissues of the trunk.
– Laboratory analyses indicated that *Trametes confragosa* (Bolt: Fr.) Jörstad was an entirely dominating fungus on the trunk; another detected fungus was the honey fungus (*Armillaria gallica* Marxmüller et Romagnesi).

Table 2. Bole rot and root system rot

Parameter	Defoliation									
	Control		0–20%		40–50%		80–90%		Dead	
	Anchor root system	Superficial root system	Anchor root system	Superficial root system	Anchor root system	Superficial root system	Anchor root system	Superficial root system	Anchor root system	Superficial root system
Number of analyzed trees (pcs)	8	4	38	4	9	3	16	26	3	9
Frost rib occurrence (in % of trees)	0	0	92	100	100	100	100	100	100	100
Bole rot surface area (in tree pcs)										
– no rot	8	4	10	0	0	0	0	0	0	0
– up to 25% trunk surface area	0	0	12	2	0	0	1	1	0	0
– up to 50% trunk surface area	0	0	14	2	6	3	6	0	0	0
– up to 75% trunk surface area	0	0	2	0	3	0	5	19	0	0
– up to 100% trunk surface area	0	0	0	0	0	0	4	6	3	9
Girth rot (in tree pcs)										
– no rot	8	4	10	0	0	0	0	0	0	0
– up to 25% girth	0	0	26	4	2	1	1	1	0	0
– up to 50% girth	0	0	2	0	7	2	5	10	0	0
– up to 75% girth	0	0	0	0	0	0	8	14	0	0
– up to 100% girth	0	0	0	0	0	0	2	1	3	9
Trees with root system rot (pcs)	2	0	19	2	9	3	16	26	3	9
Number of decomposing roots (in % of total number of roots)	6.6 ± 0.7+	0	13.4 ± 8.1	12.3 ± 3.2	41.0 ± 3.8+	37.6 ± 8.6+	70.2 ± 12.4+	72.4 ± 19.3+	100	100

Table 3. Mycorrhizal infection and viability of fine roots (in humus horizons)

Stand – Defoliation	Amount of glucosamine (μg/100 mg DM)	Viability (%)[1]	Viability variance within the stand (%)
71B3 – Control	8.31 ± 0.69	54	–
72B2c – 0 to 20%	9.07 ± 0.85–	49	11
72B2c – 80 to 90%	8.30 ± 0.76–	38	
220C3a – 0 to 20 %	8.53 ± 0.75–	68	17
220C3a – 80 to 90%	8.67 ± 0.65–	51	

[1]100% = viability of fine roots in birch transplants in a forest nursery unaffected by air pollution

Root system rot (Table 2)

Similarly like in bole rot (from the defoliation of 40 to 50%), the root systems of all analyzed trees were infected by rot. The root system rot was also found in control trees, though. Trees with defoliation of 0–20% showed at least one type of rot (bole rot or root system rot).

- With increasing defoliation, the number of rot-infected branches (roots) of the root system increased at all times.
- Laboratory analyses indicated that the honey fungus (*Armillaria gallica*, *Armillaria ostoyae* Romagn) was a fungus dominating on the roots, another detected fungus being also *Phytophthora* sp.

Analyses of fine roots (Table 3)

- Root branches without rot exhibited ample branching into fine roots while root branches infected by rot showed hardly any occurrence of fine roots. It indicates that the biomass of fine roots decreased (in dependence on defoliation) with the decreasing percentage of root branches uninfected by rot.
- Partial investigations demonstrated that defoliation has no effect on the mycorrhizal infection of fine roots occurring on root branches without rot.
- It was found out by the analyses of morphological structure of fine roots and anatomic structure of mycorrhiza that the root system of birch exhibited the occurrence of ectomycorrhiza (60% white mycorrhiza, 40% black mycorrhiza). It was furthermore found out that trees with defoliation over 60% exhibited a partial change of ectomycorrhiza into ectendomycorrhiza.
- The partial investigations demonstrated that the viability of birch fine roots was considerably lower in the studied area (as compared with the viability of fine roots in birch planting stock grown in a classical forest nursery) and that it was further impaired by the increasing defoliation.

DISCUSSION

The analyses of root systems together with the evaluation of trunk health condition – at all times evaluated individually according to the degree of tree defoliation – demonstrated that the tree defoliation correlated with the extent of bole rot, root system rot, and with the rooting depth. Regarding the fact that defoliation occurred as a single and large-scale event and that it was also markedly individual particularly in older stands, the triggering factor must have been strong with defoliation being influenced by individual predispositions of each tree. One of the main predispositions appears to be the rooting depth and the "size" of the root system. It follows unambiguously from a comparison with the data of other authors (KREUTZER 1961; VÁLEK 1977; MAYER 1977) that the root system of analyzed birch trees in the area under study (despite of the fact that the authors of this paper did not analyze waterlogged sites) is not only very shallow but also often superficial and that the rooting depth increases only with the growing age. It was also found by other investigations unpublished herein that at sites unaffected by air-pollution birch develops a relatively deep root system from the young age, its roots reaching down to a depth of even 120 cm at the age of twenty years. The reasons for the development of shallow and superficial root systems in the studied area are likely individual responses of trees to changes in soil chemistry in consequence of the long-term air-pollution load, to humus deficiency during the initial stages of growth due to site preparation, and to the hydrological situation in the area under study (severe summer droughts). It is assumed that the birch root system response is identical to that found by HARABIN (1970, 1971) on recent formations with the changed chemistry and hydrological regime. The opinion that the degree of birch defoliation relates to the rooting depth – although deduced by the authors from the depth of groundwater table at the site – was also published by ŠRÁMEK et al. (1999) and KULA et al. (1999). The development of shallow root systems in birch at waterlogged sites was described for example by SVOBODA (1957) and KAVKA (1995). The adverse impact of frost or drought is also supported by the authors' finding that trees with large-diameter superficial skeletal roots are relatively more resistant to defoliation.

A serious predisposition to defoliation is bole rot which is unambiguously induced by the development of frost ribs. Some trees exhibited three and even more frost ribs. The formation of frost ribs is often overlooked at a perfunctory inspection of the trunk. Visually it appears to be often only a short crack (or none at all) in the bark. In reality, frost ribs together with rots affect even several meters of the trunk length. The analyses made by the authors revealed that the extent of bole rot could rapidly change – differences in the affected cross-section area by the order of tens of per cent can be seen on a trunk length as short as 20 cm only. The rot does not always affect the basal part of the trunk. Considerable impairment of mechanical stability in living trees with defoliation of 80–90% can be documented by the fact that the trunks can easily be broken at the point of the frost rib.

Several tens of trees younger than 15 years were also included in the analyses (the results not published herein) and it must be stated that nearly all of them died, particularly in the exposed localities. The analysis into their root system architecture and incidence of frost ribs revealed that all of them exhibited very marked frost ribs (which should be assessed in relation to their small stem diameter) and only superficial root systems with small-diameter skeletal roots.

Silver birch is capable to resist to very low temperatures but its hardiness is influenced by the course of weather in winter and early spring periods. If the period of low temperatures is long enough for the trees to overcome dormancy, favourable temperature conditions can initiate biochemical and physiological processes and the growth can be restored including flushing (MYKING, HEIDE 1995). According to TATTAR and TATTAR (1999), water movement in the roots and stems of silver birch occurs if the soil temperature increases above +5°C with the soil temperature sufficient for the restoration of root growth being by up to 5°C lower than the soil temperature required for bud break (POLOMSKI, KUHN 1998). Frost return after the preceding warm period can result in the development of frost ribs. The frequent incidence of frost ribs in the studied area documents that this type of stress occurs relatively often there. A similar event – frost periods after the preceding period of warm weather – apparently resulted in a large-scale dieback of birch in Canada in 1936–1954 (BRAATHE 1995). ŠRÁMEK et al. (1998) assumed that the decline of birch in the Krušné hory Mts. was induced by the unfavourable climatic conditions in the winter period of 1996 (before defoliation). The resistance of birch to temperature fluctuations is markedly reduced by air-pollution attacks and by using the planting stock of improper provenance (HYNEK 1999) as well as by ignoring the phenological form of birch (SVOBODA 1957). And it is just these aspects that were not always taken into consideration at the regeneration of clearings due to salvage felling in the Krušné hory Mts. The fact that it is really the air-pollution and climatic factors that weaken birch in the studied area can further be documented by other verifications made by the authors of this paper (unpublished in the results). The occurrence of frost ribs and defoliation was investigated in 20 years old pure stands of birch in the area of two mountains (Jahodník, Sv. Anna – extended slopes with open aspect and height difference of about 200 m) on transects localized on the hill top, mid-slope and at the slope foot (sheltered stands). The results were unambiguous: trees of mountain peaks exhibited 100% occurrence of frost ribs together with nearly 100% defoliation, trees of mid-slopes showed frost ribs at 60% with over 50% of them being affected by defoliation, and trees growing at the foot of the hills were not observed to show any defoliation with the damage by frost ribs not exceeding 10% of all trees. Another indirect evidence can be the fact that – growing next to birch – the other tree species (larch, Norway spruce, blue spruce, mountain ash) do not exhibit so much pronounced symptoms of decline for the time being.

It should be pointed out that all results presented in the paper were obtained by analyzing trees at the main level. But some stands show the decline and dieback of birch in consequence of neglected tending. Most of these usually suppressed trees, i.e. trees with impaired vitality, exhibited marked defoliation as early as in 1997.

Honey fungus is an important pathogen of birch roots and trunk. Conditions for its development in the studied area are ideal. Nearly all original spruce stands were infected by the fungus. Honey fungus only weakens the tree and the infestation itself is not conditioned by mechanical injury of the trunk or roots. The infestation by honey fungus was detected not only by cultivation on nutrient media but also in the field where abundant resin exudations were observed on the roots and great amounts of honey fungus fruiting bodies grew out not only from the bases of dead trees but also from the bases of trees with defoliation of 80%. If there is a higher number of damaged trees within the stand, they frequently occur in circles, which points to the attack of honey fungus once again. In addition to the impairment of trees by air pollution and climatic factors, the spread of the fungus is obviously supported also by frequent grafting of root branches.

A serious disadvantage of this study is the fact that the investigations were made retrospectively. Although there could have been some changes since the beginning of the large-scale decline in the course of three years, particularly in terms of rot extent and dieback dynamics, the knowledge of root system architecture and all other documented variances between the trees with different defoliation may contribute to a contemplation about the reasons of birch dieback at the present time.

Notwithstanding the above-mentioned facts, it is possible to claim that silver birch has been fulfilling all functions of the stands of substitute species. As it is impossible to eliminate even in the future the negative influence of predispositions and triggering factors, it is desirable that the existing stands of silver birch will be replaced in the localities most exposed to air pollution and climatic stress by a more resistant provenance or by a more resistant tree species.

CONCLUSIONS

Based on the analysis of more than 120 root systems and trunks at the age of 20 years and 60 root systems and trunks of 15 years old silver birches affected by defoliation and with no visual symptoms of injury, it is possible to draw the following conclusions:

- In the studied area birch develops a superficial or anchor root system of circular or elliptic shape with trunk in the middle. Length of superficial horizontal roots does not exceed 3 m.

– Defoliation of trees is in correlation with the extent of bole rot, root system rot and rooting depth.
– Trees with the superficial root system are affected by defoliation to a larger extent. The number of root system branches infected by rot increases with increasing defoliation. The fungi dominating on the roots are *Armillaria gallica* and *Armillaria ostoyae*.
– The degree of defoliation has a direct relation to the extent of bole rots induced by *Trametes confragosa* and *Armillaria gallica*, which infect frost ribs on the trunks. Conspicuous defoliation occurs if the rots affect more than 25% of the peripheral tissues of the trunk and more than 15% of the root system branches.
– Defoliated trees were observed to show a marked loss of fine roots, impaired viability of fine roots and change of ectomycorrhiza into ectendomycorrhiza.
– Air pollution stress is the basic predisposition factor inducing birch decline and dieback. A contributing factor is frost (climatic fluctuations) that promotes development of frost ribs on the trunk and influences superficial roots (to a depth of about 20 cm). Due to the effect of predisposition factors, the trunks and roots are infested by fungal pathogens. Triggering factors of large-scale defoliation can be both the single-action extreme temperature effect or the unrepeated acute or synergistic damage by air pollution.
– The trees with deep-reaching root systems better resist to negative effects.

References

AMANN G., 1967. Bäume und Sträucher des Waldes. Melsungen, Verlag J. Neumann: 231.

BRAATHE P., 1995. Birch dieback – caused by prolonged early spring thaws and subsequent frost. Norw. J. Agric. Sci., *20,* Suppl.: 1–59.

HARABIN Z., 1970. Ukorzenianie sie niektórych gatunkóv drzew i krzewow na zwalach popiolowych. Sylwan, *114*: 45–50.

HARABIN Z., 1971. Wplyw toksycznych wlasciwósti materialu zwalowego na kszaltowanie sie systemow korzeniowych drzew. Sylwan, *115*: 51–65.

HOFFMANN G., 1966. Verlauf der Tiefdurchwurzelung und Feinwurzelbildung bei einigen Baumarten. Arch. Forstwes., *15*: 825–856.

HYNEK V., 1999. Vliv původu náhradních dřevin na jejich odolnost k měnícím se ekologickým podmínkám. In: Sbor. ref. z konf. Problematika zachování porostů náhradních dřevin v imisní oblasti Krušných hor, Most 18.–19. 5. 1999. Praha, MZe ČR: 15–18.

JOSLIN J.D., HENDERSON G.S., 1984. The determination of percentages of living tissue in woody fine root samples using triphenyltetrazolium chloride. Forest Sci., *30*: 965–970.

KAVKA B., 1995. Sadovnická dendrologie I. Listnaté dřeviny. Brno, Eden: 203.

KLÁN J., 1989. Co víme o houbách. Praha, SPN: 310.

KONŠEL J., 1936. Literární rozhledy. (E. Laitakari Kořenová soustava břízy, Helsinki 1934, Acta Forestalia Fennica č. 41). Lesn. Práce, *15*: 124–126.

KOWALSKI S., 1987. Mycotrophy of trees in converted stands remaining under strong pressure of industrial pollution. Angew. Bot., *61*: 64–83.

KOZLOWSKI T.T., PALLARDY S.G., 1997. Physiology of Woody Plants. London, Academic Press: 411.

KÖSTLER J.N., BRÜCKNER E., BIEBELRIETHER H., 1968. Die Wurzeln der Waldbäume. Hamburg und Berlin, Verlag Paul Parey: 284.

KREUTZER K., 1961. Wurzelbildung junger Waldbäume auf Pseudogleyböden. Forstwiss. Cbl., *80*: 356–392.

KULA E., RYBÁŘ V., KAWULOK T., 1999. Stanovištní podmínky a dynamika vývoje zdravotního stavu porostů břízy postižených nevyrašením. In: Sbor. ref. z konf. Problematika zachování porostů náhradních dřevin v imisní oblasti Krušných hor, Most 18.–19. 5. 1999. Praha, MZe ČR: 55–62.

MAUER O., 1989. Vliv antropogenní činnosti na vývoj kořenového systému smrku ztepilého (*Picea abies* /L./ Karsten). [Doktorská dizertační práce.] Brno, VŠZ, LF: 322.

MAYER H., 1977. Waldbau. Stuttgart, New York, Gustav Fischer Verlag: 483.

MELZER E.W., 1964. Die Wurzelausbildung der Holzarten auf den meliorierten Standorten der Oberförsterei Adorf (Vogtland). Arch. Forstwes., *15*: 407–438.

MYKING T., HEIDE O.M., 1995. Dormancy release and chilling requirement of buds of latitudinal ecotypes of *Betula pendula* and *B. pubescens*. Tree Physiol., *15*: 697–704.

PLASSARD C.S., MOUSAIN D.G., SALSAC L.E., 1982. Estimation of mycelial growth of basidiomycetes by means of chitin determination. Phytochemistry, *21*: 345–348.

POLOMSKI J., KUHN N., 1998. Wurzelsysteme. Bern, Stuttgart, Wien, Verlag Paul Haupt: 290.

STARIKOV JU.A.,1969. Osobennosti rosta korněvych sistem někotorych drevesnych porod v pitomnikach. Les. Choz., *12*: 28–30.

SVOBODA P., 1957. Lesní dřeviny a jejich porosty. Část III. Praha, SZN: 457.

ŠRÁMEK V., LOCHMAN V., PASUTHOVÁ J., ŠEBKOVÁ V., 1998. Odumírání březových porostů v Krušných horách. [Závěrečná zpráva.] Jíloviště-Strnady, VÚLHM: 44.

ŠRÁMEK V., LOMSKÝ B., ŠEBKOVÁ V., 1999. Působení abiotických faktorů na porosty náhradních dřevin. Sbor. ref. z konf. Problematika zachování porostů náhradních dřevin v imisní oblasti Krušných hor, Most 18.–19. 5. 1999. Praha, MZe ČR: 27–32.

TATTAR T.A., TATTAR S.J., 1999. Evidence for the downward movement of materials injected into trees. J. Arboric., *25*: 325–332.

VÁLEK Z., 1977. Lesní dřeviny jako vodohospodářský a protierozní činitel. Praha, SZN: 203.

VIGNON C., PLASSARD C.S., MOUSAIN D.G., SALSAC L.E., 1986. Assay of fungal chitin and estimation of mycorrhizal infection. Physiol. Vég., *24*: 201–207.

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Úloha kořenového systému v odumírání břízy bělokoré *(Betula pendula* Roth*)* v imisní oblasti Krušných hor

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ABSTRAKT: V imisní oblasti Krušných hor bylo analyzováno 120 kořenových systémů a kmenů dvacetiletých bříz a 60 kořenových systémů a kmenů patnáctiletých bříz postižených defoliací a bez vizuálních symptomů poškození. Bříza vytváří v zájmové oblasti povrchový nebo kotevní kořenový systém kruhového tvaru. Defoliací jsou více postiženy stromy s povrchovým kořenovým systémem. Defoliace je v korelaci s rozsahem hniloby kmene, hniloby kořenového systému a hloubkou prokořenění. S rostoucí defoliací se zvyšuje podíl větví kořenového systému napadených hnilobou. Dominujícími houbami na kořenech jsou *Armillaria gallica* a *Armillaria ostoyae*. Stupeň defoliace je v přímé vazbě s rozsahem hnilob kmene, vyvolaných *Trametes confragosa* a *Armillaria gallica,* které infikují mrazové kýly na kmenech. K výrazné defoliaci dochází tehdy, je-li hnilobou zasaženo více než 25 % obvodových pletiv kmene a více než 15 % větví kořenového systému. Na defoliovaných stromech byl zaznamenán výrazný úbytek jemných kořenů, snížení jejich životnosti a přechod ektomykorhizy na ektendomykorhizu.

Klíčová slova: *Betula pendula* Roth; kořenový systém; imise; hniloba kmene; hniloba kořenů; mykorhiza

V Krušných horách si imisně ekologická situace vynutila zakládání porostů náhradních dřevin, v nichž je 40 % zastoupena bříza bělokorá (*Betula pendula* Roth). Porosty břízy do poloviny devadesátých let plnily své funkce dobře. V roce 1997 však bříza velkoplošně nevyrašila, mnoho stromů odumřelo nebo od této doby chřadne – dochází k prosychání korun a k celkové defoliaci. Cílem práce bylo posoudit, jaká byla reakce kořenového systému této dřeviny na defoliaci, event. zjistit, zda defoliace nebyla vyvolána poškozením kořenového systému. Za tímto účelem bylo v imisní oblasti Krušných hor analyzováno 120 kořenových systémů a kmenů dvacetiletých bříz a 60 kořenových systémů a kmenů desetiletých bříz, postižených defoliací a bez vizuálních symptomů poškození. Kořenové systémy stromů byly vyzvednuty archeologickým způsobem a biometricky zhodnoceny podle metodiky publikované MAUEREM (1989). U nejvíce poškozených porostů a porostů kontrolních byla vizuálně sledována morfologická stavba jemných kořenů, anatomická stavba mykorhiz a kvantifikována mykorhizní infekce metodou stanovení glukosaminu (VIGNON et al. 1986) po kyselé hydrolýze chitinu (PLASSARD et al. 1982). Byly zjišťovány biometrické charakteristiky nadzemní části analyzovaných stromů a hodnocen rozsah poškození kmenů a kořenových větví hnilobou.

Výsledky lze shrnout do následujících závěrů:

- Bříza vytváří v zájmové oblasti povrchový nebo kotevní kořenový systém kruhového nebo eliptického tvaru s centrálním umístěním kmene. Délka povrchových horizontálních kořenů nepřesahuje 3 m.
- Defoliace stromů je v korelaci s rozsahem hniloby kmene, hniloby kořenového systému a hloubkou prokořenění.
- Defoliací jsou více postiženy stromy s povrchovým kořenovým systémem. S rostoucí defoliací se zvyšuje podíl větví kořenového systému napadených hnilobou. Dominujícími houbami na kořenech jsou *Armillaria gallica* a *Armillaria ostoyae*.
- Stupeň defoliace má přímou vazbu na rozsah hnilob kmene, vyvolaných *Trametes confragosa* a václavkou *Armillaria gallica,* které infikují mrazové kýly na kmenech. K výrazné defoliaci dochází tehdy, je-li hnilobou zasaženo více než 25 % obvodových pletiv kmene a více než 15 % větví kořenového systému.
- Na defoliovaných stromech byl zaznamenán výrazný úbytek jemných kořenů, snížení jejich životnosti a přechod ektomykorhizy na ektendomykorhizu.
- Základním predispozičním faktorem vyvolávajícím chřadnutí a odumírání břízy je imisní atak. Přispívajícím faktorem je působení mrazu (klimatické výkyvy), který vyvolává tvorbu mrazových kýl na kmeni a negativně působí na povrchové kořeny (do hloubky asi 20 cm). Následkem působení predispozičních faktorů jsou kmeny i kořeny napadány houbovými patogeny. Spouštěcím faktorem velkoplošné defoliace potom může být jak jednorázové extrémní působení teplot, tak jednorázové akutní nebo synergické poškození imisemi.
- Negativním vlivům více odolávají stromy s hlubokým kořenovým systémem.

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