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Phytoparameters and content of risk elements in *Dryopteris dilatata* (Hoffm.) A. Gray populations

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Abstract

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The research plots were established in damaged – by pollutants, fungi and bark beetle, and parallel damaged (control) spruce geobiocoenoses pertaining to company Forest of Spišská Nová Ves city Ltd. (locality Muráň – 1,100 m asl, group of forest types Fageta abietino-piceosa, Skeli-Humic Podzol; locality Hliníky – 950 m asl, group of forest types Abieti-Fageta inferiora, very acid Dystric Cambisol). The higher mean shoot length, weight and energy content were found in populations of *Dryopteris dilatata* species growing on locality Hliníky and in damaged spruce stand on locality Muráň. On the other hand the higher ash content was in shoots sampled on non-damaged plots. Content of risk elements ranged in following intervals (mg kg^{-1} of dry matter): Al (88.3–225.0), Pb (2.184–3.340), Ni (0.873–4.379), Cr (<0.050–0.220), Cd (0.571–1.918), Hg (0.0312–0.0423). Limit value Hg (0.02 mg kg^{-1}) was exceeded on all studied plots, while the normal value of Al (about 200 mg kg^{-1}) only in case of population growing in damaged stand on locality Hliníky.

Key words

spruce ecosystem, *Dryopteris dilatata*, growth parameters, risk elements

Introduction

The forest management in Spiš region is difficult on account of unfavourable health state of spruce stands. On that account it was by organs of state administration of forest management integrated among regions with endangered forests.

The spruce declines owing excessive lost of assimilatory organs caused by unfavourable synergic impact of abiotic and biotic factors. The problems are caused primarily by insufficient nutrition of stands cultivated on acid soils formed from rocks poor in basic cations, secondary mainly the consequences of mine activities, long-term impact of acid atmospheric pollutants and acid spruce litter, excessive pressure of wind and snow, unfavourable influence of bark beetles and fungi and insufficient level of forest hygiene and protection.

Cultivation of spruce as economically very advantageous tree species has in Spiš region long-term tradition. At present there are often cultivated spruce monocultures of the 2nd to 3rd generation, which origin, genetic quality and ecological requirements are not known. Homogeneous, by age, height and thickness non-differentiated, ecologically non-stabile spruce stands become progressively sparse, open, what is consequently manifested in succession changes running in their undergrowth. In consequence of the soil acidification the natural reproduction of autochthonous tree species (beech, fir, sycamore maple) is very slow and the stands must be regenerated artificially.

The stress phenomena connected with unfavourable environmental impacts, including immissions, it is possible to observe as on the tree species as herb layer species populations of spruce ecosystems. There can be sufficiently characterised by means of phytoparameter values and results of chemical analyses of samples taken from suitably selected herb species. The object advisable for evaluation of air quality and pollution load of forest ecosystems are mainly the species of herb layer having greater ecological amplitude currently occurring in the forest stands in sufficient amounts. One of these is even *Dryopteris dilatata* (Hoffm.) A. Gray species occurring on all studied plots. The paper is aimed at evaluation of the stress factor impacts acting in segments undamaged and damaged spruces geobiocoenoses on values of phytoparameters of this fern species populations and their connections to content of some risk elements in aboveground biomass.

Material and methods

The investigation was realized in spruce geobiocoenoses pertaining to company Forest of Spišská Nová Ves city Ltd. in 2003. The research plots were established in damaged – by pollutants, fungi and bark beetle, and parallel undamaged (control) spruce stands situated along a vertical transect (plots A and B in the locality Muráň – 1,100 m asl, plots C and D in the locality Hliníky – 950 m asl). Basic characteristics of studied forest ecosystems are described in Table 1.

The soils were classified according to Collective (2000), the geobiocoenoses in the sense of Zlatník (1976a, b) and the names of plant taxa were given according to Dostál (1989). The plant material was obtained by means of random sampling from an area of 400 m^2 of the phytocoenological relevé. As plant individuum was considered each shoot (leaf) in polycormon of the *Dryopteris dilatata* species. There were determined the length of sampled shoots and after drying at 80 °C during 48 hours the mass with a precision of 0.002 g. The energy values of shoots were determined using an adiabatic calorimeter IKA C 4000 (C-402 software). By planetary micro mill homogenised (<0.001 mm) sample weighing 0.7–1 g was pressed into a form of briquette, dried at 105 °C, to a constant weight, and burnt in pure oxygen under a pressure of 3.04 MPa. The content of ash components was determined gravimetrically, by perfect burning of specimens in a muffle oven at 500 °C (Javorský et al., 1987).

The plant material was not washed before performing of chemical analyses. The samples were homogenised and decomposed using the method of micro-wave mineralising. The content of risk elements (Cd, Hg, Al, Pb, Ni, Cr) was determined using absorption spectrophotometry, by means of an analyser AES-ICP (firm LECO). All the analyses were performed in the laboratory of the Forest Research Institute in Zvolen.

The influence of ecological conditions on the average shoot length of the studied species was evaluated using the method ANOVA and the Scheffe´s test at the significance level $p < 0.01$. Homogeneity of the shoot variance was evaluated with the Bartlett´s test (Statgraphics software).

Results and discussion

Character of the phytocoenoses and geobiocoenoses

The soils of geobiocoenoses occurring on the vertical transect Hliníky – Muráň were formed from quartz conglomerates changing in the locality Muráň to violet-grey schist. Owing to the low content of nutrients were in conditions of cold climate formed the very acid Dystric Cambisols and Skeli-Humic Podsols (Table 1). Dystric Cambisols are deep soils with medium skeleton content and sufficient water capacity, but low nutrient reserves. Active reaction of these soils is, similar to podsols, very acid – in humus horizons fell below the pH value of 3.9, that means in the range characteristic for oligotrophic order of geobiocoenoses (according to Kukla, 1993). The Skeli-Humic Podsols have, apart from very low nutrient supply, also low water capacity and they do not provide sufficient space for growth of root system of spruce stands.

The species composition of the phytocoenoses corresponds to the trophic character of soils in the studied geobiocoenoses. Characteristic is abundant to dominant presence of hemi-oligotrophic to oligotrophic species as *Avenella flexuosa, Vaccinium myrtillus, Luzula luzuloides* and *Maianthemum bifolium*, occurring together with species tolerating acid soil environment as *Oxalis acetosella, Dryopteris dilatata, Rubus idaeus,* and others. The presence of mesotrophic species is very low or these species are totally absent (Kukla and Kuklová, 2005). The differential species distinguishing the 6th forest vegetation degree and 5th forest vegetation degree is *Luzula sylvatica*.

Growth parameters of the *Dryopteris dilatata* species

The values of selected parameters of the *Dryopteris dilatata* species populations growing on plots along the vertical transect are in Table 2. Higher mean length, weight and energy content were found in shoots sampled on plots situated in the locality Hliníky and from damaged spruce stands. On the other hand, the higher contents of ash components were found in shoots sampled from control plots.

Statistical analysis has revealed significant differences in average shoot lengths of this species growing at different altitudes. This fact, however, was probably not connected with different climate but with specific soil-ecological conditions (high acidity and skeleton content). There were also significant differences in shoot length between parallel plots C and D, evidently connected with substantially higher light supply to the calamity plot.

The total energy content in plants is primarily dependent on amount of energy contained in the separate organic components as carbohydrates (especially saccharides), proteins and lipids (Usui et al., 1994). In case of *Dryopteris dilatata* species were not found significant fluctuations in mean weight and energy content per 1 g of dry matter and the higher values were found in samples taken from damaged spruce stands. The higher contents of ash in material sampled from control plots were probably connected with unfavourable light conditions. The contents of ash found on damaged plots A and C are, according to LARCHER (1988), characteristic for soils very poor in accessible nutrients.

Content of risk elements in the *Dryopteris dilatata* species

Basic information about the content of risk elements in shoots of *Dryopteris dilatata* species is in Table 3. The highest content of **aluminium** – one of the most toxic element for plants was found in plant material sampled from the damaged spruce stand in the locality Hliníky where concentration of this element was above normal content in plants (about 200 mg kg^{-1} of dry matter) reported by KABATA-PENDIAS and PENDIAS (1989). Rather high amounts of aluminium were also found in samples taken from the control plots (162–194 mg kg^{-1} of dry matter). This fact is probably connected with low pH_{H2O} values in the surface humus of soils. SKUHRAVÝ et al. (1995) found the similar values (139 do 177 mg kg^{-1} of dry matter) in 1–4 years old spruce needles sampled from 23 localities in Czech Republic.

Table 1. Base characteristics of the studied geobiocoenoses

Locality	Muráň		Hliníky	
Stand	173		411	394
Research plot	damaged	control	damaged	control
	A	B	C	D
Altitude (m)	1,110	1,080	960	950
Slope aspect	SZ	SSZ	J	JZ
Inclination (º)	30	30	10	10
Parent rock	quartz conglomerates	violet-grey schist	quartz conglomerates	
Soil subtype Skeleton (%)	Skeli-Humic Podzol 80– 90		Dystric Cambisol 20–40	
Soil depth (cm)	70	110	90	75
Forest vegetation degree	6th spruce-beech-fir		5th fir-beech	
Edaphic-hydric order	a little limited		leading	
Edaphic-trophic order/interorder	oligotrophic		hemioligotrophic	
Group of types of geobiocoens	Fageta abietino-piceosa		Abieti-Fageta inferiora	

Table 2. The growth parameters of *Dryopteris dilatata* species

Research plot	Length					Weight	Content of		
	Sample size	Average	Min	Max	SD		energy		ash
	(cm)					(g shoot $^{-1}$)	(kJ $shoot^{-1}$)	(J g^{-1} of dry matter)	(%)
A damaged	21	31.4 (C, D)	17	49	±8.5	0.616	12.0	19,507	5.53
B control	35	22.7 (C, D)	14	44	±6.3	0.256	4.9	19,293	6.28
C damaged	30	49.9 (D)	21	73	±10.4	2.202	44.5	20,221	5.55
D control	30	40.9	28	65	±9.9	0.973	19.4	19,901	5.77

The plots with significant differences in shoot length ($p < 0.01$, Scheffe's test) are given in brackets.

Table 3. Content of risk elements in *Dryopteris dilatata* shoots

Locality Research plot Element	Muráň		Hliníky	
	A – damaged	B – control	C – damaged	D – control
	(mg kg^{-1}of dry matter)			
Al	88.300	194.000	225.000	162.000
Pb	2.818	3.340	2.958	2.184
Ni	0.873	1.917	3.749	4.379
Cr	< 0.050	< 0.050	0.220	0.095
Cd	1.056	1.918	1.137	0.571
Hg	0.0312	0.0379	0.0342	0.0423

Normal values of **lead** content in plants range between 0.2–20 mg kg^{-1} of dry matter (Bowen, 1979) and the critical concentrations are between 30–300 mg kg^{-1} of dry matter (Kabata-Pendias and Pendias, 1989). On the other hand, Facek et al. (1983, in Dykyjová et al., 1989) consider as toxic already content 3.0–5.0 mg kg^{-1} of dry matter. The lead contents (1.8–3.6 mg kg^{-1} of dry matter) in leaves of *Dryopteris dilatata* species sampled from the plots along the vertical transect were found under the threshold of mentioned toxic range. The similar concentrations of lead found Kozanecka et al. (2002) in the *Dryopteris filix-mas* species sampled in non-polluted region of Puszcza Biała in Poland.

The content of **nickel** in phytomass is mainly dependent on the content of this element in soil (Uhlig and Junttila, 2001). The critical concentrations of Ni in plants range, according to Kabata-Pendias and Pendias (1989) between 10 and 100 mg kg^{-1}1 of dry matter. In case of agricultural products crops it is, by Sauerbeck (1982, in Uhlig and Junttila, 2001) 20 mg Ni kg^{-1} of dry matter. The natural content of Ni in plants is according to Facek et al. (1983, in Dykyjová et al., 1989) 1–4 mg kg^{-1} dry matter, the toxic is 5.7–7.0 mg kg^{-1} of dry matter. Bowen (1979) considers as a normal value 0.02–5 mg Ni kg^{-1} of dry matter. Concentrations of Ni in leaves of the *Dryopteris dilatata* species did not exceed the upper limit of the allowable range reported by Bowen (1979). Kozanecka et al. (2002) found in some samples of *Dryopteris filix-mas* species taken from non-polluted region Puszcza Biała in Poland up to 9 mg Ni kg^{-1} of dry matter (1.9–8.8 mg kg^{-1} dry matter).

The normal content of **chromium** in plants is, according to Bowen (1979) ranging between 0.03–14 mg kg^{-1} of dry matter. Facek et al. (1983, in Dykyjová et al., 1989) consider normal Cr content 0.2–1.5 mg kg^{-1} of dry matter and Cr content higher than 5 mg kg^{-1} of dry matter toxic. The Cr values critical for plants, according to Kabata-Pendias and Pendias (1989) are 5–30 mg kg^{-1} of dry matter. The values found in *Dryopteris dilatata* species growing on localities Hliníky and Muráň are rather low, lower than the values of 0.3–1.8 mg kg^{-1} found in the species *Dryopteris filix-mas* sampled in non-polluted region Puszcza Biała by Kozanecka et al. (2002).

Cadmium is a heavy metal with significant toxic effects on plants. The most part of Cd is received by plant roots, which are the first indicator of its toxic impact. The highest Cd content is in general in root tissues, lower amounts are in leaves, stems, fruits and seeds (Szabová et al., 1998). Normal range of Cd concentration in plants is, by Bowen (1979) 0.1–2.4 mg kg^{-1} of dry matter. The values 5–30 mg kg^{-1} of dry matter are considered to be critical (Kabata-Pendias and Pendias, 1989). Loading of the *Dryopteris dilatata* species by Cd is not significant. It is similar to the values found by Kozanecka et al. (2002) for *Dryopteris filix-mas* species growing in non-polluted region Puszcza Biała in Poland (0.6–2.2 mg Cd kg^{-1} in dry matter). Bublinec (1994) found in beech leaves only 0.3 mg Cd kg^{-1} of dry matter.

Mercury is a risk element with toxic effects on living organisms even at very low concentrations (Bencko et al., 1995). Bowen (1979) considers normal range of Hg in plants 0.005–0.17 mg kg^{-1} of dry matter. On the other hands according to Facek et al. (1983, in Dykyjová et al., 1989) the natural Hg content in plants reaches 0.02 mg kg^{-1} of dry matter. The critical Hg value in plants ranges between 1–3 mg kg^{-1} of dry matter (Kabata-Pendias and Pendias, 1989). The content of mercury found in *Dryopteris dilatata* species along a vertical transect is higher than the natural content of this element in plants (0.02 mg kg^{-1}), but lower than the critical values reported by Kabata-Pendias and Pendias (1989).

Conclusions

The process of contamination of plant organisms by pollutants is a very complicated. Their content depends as on the plant species and its development state as on the state and development of soil, climatic and biotic factors. The heavy metals represent a stressing agent for plants, unfavourably influencing their health state and vitality, which can result in substantial changes initiating extinction of the whole biocoenoses.

The effect of stressing agents on the locality Muráň was manifested with the earlier start and higher rate of spruce stands decline, in comparison with the other plots on the vertical transect. The species in the herb undergrowth were responding to unfavourable ecological conditions especially through lowering their vitality and values of their phytoparameters.

In case of *Dryopteris dilatata* species, higher average values of shoot length, weight and energy content were found in the locality Hliníky (plots C, D). There were also differences in phytoparameters of shoots sampled from damaged and undamaged control plots. Significantly different length of shoots sampled from parallel plots C and D was evidently connected with substantially higher light supply to the disaster plot.

The results of chemical analyses of aboveground phytomass of the examined species have shown that the amounts of selected risk elements in the control and disaster spruce stands of the 5th and 6th forest vegetation degree, situated on plots along the vertical transect Muráň – Hliníky are in general corresponding to the normal values reported in the literature. The threshold values have only been exceeded in case of aluminium (damaged stand in locality Hliníky) and the natural content of mercury on all plots.

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References

BENCKO, V., CIKRT, M., LENER, J. 1995. T*oxické kovy v životním a pracovním prostředí člověka* [Toxic metals in the human living and working environment]. Praha: Grada, Publishing. 282 p.

BOWEN, H. J. M.. 1979. *Environmental chemistry of the elements.* London: Academic Press. 333 p.

BUBLINEC, E. 1994. *Koncentrácia, akumulácia a kolobeh prvkov v bukovom a smrekovom ekosystéme* [Concentration, accumulation and cycling of elements in beech and spruce ecosystems]. Acta dendrobiol. Bratislava: Veda. 85 p.

COLLECTIVE. 2000. *Morfogenetický klasifikačný systém pôd Slovenska. Bazálna referenčná taxonómia* [Morphogenetic soil classification system of Slovakia. Basic referential taxonomy]. Bratislava: VÚPOP, Societas pedologica Slovaka. 76 p.

DOSTáL, J. 1989. *Nová květena ČSSR 2* [New flora of the Czechoslovak Socialistic Republic 2]. Praha: Academia. 1548 p.

DYKYJOVÁ, D. 1989. *Metody studia ekosystémů* [Methods of ecosystems studies]. Praha: Academia. 690 p.

JAVORSKÝ, P., FOJTÍKOVÁ, D., KALAŠ, V., SCHWARZ, M. 1987. *Chemické rozbory v zemědělských laboratořích* [Chemical analyses in an agricultural laboratory]. České Budějovice: MZVž. 397 p.

KABATA-PENDIAS, A., PENDIAS, H. 1989. Mikroelementy v pochvakh i rasteniyakh [*Trace Elements in Soils and Plants*]. Moskva: Mir. 439 p.

KOZANECKA, T., CHOJNICKI, J., KWASOWSKI, W. 2002. Content of heavy metals in plants from pollution-free regions. *Pol. J. envir. Stud*., 11, 4: 395–399.

KUKLA, J. 1993. A direct determination of the geobiocene edaphic-trophic orders and interorders. *Ekológia (Bratislava)*, 12: 373̄385.

KUKLA, J., KUKLOVÁ, M. 2005. Pedoekologické podmienky a fytoparametre druhov Dryopteris dilatata (Hoffm.) A. Gray a Vaccinium myrtillus (L.) v oblasti Spiša [Pedo-ecological conditions and phytoparameters of Dryopteris dilatata (Hoffm.) A. Gray and Vaccinium myrtillus (L.) species in the Spiš region]. In SOBOCKÁ, J. (ed.). *Štvrté pôdoznalecké dni na Slovensku. Zborník referátov z vedeckej konferencie pôdoznalcov.* Bratislava: VÚPOP, p. 201–206.

LARCHER, W. 1988. *Fyziologická ekologie rostlin* [Physiological plant ecology]. Praha: Academia. 361 p.

SKUHRAVÝ, V., ČÍHALÍK, J., MATERNA, J., HRUBÍK, P. 1995. Content of 16 heavy metals and other elements in spruce needles (1–4 years old) from 23 sites of the Czech Republic. *Ekológia (Bratislava)*, 14: 323–330.

SZABOVÁ, T., LEŠČINSKÁ, M., GONDOVÁ, A. 1998. Vplyv aplikácie čistiarenských kalov na kumuláciu ťažkých kovov v rastlinách [Heavy metal accumulation in crops after sewage sludge application]. *Acta Montanistika Slovaca*, 3, 4: 478–481.

UHLIG, C., JUNTTILA, O. 2001. Airborne heavy metal pollution and its effects on foliar elemental composition of Empetrum hermaphroditum and Vaccinium myrtillus in Sør-Varanger, northern Norway. *Envir. Poll.*, 114: 461–469.

USUI, M., KAKUDA, Y., KEVAN, P. G. 1994. Composition and energy values of wild fruits from the boreal forest of northern Ontario. *Can. J. Pl. Sc*., 74: 581–587.

Zlatník, A. 1976a. Přehled skupin typů geobiocénů původne lesních a křovinových v ČSSR [Survey of groups of types of geobiocoens primarily forest and shruby in the C.S.S.R]. *Zprávy Geogr. Úst. ČSAV*, 13: 55–64.

Zlatník, A. 1976b. *Lesnická fytocenologie* [Forest phytocenology]. Praha: Státní zemědělské nakladatelství. 495 p.

Fytoparametre a obsah rizikových prvkov v populáciách druhu *Dryopteris dilatata* (Hoffm.) A. Gray

Súhrn

Výskumné plochy boli založené v imisiami, hubami a podkôrnym hmyzom poškodených a v paralelných nepoškodených (kontrolných) smrekových geobiocenózach patriacich spoločnosti Lesy mesta Spišská Nová Ves s. r. o. (lokalita Muráň – 1 100 m n. m., skupina lesných typov Fageta abietino-piceosa, veľmi skeletnatý humusovo-železitý podzol; lokalita Hliníky – 950 m n. m., skupina lesných typov Abieti-Fageta inferiora, veľmi kyslé kambizeme podzolové). Vyššia priemerná dĺžka, hmotnosť a obsah energie výhonkov sa zistili v populáciách druhu *Dryopteris dilatata* rastúcich na lokalite Hliníky a v kalamitne poškodenom smrekovom poraste na lokalite Muráň. Vyšší obsah popola bol naopak vo výhonkoch odobratých na nepoškodených plochách. Obsah rizikových prvkov sa pohyboval v nasledovných intervaloch (mg kg^{-1} sušiny): Al (88,3–225,0), Pb (2,184–3,340), Ni (0,873–4,379), Cr (<0,050–0,220), Cd (0,571–1,918), Hg (0,0312–0,0423). Prirodzený obsah Hg (0,02 mg kg^{-1}) bol prekročený na všetkých skúmaných plochách, zatiaľ čo normálna hodnota Al (okolo 200 mg kg^{-1}) len v prípade populácie druhu rastúcej v kalamitou poškodenom poraste na lokalite Hliníky.