

Entomophthoralean fungi associated with aphids in woody plants in the Arboretum Mlyňany SAS

Marek Barta

Department of Applied Dendrology, Arboretum Mlyňany SAS, Vieska nad Žitavou 178, 951 52 Slepčany,
Slovak Republic, E-mail: marek.barta@savba.sk

Abstract

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A survey of entomophthoralean fungi infecting aphids in collections of woody plants in the Arboretum Mlyňany SAS was conducted during vegetation periods 2007 and 2008. Altogether, eight fungal species were identified in the aphid colonies. Of the fungi recorded, *Pandora neoaphidis* (Remaudière et Hennebert) Humber, *Entomophthora planchoniana* Cornu and *Neozygites fresenii* (Nowakowski) Remaudière et Keller were predominating ones. *Zoophthora radicans* (Brefeld) Batko, *Zoophthora aphidis* (Hoffman in Fresenius) Remaudière et Hennebert, *Neozygites cinarae* Keller, *Conidiobolus coronatus* (Costantin) Batko and *Conidiobolus obscurus* (Hall et Dunn) Remaudière et Keller were less important parasitic fungi. The number of species of fungi recorded reflects a great diversity in aphid-pathogenic flora in the arboretum. The entomophthoralean fungi were recorded from 40 aphid species belonging to 4 families (*Aphididae*, *Drepanosiphidae*, *Lachnidae* and *Anoeciidae*). Findings of entomophthoralean infection in *Myzocallis castanicola* Baker, *Myzocallis carpini* (Koch), *Myzocallis walshii* Monell and *Myzus ligustri* Mosley colonies are considered first reports from these aphid species at all. In Slovakia, *C. coronatus* is recorded from natural aphid colonies for the first time.

Key words

Arboretum Mlyňany SAS, entomopathogenic fungi, Entomophthorales, tree aphids

Introduction

Entomophthoralean fungi have been found to be important mortality factors for aphids all over the world (LATGÉ and PAPIEROK, 1988). The fungi can cause lethal infections of various aphid species, and they belong to the most effective control agents of natural aphid colonies. At present, 33 entomophthoralean species are known causing mycoses in aphid populations (BARTA and CAGÁŇ, 2006a). Intensive studies were realised to contribute to understanding the fungal distribution and epidemiology in insect populations and to the fungal management within the biological control strategies in agricultural crops (PELL et al., 2001). In Slovakia, several studies were realised on entomophthoralean fungi infecting economically important aphids in agriculture (CAGÁŇ and BARTA, 2001; BARTA and CAGÁŇ, 2002, 2003, 2004), and 15 fungal species have been identified from the infected aphids (BARTA and CAGÁŇ, 2006b).

Most of the fungal pathogens have been reported from aphids living in various herbs or in field crops (BARTA and CAGÁŇ, 2006b). However, the activity of this group of fungi in tree aphid populations has not been documented yet. Different species spectrum of aphids and their pathogens can be expected on trees, therefore investigation of these aphid colonies should reveal additional fungal species in Slovakia.

The Arboretum Mlyňany SAS, a park of exotic woody plants established in southern Slovakia, is focused on planting evergreen woody plants, especially those from the Mediterranean, East-Asian and North American flora. A great richness of dendroflora in the arboretum, with more than 2000 woody plant taxa, provides an opportunity for study the species spectrum of aphids and their fungal pathogens.

We initiated an investigation to determine the species complex of entomopathogenic fungi in aphid colonies associated with the woody plants in the Arboretum

Mlyňany SAS. In this paper, we provide a list of aphid pathogenic fungi from the order Entomophthorales recorded in the aphids.

Material and methods

We studied aphid pathogens in collections of woody plants in the Arboretum Mlyňany SAS. This botanical garden, with a total area of 67 ha, is situated in southern Slovakia in the village of Vieska nad Žitavou (48°19'12" N, 18°22'09" E) at an altitude of 168–214 m asl. The mean annual temperature is 9.7 °C, and the mean annual precipitation is 558 mm.

The sampling of aphids was carried out at one-week intervals during growing seasons 2007 and 2008. The survey started at the beginning of May and finished at the end of October. All cadavers of aphids (fungus-killed aphids) were collected randomly. If woody plants were found infested with aphids, the aphid colonies were visually examined to find fungus-killed individuals. Cadavers with external symptoms of entomophthoralean infection were carefully removed from the plants and placed into plastic tubes (12 ml). As many as possible aphid cadavers were picked up from aphid colonies at each sampling event. If fungus-killed aphids showed the same external signs of disease in the same colony, they were suspected to be infected by the same fungal pathogen, and they were placed together in one plastic tube. Aphids with apparently different symptoms of disease were placed in separate tubes. The samples of fungus-killed aphids were used for identification of pathogen species with using the keys by KELLER (1987, 1991) and BALÁZY (1993). Samples of living aphids were also collected from colonies where

infected aphids occurred, and the aphids were stored in small polystyrene tubes (5 ml) filled with 70% ethanol. These samples were used for aphid identification. The aphids were identified using the key by BLACKMAN and EASTOP (1994).

Results and discussion

Eight species of entomopathogenic fungi belonging to three entomophthoralean families were identified from aphid colonies in the course of the survey: *Pandora neoaphidis* (Remaudière et Hennebert) Humber, *Entomophthora planchoniana* Cornu, *Zoophthora radicans* (Brefeld) Batko and *Zoophthora aphidis* (Hoffman in Fresenius) Remaudière et Hennebert from the family Entomophthoraceae, *Neozygites fresenii* (Nowakowski) Remaudière et Keller, *Neozygites cinarae* Keller from then family *Neozygiteaceae* and *Conidiobolus obscurus* (Hall et Dunn) Remaudière et Keller and *Conidiobolus coronatus* (Costantin) Batko from the family Ancylistaceae. The eight species of entomopathogenic fungi recorded in the arboretum reflect a great diversity in the aphid-pathogenic mycoflora. Of the Entomophthorales recorded, seven species have already been reported from Slovakia (BARTA and CAGÁN, 2006b), but *C. coronatus* is considered as the first record from natural aphid colonies in Slovakia. The fungal pathogens were identified altogether from 40 aphid species. A complete list of aphids, their host trees and fungal pathogens is in Table 1. Majority of the aphid species belonged to the family Aphididae (28 species) and the remaining species were from the families Drepanosiphidae (10 species), Lachnidae (one species), and Anoecidae (one species).

Table 1. List of aphid species and their fungal pathogens observed on woody plants in Arboretum Mlyňany SAS in 2007 and 2008

Host woody plant	Aphid species	Aphid pathogens
<i>Acer buergerianum</i> Miq.	<i>Periphyllus testudinaceus</i> (Ferne)	<i>Neozygites fresenii</i>
<i>Acer campestre</i> L.	<i>Periphyllus testudinaceus</i> (Ferne)	<i>Pandora neoaphidis</i>
<i>Acer platanoides</i> L.	<i>Drepanosiphum platanoidis</i> (Schrank)	<i>Entomophthora planchoniana</i> <i>Conidiobolus coronatus</i>
<i>Acer pseudoplatanus</i> L.	<i>Periphyllus testudinaceus</i> (Ferne)	<i>Neozygites fresenii</i>
<i>Betula pendula</i> Roth	<i>Callipterinella calliptera</i> (Hartig)	<i>Pandora neoaphidis</i>
	<i>Euceraphis betulae</i> Koch	<i>Neozygites fresenii</i> <i>Entomophthora planchoniana</i>
<i>Betula platyphylla</i> Sukatshev	<i>Callipterinella calliptera</i> (Hartig)	<i>Pandora neoaphidis</i>
	<i>Euceraphis betulae</i> Koch	<i>Neozygites fresenii</i> <i>Entomophthora planchoniana</i>
<i>Castanea sativa</i> Mill.	<i>Myzocallis castanicola</i> Baker	<i>Entomophthora planchoniana</i>

Table 1. Continued

Host woody plant	Aphid species	Aphid pathogens
<i>Carpinus betulus</i> L.	<i>Myzocallis carpini</i> (Koch)	<i>Entomophthora planchoniana</i>
<i>Cerasus avium</i> (L.) Moench	<i>Myzus cerasi</i> (Fabricius)	<i>Entomophthora planchoniana</i> <i>Neozygites fresenii</i> <i>Zoophthora aphidis</i> <i>Pandora neoaphidis</i> <i>Conidiobolus coronatus</i>
<i>Cornus mas</i> L.	<i>Anoecia corni</i> (Fabricius)	<i>Zoophthora aphidis</i>
<i>Cornus sanguinea</i> L.		<i>Entomophthora planchoniana</i>
<i>Crataegus monogyna</i> Jacq.	<i>Dysaphis crataegi</i> (Kaltenbach)	<i>Pandora neoaphidis</i>
<i>Corylus avellana</i> L.	<i>Myzocallis coryli</i> (Goeze)	<i>Entomophthora planchoniana</i>
<i>Corylus maxima</i> Mill. 'Purpurea'	<i>Myzocallis coryli</i> (Goeze)	<i>Entomophthora planchoniana</i>
<i>Elaeagnus angustifolia</i> L.	<i>Capitophorus elaeagni</i>	<i>Neozygites fresenii</i>
<i>Elaeagnus multiflora</i> Thunb.	(del Guercio)	<i>Entomophthora planchoniana</i>
<i>Elaeagnus umbellata</i> Thunb.		
<i>Eucommia ulmoides</i> Oliv.	<i>Myzus persicae</i> (Sulzer)	<i>Entomophthora planchoniana</i> <i>Neozygites fresenii</i> <i>Conidiobolus coronatus</i>
<i>Euonymus alatus</i> (Thunb.) Sieb.	<i>Aphis fabae</i> Scopoli	<i>Neozygites fresenii</i>
<i>Euonymus europaeus</i> L.	<i>Aphis fabae</i> Scopoli	<i>Pandora neoaphidis</i> <i>Entomophthora planchoniana</i> <i>Neozygites fresenii</i>
<i>Euonymus grandiflorus</i> Wall. ex Roxb.	<i>Aphis fabae</i> Scopoli	<i>Pandora neoaphidis</i> <i>Entomophthora planchoniana</i> <i>Neozygites fresenii</i>
<i>Euonymus hamiltonianus</i> Wall.	<i>Aphis fabae</i> Scopoli	<i>Pandora neoaphidis</i> <i>Entomophthora planchoniana</i> <i>Neozygites fresenii</i>
<i>Euonymus hamiltonianus</i> Wall. var. <i>maackii</i>	<i>Aphis fabae</i> Scopoli	<i>Pandora neoaphidis</i> <i>Conidiobolus obscurus</i>
<i>Euonymus yedoensis</i> Koehne.	<i>Aphis fabae</i> Scopoli	<i>Pandora neoaphidis</i>
<i>Fagus silvatica</i> L.	<i>Phyllaphis fagi</i> (L.)	<i>Entomophthora planchoniana</i>
<i>Fagus silvatica</i> L. 'Rohanii'	<i>Phyllaphis fagi</i> (L.)	<i>Entomophthora planchoniana</i>
<i>Hibiscus syriacus</i> L.	<i>Aphis fabae</i> Scopoli	<i>Entomophthora planchoniana</i> <i>Neozygites fresenii</i>
	<i>Aphis gossypii</i> Glover	<i>Neozygites fresenii</i>
<i>Hippophae rhamnoides</i> L.	<i>Capitophorus elaeagni</i>	<i>Neozygites fresenii</i>
	(del Guercio)	<i>Entomophthora planchoniana</i>
<i>Laburnum anagyroides</i> Med.	<i>Aphis craccivora</i> Koch	<i>Neozygites fresenii</i>
<i>Ligustrum vulgare</i> L.	<i>Myzus ligustri</i> Mosley	<i>Entomophthora planchoniana</i>
<i>Malus sikkemensis</i> (Wenzig) Koehne	<i>Aphis pomi</i> De Geer	<i>Pandora neoaphidis</i> <i>Neozygites fresenii</i>
<i>Malus</i> sp.	<i>Aphis pomi</i> De Geer	<i>Pandora neoaphidis</i> <i>Entomophthora planchoniana</i> <i>Neozygites fresenii</i> <i>Conidiobolus obscurus</i> <i>Zoophthora aphidis</i>

Table 1. Continued

Host woody plant	Aphid species	Aphid pathogens
	<i>Dysaphis plantaginea</i> (Passerini)	<i>Entomophthora planchoniana</i>
<i>Padus avium</i> Mill.	<i>Rhopalosiphum padi</i> (L.)	<i>Pandora neoaphidis</i> <i>Neozygites fresenii</i> <i>Conidiobolus obscurus</i> <i>Zoophthora aphidis</i> <i>Zoophthora radicans</i>
<i>Picea abies</i> Karst.	<i>Cinara pilicornis</i> (Hartig)	<i>Conidiobolus obscurus</i> <i>Neozygites cinarae</i>
<i>Populus nigra</i> L.	<i>Chaitophorus leucomelas</i> Koch	<i>Zoophthora radicans</i>
<i>Prunus x amygdalo-persica</i> (West.) Rheder	<i>Myzus persicae</i> Sulzer	<i>Entomophthora planchoniana</i> <i>Neozygites fresenii</i>
<i>Prunus domestica</i> L.	<i>Hyalopterus pruni</i> (Goeffroy)	<i>Neozygites fresenii</i>
<i>Prunus spinosa</i> L.	<i>Hyalopterus pruni</i> (Goeffroy)	<i>Entomophthora planchoniana</i>
<i>Prunus persica</i> (L.) Batsch	<i>Myzus persicae</i> Sulzer	<i>Conidiobolus obscurus</i> <i>Entomophthora planchoniana</i> <i>Neozygites fresenii</i> <i>Zoophthora radicans</i>
<i>Quercus rubra</i> L.	<i>Myzocallis walshii</i> Monell	<i>Entomophthora planchoniana</i>
<i>Rhamnus catharticus</i> L.	<i>Aphis nasturtii</i> Kalténbach	<i>Neozygites fresenii</i>
<i>Ribes alpinum</i> L.	<i>Cryptomyzus gaelopsidis</i> (Kalténbach)	<i>Pandora neoaphidis</i> <i>Neozygites fresenii</i>
	<i>Cryptomyzus korschelti</i> Börner	<i>Entomophthora planchoniana</i>
	<i>Cryptomyzus ribis</i> (L.)	<i>Pandora neoaphidis</i> <i>Entomophthora planchoniana</i>
<i>Robinia pseudoacacia</i> L.	<i>Aphis craccivora</i> Koch	<i>Neozygites fresenii</i>
<i>Rosa canina</i> L.	<i>Macrosiphum euphorbiae</i> (Thomas)	<i>Entomophthora planchoniana</i>
	<i>Macrosiphum rosae</i> (L.)	<i>Pandora neoaphidis</i> <i>Entomophthora planchoniana</i> <i>Neozygites fresenii</i>
	<i>Metopolophium dirhodum</i> (Walker)	<i>Pandora neoaphidis</i> <i>Entomophthora planchoniana</i>
<i>Rosa x hybrida</i>	<i>Macrosiphum rosae</i> (L.)	<i>Pandora neoaphidis</i> <i>Entomophthora planchoniana</i>
	<i>Metopolophium dirhodum</i> (Walker)	<i>Entomophthora planchoniana</i>
<i>Rubus</i> sp.	<i>Aphis idaei</i> van der Goot	<i>Neozygites fresenii</i>
	<i>Macrosiphum funestum</i> (Macchiati)	<i>Pandora neoaphidis</i> <i>Neozygites fresenii</i>
	<i>Macrosiphum rosae</i> (L.)	<i>Pandora neoaphidis</i>
	<i>Sitobion fragariae</i> (Walker)	<i>Pandora neoaphidis</i> <i>Entomophthora planchoniana</i>
<i>Salix caprea</i> L.	<i>Cavariella pastinacae</i> (L.)	<i>Entomophthora planchoniana</i>
	<i>Cavariella theobaldi</i> (Gillette et Bragg)	<i>Entomophthora planchoniana</i>
<i>Sambucus nigra</i> L.	<i>Aphis sambuci</i> L.	<i>Pandora neoaphidis</i> <i>Entomophthora planchoniana</i> <i>Conidiobolus obscurus</i>

Table 1. Continued

Host woody plant	Aphid species	Aphid pathogens
<i>Sambucus nigra</i> L. 'Laciniata'	<i>Aphis sambuci</i> L.	<i>Pandora neoaphidis</i> <i>Entomophthora planchoniana</i>
<i>Spirea thunbergii</i> Siebold ex Blume	<i>Aphis spiraeicola</i> Patch	<i>Neozygites fresenii</i>
<i>Tilia cordata</i> Mill.	<i>Eucallipterus tiliae</i> (L.)	<i>Entomophthora planchoniana</i>
<i>Tilia platyphyllos</i> Scop.	<i>Eucallipterus tiliae</i> (L.)	<i>Entomophthora planchoniana</i>
<i>T. platyphyllos</i> Scop. 'Laciniata'	<i>Eucallipterus tiliae</i> (L.)	<i>Entomophthora planchoniana</i>
<i>Tilia petiolaris</i> DC.	<i>Eucallipterus tiliae</i> (L.)	<i>Entomophthora planchoniana</i>
<i>Viburnum opulus</i> L.	<i>Aphis fabae</i> Scopoli	<i>Neozygites fresenii</i>
<i>Viburnum dilatatum</i> Thunb.	<i>Aphis viburni</i> Scopoli	<i>Entomophthora planchoniana</i>
<i>Viburnum trilobum</i> Marshall	<i>Aphis fabae</i> Scopoli	<i>Neozygites fresenii</i>

Findings of Entomophthorales from tree aphid hosts were usually made in spring and late autumn, with isolated recordings of *E. planchoniana*, *N. fresenii* and *P. neoaphidis* during summer (from July through September). These three entomophthoralean species were also the most commonly recorded ones in the aphid colonies in the arboretum. Although they were the most frequently encountered in the aphid colonies, no epizootics due to these fungal pathogens were observed.

E. planchoniana was the predominant and the most prevalent aphid-pathogen in aphid colonies. It was identified from 28 aphid species and recorded in almost 84% aphid colonies of all mycosis-positive colonies. This fungus is known worldwide (KELLER, 1987; BALAZY, 1993), and it is frequently reported as a causal agent for epizootics in pestiferous aphids in field crops (eg MILNER et al., 1980; FENG and NOWIERSKI, 1991). KELLER (1987) noticed that the fungus preferred relatively dry habitats and did not occur in dense humid crops.

N. fresenii was the second most frequent aphid pathogen in the arboretum. It was identified from 18 aphid species and recorded in 49% mycosis-positive colonies. *N. fresenii* is known from nearly all continents including the South Pacific region (KELLER, 1997). It is considered to be the best adapted to tropical conditions (STEINKRAUS et al., 1991; KELLER, 1997), although it is effective in the subpolar region, as well (NIELSEN et al., 2001). It was observed that *E. planchoniana* and *N. fresenii* prefer different habitats. Whereas *E. planchoniana* infects aphids living in relatively dryer microclimate at upper levels of vegetation, *N. fresenii* is frequent aphid pathogen in dense colonies in humid habitats in dense ground vegetation (BARTA and CAGÁN, 2006b).

P. neoaphidis was recorded from 14 aphid species in the arboretum. This fungus is usually considered to be the most important and most prevalent pathogen on aphids infesting field crops (KELLER, 1991; PELL, et al. 2001; BARTA and CAGÁN, 2006b). In Slovakia, it is considered to be the most significant pathogen in natural aphid colonies (BARTA and CAGÁN, 2006b). The species

has a worldwide distribution, and it has been reported from almost all continents (KELLER, 1991; BALAZY, 1993). It is characteristic with an inborn tendency to develop epizootic disease, and it showed high effective in natural control of various aphid species. Its potential for epizootic development in aphid populations has also been documented in a number of studies (eg DEAN and WILDING, 1971; FENG and NOWIERSKI, 1991; BARTA and CAGÁN, 2003). Even if this fungus was found the most prevalent in aphid populations in our previous study (BARTA and CAGÁN, 2006b), its natural occurrence in the tree aphid colonies was of lower importance in the arboretum.

The remaining five fungal pathogens were identified from one to six aphid species (*C. obscurus* (6 aphid species), *Z. aphidis* (4 species), *Z. radicans* (3 species), *C. coronatus* (3 species), *N. cinarae* (1 species)). From these five fungi, *N. cinarae* and *Z. aphidis* are host-specific parasites in aphids. The first one is monophagous, infecting only *Cinara pilicornis* (Hartig) (KELLER, 1997) and the second one is oligophagous pathogen with limited host spectrum (BARTA and CAGÁN, 2006a). In the previous studies from Slovakia, *Z. aphidis* was only recorded from aphids inhabiting trees (BARTA and CAGÁN, 2006a, b) and in our observations, *Myzus persicae* Sulzer is a new host for this fungal species. *C. obscurus* is a common aphid pathogen with a broader range of hosts (KELLER, 1987). It was only sporadically observed in arboricolous aphid colonies during our survey which corresponds with the previous results from Slovakia (BARTA and CAGÁN, 2006b). *C. coronatus* has been recorded from natural aphid colonies in Slovakia for the first time. Usually it is considered as a widespread soil saprophyte utilising a variety of substrates. It has been recorded from detritus, living plants, various dead arthropods and occasionally from mammals (BALAZY, 1993). It can successfully infect insect from different orders, but it does not play a significant role in controlling aphid populations (REMAUDIÈRE et al., 1981; PAPIEROK, 1985; HATTING et al., 1999).

The results presented in this study confirm activity of entomophthoralean fungi in populations of arboricolous aphids. However, prevalence of fungal diseases and fungal species spectrum reached a lower level compared to the previous studies on the occurrence of aphid entomopathogenic fungi in Slovakia (BARTA and CAGÁŇ, 2006b). This may be explained with the fact that less aphid species were collected during our surveys and different aphid species spectrum was studied. Several new data are presented in this paper. *Myzocallis castanicola* Baker, *Myzocallis carpini* (Koch), *Myzocallis walshii* Monell and *Myzus ligustri* Mosley were found killed by entomophthoralean disease for the first time. These four aphid species were infected by *E. planchoniana*. *C. coronatus* has been recorded from natural aphid colonies in Slovakia for the first time.

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Huby z radu Entomophthorales parazitujúce vošky na drevinách v Arboréte Mlyňany SAV

Súhrn

V rokoch 2007 a 2008 sme sledovali výskyt entomopatogénnych húb z radu Entomophthorales v kolóniách vošiek na zbierkových drevinách Arboréte Mlyňany SAV. Spolu sme v kolóniách vošiek identifikovali 8 druhov entomopatogénnych húb. Dominantný výskyt sme zaznamenali pri druhoch *Pandora neoaphidis* (Remaudière et Hennebert) Humber, *Entomophthora planchoniana* Cornu a *Neozygites fresenii* (Nowakowski) Remaudière et Keller. Druhy *Zoophthora radicans* (Brefeld) Batko, *Zoophthora aphidis* (Hoffman in Fresenius) Remaudière et Hennebert, *Neozygites cinarae* Keller, *Conidiobolus coronatus* (Costantin) Batko a *Conidiobolus obscurus* (Hall et Dunn) Remaudière et Keller boli menej významné z pohľadu prevalencie. Počet zaznamenaných druhov húb poukazuje na významnú druhovú diverzitu entomopatogénnej flóry vošiek v arboréte. Entomopatogénne huby boli identifikované zo 40 druhov vošiek patriacich do 4 čeľadí (Aphididae, Drepanosiphidae, Lachnidae a Anoeciidae). Na voškách *Myzocallis castanicola* Baker, *Myzocallis carpini* (Koch), *Myzocallis walshii* Monell a *Myzus ligustri* Mosley bola infekcia entomopatogénnymi hubami z radu Entomophthorales zaznamenaná po prvýkrát. *C. coronatus* bol zistený v prirodzených kolóniách vošiek po prvýkrát na Slovensku.

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Temporal and spatial variability in allergy-triggering phenological phases of hazel and alder in Czechia

Lenka Hájková¹, Jiří Nekovář², Dáša Richterová¹

¹Czech Hydrometeorological Institute, Kočkovská 18, 400 11 Ústí nad Labem, Czech Republic,
Charles University, Faculty of Science, Albertov 6, 128 43 Praha 2, Czech Republic,
E-mail: hajkova@chmi.cz, dasar@chmi.cz

²Czech Hydrometeorological Institute, Na Šabatce 17, 143 06 Praha 4 – Komořany, Czech Republic,
E-mail: jiri.nekovar@chmi.cz

Abstract

HÁJKOVÁ, L. , NEKOVÁŘ, J. , RICHTEROVÁ, D. 2009. Temporal and spatial variability in allergy-triggering phenological phases of hazel and alder in Czechia. *Folia oecol.*, 36: 8–19.

Pollen grains of alder (*Alnus glutinosa*), hazel (*Corylus avellana*) and birch (*Betula verrucosa*) belong to the most important allergens not only in the Czech Republic but also in the whole Europe. Both alder and hazel pollen cross-react with birch pollen, and the allergenicity of the two species is moderate to high. The data on temporal and spatial variability in phenophases selected with respect to their allergenic effect (flower buttons visible, beginning and end of flowering) and compiled with using statistical and GIS methods during the period 1992–2007 were compared with the current year's outcomes of the Czech Hydrometeorological Institute phenological network. The resulting maps use a horizontal resolution of 500 meters, method Clidata – DEM, with dependence on altitude. Temporal variability was monitored in the phenological stations Lednice (48°48' N, 16°48' E, mean above sea level (MASL) 165 m) and Horní Rožmitava (50°11' N, 16°30' E, 743 m MASL), the spatial variability in 34 stations with MASL ranging from 155 m (Doksany – Polabská nížina) to 830 m (Měděnec – Krušné hory Mts). The results are presented in tables and maps. In this case study we observed the following shifts in phenophases (lowland in comparison with mountain): flower buttons visible (38.4 days), beginning of flowering 10% (21.8 days), and end of flowering (26.3 days). The results of average entrance of phenophase from this case study: flower buttons visible (Hazel – February 3 to February 22, Alder – February 7 to February 26), beginning of flowering 10% (Hazel – February 19 to March 20, Alder – February 22 to April 2), end of flowering (Hazel – March 9 to April 17, Alder – March 15 to May 13)

Keywords

Alder, flowering, GIS, hazel, phenophase, pollen, statistics

Introduction

The broadleaved tree alder (*Alnus glutinosa*) and shrub hazel (*Corylus avellana*) belong to the most widespread woody plants in Czechia and in other parts of Europe. The pollen of both are the most important allergens, namely due to cross-sensibilization among hazel, alder and birch. Phenology as the study of recurring vegetation cycles and their connection to climate plays a prominent role in forecast models system. The Czech Hydrometeorological Institute (CHMI) operates a ne-

twork of phenological stations with wild plants. Volunteer observers register onset of phenophases according to the CHMI methodology instructions number 10. Alder and hazel are in observation programme, with a special focus on phenophases closely connected with pollen season (flower buttons visible, beginning and end of flowering). The data are stored in the Fenodata database (Oracle application). Phenological data are usually recorded at the phase start, expressed in form of the day of year.

Hazel is usually a 2 to 8 m-high shrub, in the Czechia it can be found on rich-in-aluminium soils. This woody plant is abundant from lowlands to foothills, rare in mountains (maximum 1,310 m asl). The pollen grain of hazel is usually oval, isopolar, the normal size is 18–35 micrometers. Alder is a broadleaved tree or shrub the height of which can exceed 30 m. Alder trees grow in *Alnus* flood-plain forests, swamps, on clayey noncalcareous soils, rich in aluminium. In Czechia, they can be found from lowlands to foothills, rarely in mountains (maximum 900 m asl) NEKOVÁŘ (1993). An alder pollen grain is usually oval, isopolar, its normal size is 20–30 micrometers (Fig 1).

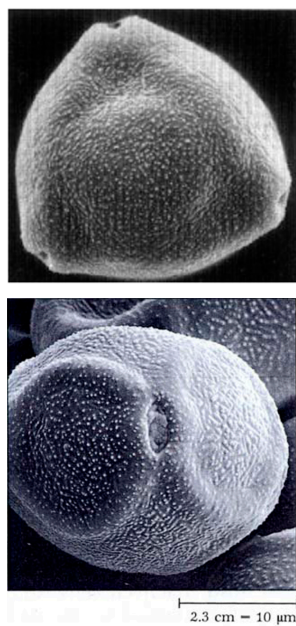


Fig 1. Hazel and alder pollen grains

There are several contributions about phenology and pollen season in hazel and alder in Europe. REMIŠOVÁ and VINCEOVÁ (2007), for example, present in their paper data on flowering of *Corylus avellana* in the Slovak Republic from 1987 to 2006. Škvareninová and Snopková (2007) studied phenological phases in *Alnus glutinosa* in relation to effective temperature values over the period of 1987–2006 in the Zvolen basin. EMBERLIN et al. (2007) reports about pollen season of *Alnus* spp. and *Corylus* spp. in the United Kingdom for period 1996–2005.

The aim of this case study was to monitor temporal and spatial variability in alder and hazel phenology in Czechia, and provide useful information for experts, general public, and especially for allergy-sensitive people. The results were processed by statistics and GIS methods in 1992–2007, as complete time series without interruption. Other species with allergy-triggering phenological phases belonging to CHMI phenological observation programme will be also studied in the future.

Material and methods

The Czech Hydrometeorological Institute (CHMI) operates with a phenological network of wild plants (Fig 2), following CHMI methodical instruction for phenological stations – wild plants number 10. In hazel and alder, there are observed the following phenological phases: sprouting, first leaves (10, 50, 100%), full leaves, flower buttons visible, flowering (10, 50, 100%), end of flowering, formation of buds, yellowing of summer leaves, lignification of sprouts, discoloration (yellowing) of autumn leaves (10, 100%), defoliation (10, 100%), ripe fruits. At present, hazel and alder are observed at 34 phenological stations. We focused on the phenological phases associated with pollen production (flower buttons visible, flowering).

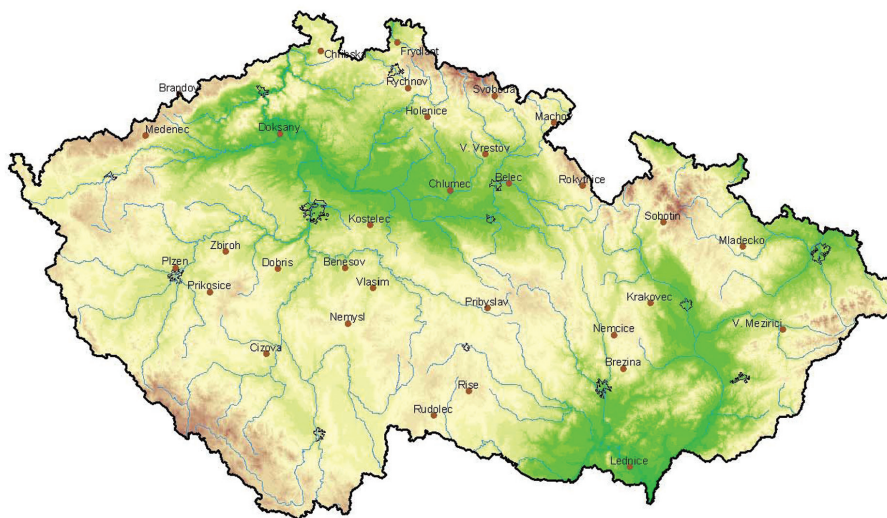


Fig 2. Phenological network for wild plants (stations observing hazel and alder)

We have subjected to basic statistic processing the data assembled over the period 1992–2007 at two stations situated at different altitudes. Hazel and alder are the most important allergenic species, cross-reacting with birch. Allergy sensitive persons can profit from information about flowering, hence we have also counted the number of days between the phenophases *flower buttons visible – beginning of flowering – end of flowering*. Hazel and alder belong to the first-blooming allergenic species. The assembled data have been processed to maps (mean dates of phenophase entrance for period 1992–2007) – temporal and spatial pattern of phenophase entrance over the whole Czechia.

The detailed phenophase description represents instruction number 10 in the methodology (CZECH HYDROMETEOROLOGICAL INSTITUTE, 1987). Patterns of phenophases are in the Phenological atlas, COUFAL et al. (2004).

From statistical characteristics we chose these parameters: average value, standard deviation, variance, minimum, maximum, variation range, average – median.

The maps were processed with using geographic information systems (Application Clidata – GIS). As the input data, we used the mean dates of phenophase entrance from the period 1992–2007. The maps use a horizontal resolution of 500 meters with reference to altitude (method of local linear regression between the measured or calculated value and the digital relief model). The regression coefficients were calculated for each station, with using the data from neighbouring stations, by the least squares method. The distance between two neighbouring phenological stations at similar conditions was 40 km. The coefficients were subsequently interpolated into the spatial model, and the spatial distribution of the specific element was calculated by using tools of map algebra and linear equations, HAJKOVÁ and NEKOVÁŘ (2006), TOLASZ et al (2007).

In total, data from 34 stations with MASL (mean above sea level) ranging from 155 m (Doksany – Polabská nížina, lowland) to 830 m (Měděnec – Krušné

hory, Mts) were used for creating the maps. The stations Lednice (165 m) and Horní Rokytnice (743 m) are described in details in the statistical results. The first station is situated in a lowland, the second in mountains, the first one is in the South and the second one on the North-east of the Republic. Both stations have recorded complete time series, without interruption, for the period 1992–2007. The station Lednice (48°48' N, 16°48' E, 165 m asl) is situated in the Southern Moravia, in the river basin of the Dyje River, Castle Park Lednice. Hazel and alder trees are observed at the site 1 (this station consists of 2 sites), vegetation unit – dispersed green vegetation, macrorelief – flat ground, geological substrate – clayey drift and combined soil, level of protection – the other categories of non-forest land. Hazel and alder site conditions: micro-relief – flat ground, slope – up to 5 degrees, illumination of site – full illumination, water conditions – hygromesophyte, initial age: 20–40 years. The station Horní Rokytnice (50°11' N, 16°30' E, 743 m asl) is situated in the Orlické hory Mts, in the river basin of Divoká Orlice. Alder trees are observed at the site 2 (this station comprises 7 sites), vegetation unit – mountain pine grove, macrorelief – plateau, geological substrate – crystalline slate, level of protection – protected provincial area. Alder site conditions: micro-relief – rampart, slope – up to 5 degrees, illumination of site – full illumination, humidity conditions – mesophyte, initial age – 20–40 years.

Hazel trees are observed at the site 4, vegetation unit – damp meadow and wetland, macrorelief – plateau, geological substrate – crystalline slate, level of protection – protected provincial area. Hazel site conditions: micro-relief – flat-ground, slope – up to 5 degrees, illumination of site – full illumination, humidity conditions – hydrohygrophyte, initial age – 20–40 years.

Statistical results for hazel and alder (station Lednice and Horní Rokytnice, period 1992–2007) in the tables (Tables 1–14), are given in form of the day of year.

Table 1. Phenophase – Flower buttons visible, *Corylus avellana* (statistical results)

Station	Average	Standard deviation	Variance	Minimum	Maximum	Variation range	Average – median
Lednice	42.1	21.7	470.6	10 (10.1.)	79 (20.3.)	69	–2.9
H. Rokytnice	79.2	17.2	295.6	46 (15.2.)	108 (18.4.)	62	1.2

Table 2. Phenophase – Flower buttons visible, *Alnus glutinosa* (statistical results)

Station	Average	Standard deviation	Variance	Minimum	Maximum	Variation range	Average – median
Lednice	46.2	20.4	415.2	18 (18.1.)	84 (25.3.)	66	1.7
H. Rokytnice	84.6	14.8	218.1	61 (2.3.)	110 (20.4.)	49	1.6

Table 3. Phenophase – Beginning of flowering 10%, *Corylus avellana* (statistical results)

Station	Average	Standard deviation	Variance	Minimum	Maximum	Variation range	Average – median
Lednice	54.9	21.0	443.1	12 (12.1.)	87 (28.3.)	75	6,9
H. Rokytnice	85.4	14.7	216.0	59 (28.2.)	111 (21.4.)	52	-1,1

Table 4. Phenophase – Beginning of flowering 10%, *Alnus glutinosa* (statistical results)

Station	Average	Standard deviation	Variance	Minimum	Maximum	Variation range	Average – median
Lednice	64.5	15.9	252.8	37 (6.2.)	90 (31.3.)	53	1.5
H. Rokytnice	86.3	15.2	230.7	60 (1.3.)	112 (22.4.)	52	0.3

Table 5. Phenophase – Beginning of flowering 50%, *Corylus avellana* (statistical results)

Station	Average	Standard deviation	Variance	Minimum	Maximum	Variation range	Average – median
Lednice	60.1	21.3	454.0	16 (16.1.)	94 (4.4.)	78	7.1
H. Rokytnice	89.1	15.1	227.7	61 (2.3.)	114 (24.4.)	53	-0,9

Table 6. Phenophase – Beginning of flowering 50%, *Alnus glutinosa* (statistical results)

Station	Average	Standard deviation	Variance	Minimum	Maximum	Variation range	Average – median
Lednice	69.1	15.8	248.4	43 (12.2.)	96 (6.4.)	53	2.1
H. Rokytnice	92.2	15.9	254.1	61 (2.3.)	113 (23.4.)	52	-1.3

Table 7. Phenophase – Beginning of flowering 100%, *Corylus avellana* (statistical results)

Station	Average	Standard deviation	Variance	Minimum	Maximum	Variation range	Average – median
Lednice	68.1	21.5	464.0	25 (25.1.)	101 (11.4.)	76	4.6
H. Rokytnice	97.1	12.4	154.3	74 (15.3.)	115 (25.4.)	41	0.1

Table 8. Phenophase – Beginning of flowering 100%, *Alnus glutinosa* (statistical results)

Station	Average	Standard deviation	Variance	Minimum	Maximum	Variation range	Average – median
Lednice	75.7	15.4	235.6	55 (24.2.)	101 (11.4.)	46	0.7
H. Rokytnice	101.2	11.4	130.5	77 (18.3.)	115 (25.4.)	38	-5.8

Table 9. Phenophase – End of flowering, *Corylus avellana* (statistical results)

Station	Average	Standard deviation	Variance	Minimum	Maximum	Variation range	Average – median
Lednice	79.9	21.3	453.6	33 (2.2.)	108 (18.4.)	75	0.4
H. Rokytnice	104.8	12.7	162.0	77 (18.3.)	120 (30.4.)	43.0	-3.2

Table 10. Phenophase – End of flowering, *Alnus glutinosa* (statistical results)

Station	Average	Standard deviation	Variance	Minimum	Maximum	Variation range	Average – median
Lednice	81.6	15.2	231.7	60 (1.3.)	106 (16.4.)	46	2.6
H. Rokytnice	107.9	10.6	111.5	81 (22.3.)	119 (29.4.)	38	-3.1

Table 11. Average number of days between phenophases, *Corylus avellana*

Station	Flower buttons visible – beginning of flowering	Beginning of flowering – end of flowering	Flower buttons visible – end of flowering
Lednice	12.8	25.0	37.8
H. Rokytnice	6.2	19.4	25.6

Table 12. Average number of days between phenophases, *Alnus glutinosa*

Station	Flower buttons visible – beginning of flowering	Beginning of flowering – end of flowering	Flower buttons visible – end of flowering
Lednice	18.3	17.1	35.4
H. Rokytnice	1.7	21.6	23.3

Table 13. Beginning of flowering – end of flowering, *Corylus avellana* (statistical results)

Station	Average	Standard deviation	Variance	Variation range
Lednice	25.0	9.7	94.7	36
H. Rokytnice	15.8	7.6	57.2	24

Table 14. Beginning of flowering – end of flowering, *Alnus glutinosa* (statistical results)

Station	Average	Standard deviation	Variance	Variation range
Lednice	16.8	3.7	14.0	15
H. Rokytnice	18.6	9.1	82.8	28

Results

Phenophase: Flower buttons visible

Phenophase entrance: in lowlands and at medium altitudes started the phenophase *flower buttons visible* in

hazel already from February 3 to February 22; in alder from February 7 to February 26. Interval of mean dates of phenophase entrance was smaller in hazel than in alder. Phenophase entrance: in the highest situated mountain positions from March 15 to March 24 in hazel; from the end of March to the mid-April in alder.

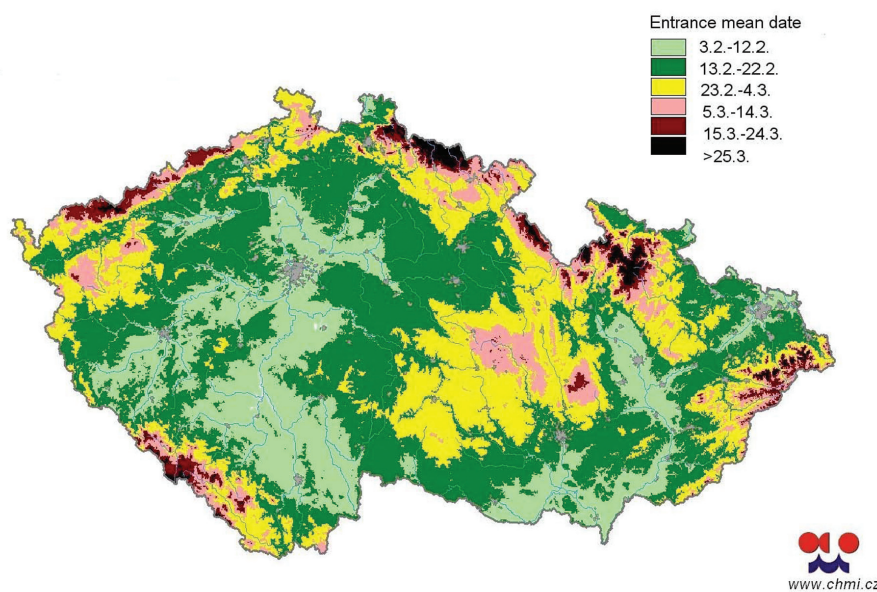


Fig 3. Phenophase – flower buttons visible, mean dates for period 1992–2007, *Corylus avellana*

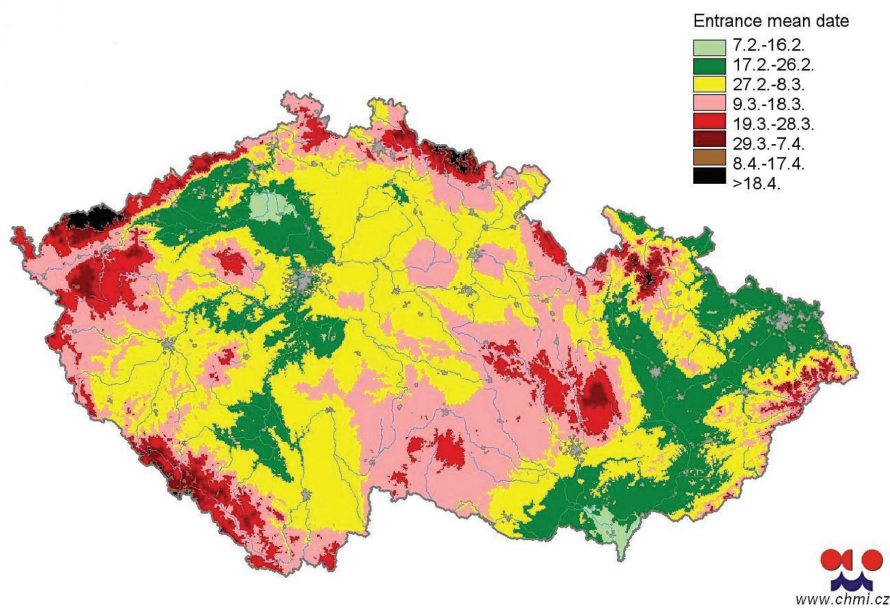


Fig 4. Phenophase – flower buttons visible, the mean dates for period 1992–2007, *Alnus glutinosa*

Phenophase: Beginning of flowering 10%

Phenophase entrance: across the major part of the Czech Republic started the phenophase *beginning of flowering 10%* in hazel from February 19 to March 20; in alder

from February 22 to April 2. In the highest situated mountain positions it started at latest on March 31 in hazel, and on April 23 in alder.

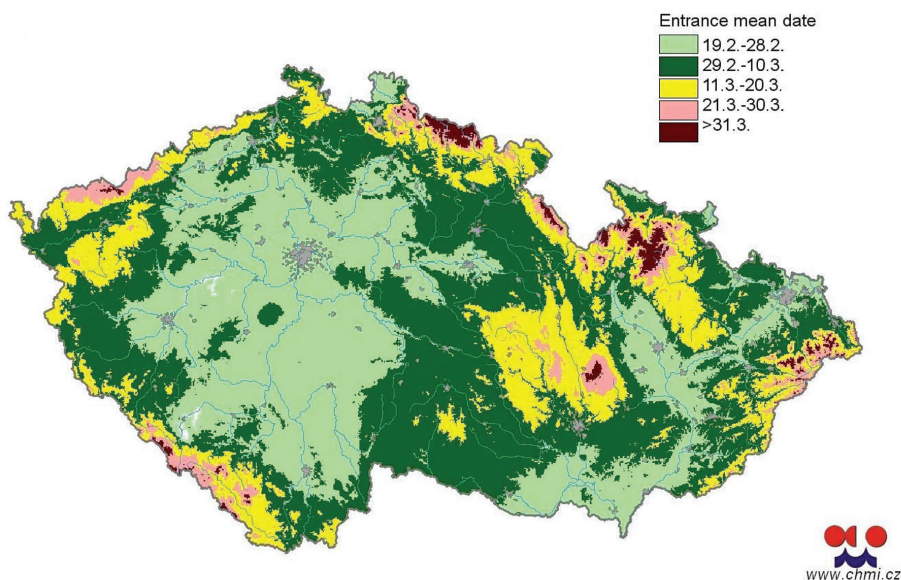


Fig 5. Phenophase – beginning of flowering 10%, the mean dates for period 1992–2007, *Corylus avellana*

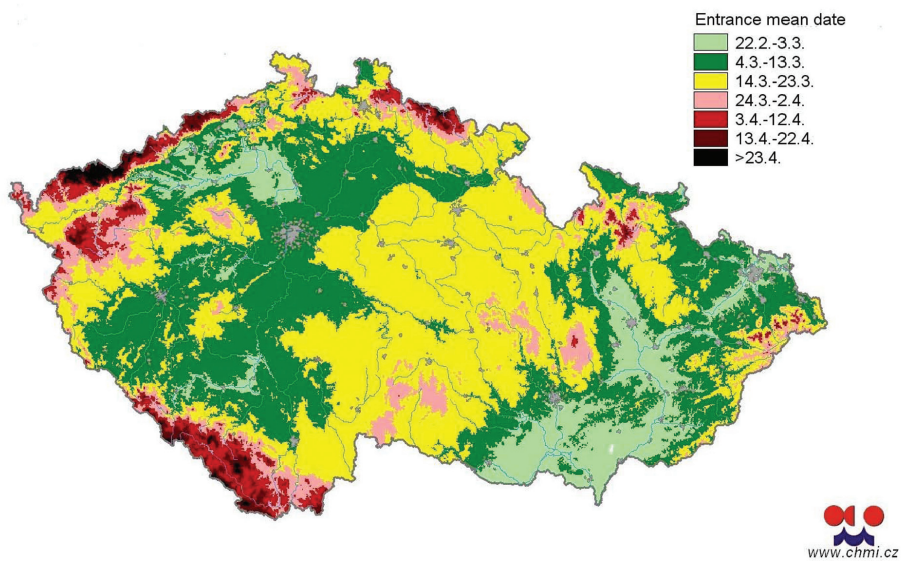


Fig 6. Phenophase – beginning of flowering 10%, the mean dates for period 1992–2007, *Alnus glutinosa*

Phenophase: Beginning of flowering 50%

Phenophase entrance: across the major part of the Czech Republic, the phenophase *beginning of flowering 50%* starts from February 24 to April 4 in hazel and from February 27 to April 27 in alder.

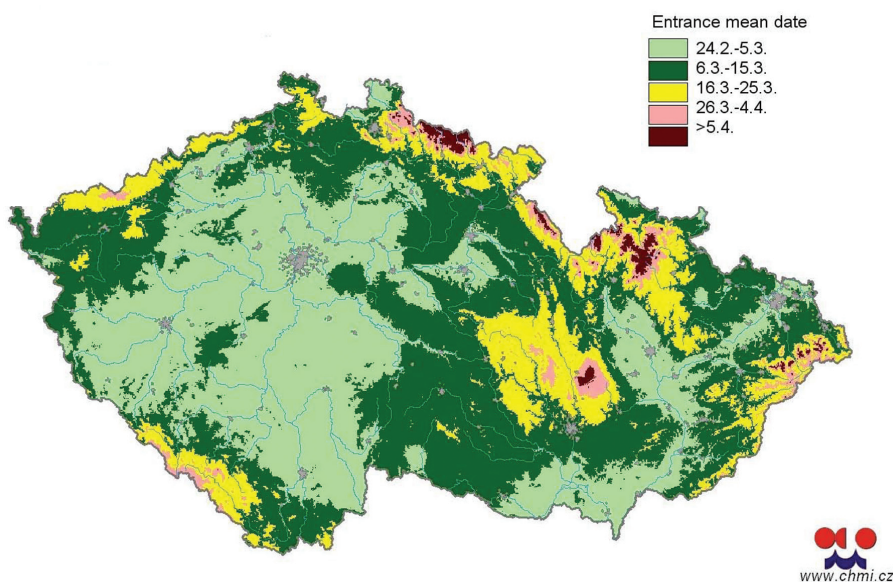


Fig 7. Phenophase – beginning of flowering 50%, the mean dates for period 1992–2007, *Corylus avellana*

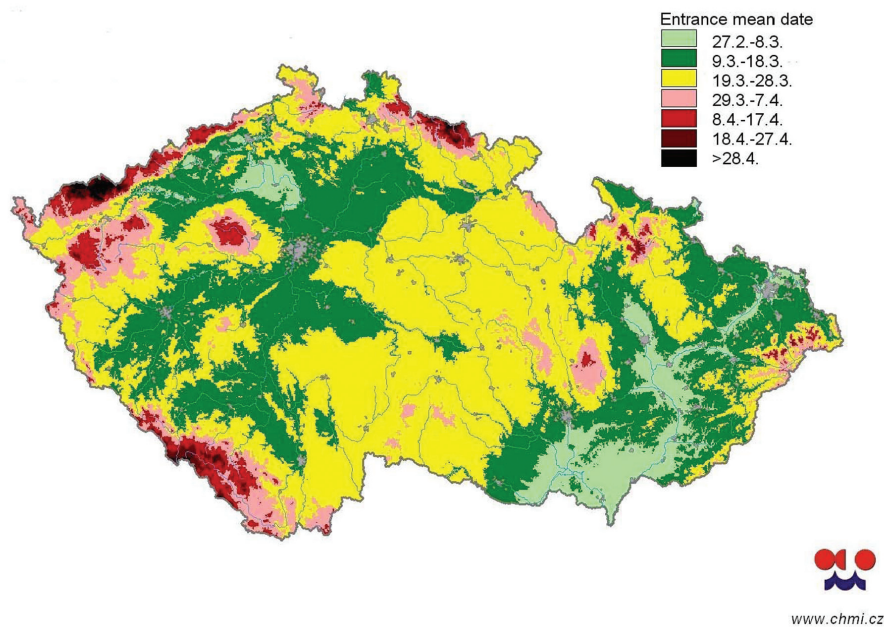


Fig 8. Phenophase – beginning of flowering 50%, the mean dates for period 1992–2007, *Alnus glutinosa*

Phenophase: Beginning of flowering 100%

Phenophase entrance: across the major part of the Czech Republic started the phenophase *beginning of flowering 100%* in hazel from February 28 to April 8; in alder

from March 4 to May 2. In the highest situated mountain positions, the start could shift at latest on April 9 in hazel; in alder at latest on May 3.

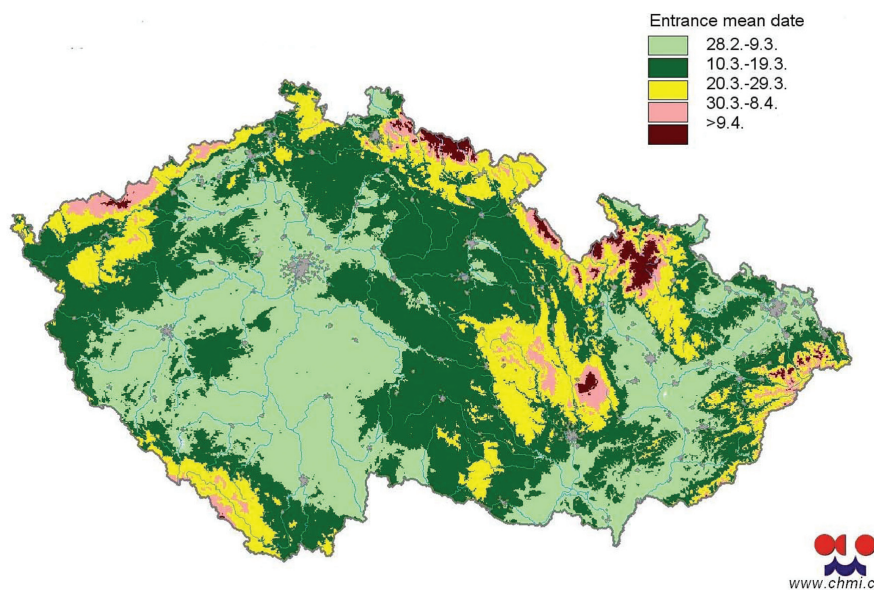


Fig 9. Phenophase – beginning of flowering 100%, the mean dates for period 1992–2007, *Corylus avellana*

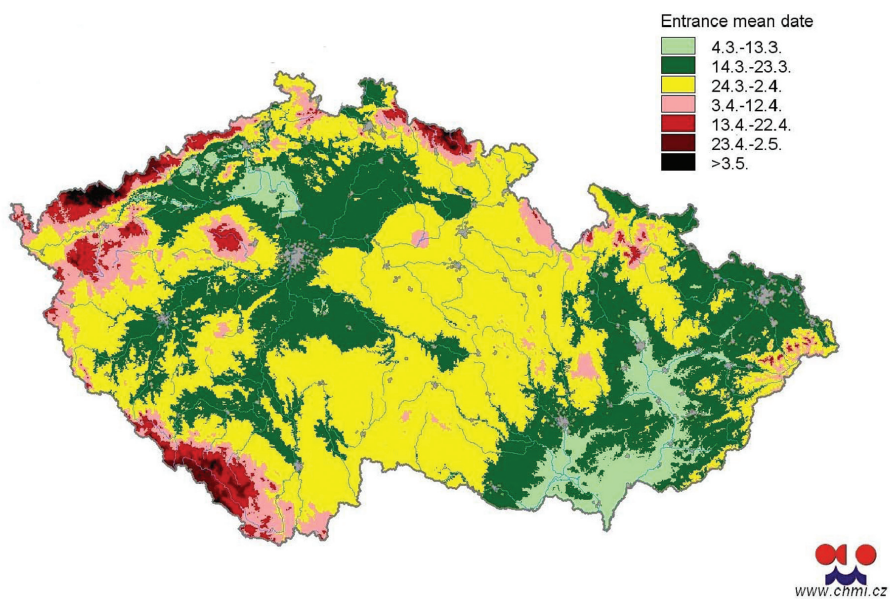


Fig 10. Phenophase – beginning of flowering 100%, the mean dates for period 1992–2007, *Alnus glutinosa*

Phenophase: End of flowering

Phenophase entrance: across the major part of the Czech Republic started the phenophase *end of flowering* in hazel from March 9 to April 17; in alder from March 15 to

May 13; in the highest situated mountain positions, the start could be shifted at latest on April 18 in hazel; and on May 14 in alder.

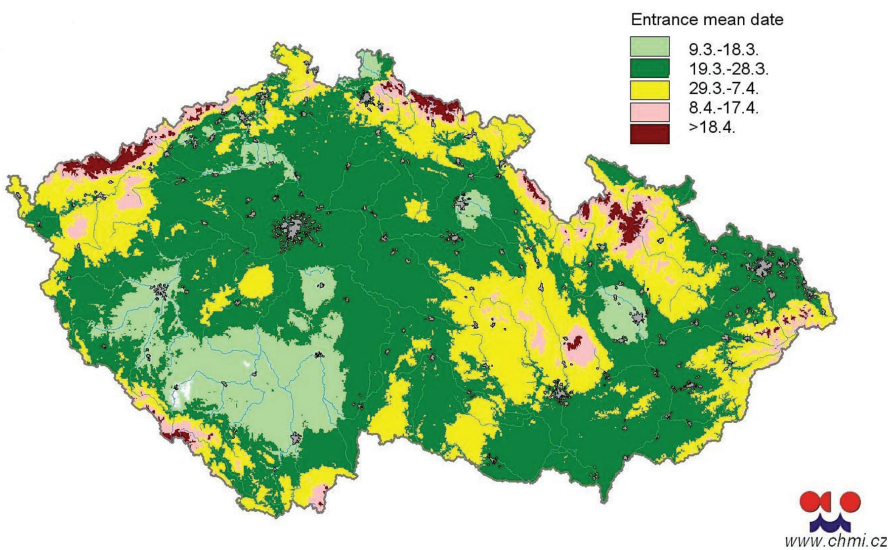


Fig 11. Phenophase – end of flowering, the mean dates for period 1992–2007, *Corylus avellana*

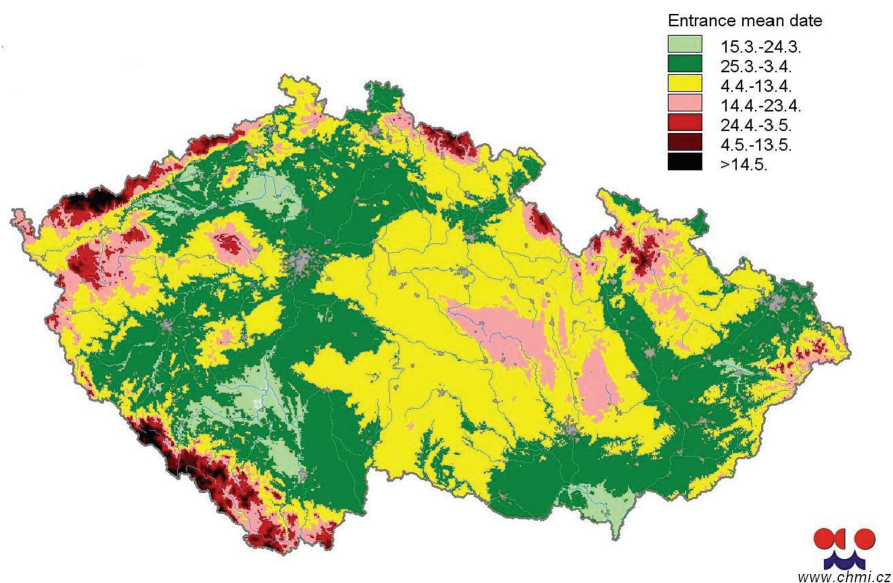


Fig 12. Phenophase – end of flowering, the mean dates for period 1992–2007, *Alnus glutinosa*

Discussion

The entrance of individual phenophases in hazel and alder was studied based on the data provided by two selected phenological stations (lowland and mountain) and subjected to detailed statistical processing. The station Lednice is situated in a lowland in the southern Moravia; the station Horní Rokytnice is in the North-east of the Czech Republic (Orlické hory Mts). The beginning and duration of phenological phases are influenced by multiple environmental factors (air temperature, soil temperature, water conditions, position of locality, sunshine duration) together with genetic equipment of the plants – similar results were obtained for birch HÁJKOVÁ et al. (2007). Comparison of phenophase entrance in different conditions was made on dependence on altitude and aspect. The timing of phenophase entrance in *Corylus avellana* was in average earlier in lowlands: the flower buttons visible by 37.1 days earlier, the beginning of flowering 10% by 30.5 days earlier, the end of flowering by 24.9 days earlier. The dating of phenophase entrance in *Alnus glutinosa* was on average also earlier in lowlands: the flower buttons visible by 38.4 days earlier, the beginning of flowering 10% by 21.8 days earlier, the end of flowering by 26.3 days earlier. Values of variance and also variation range were bigger in lower altitudes. *Corylus avellana* is the earliest allergen, the earliest phenophase entrance over the period 1992–2007 was found out on January 10th (flower buttons visible) and on January 12th (beginning of flowering). For *Alnus glutinosa*, the second earliest allergen, the earliest phenophase entrance was recorded

on January 18 (flower buttons visible) and on February 6 (beginning of flowering). Both extremes were recorded at the Lednice station. There was a large gap between the earliest and latest phenophase entrance (column *minimum* and *maximum* in tables) during the period 1992–2007. The variation range was found expressively higher at the lowland station Lednice than in the mountains. Difference between the average and median (a value expressing whether lower or higher values are more important than the median or not) was in most cases positive – it means, that the later phenophase entrance was more important. The pollen season (period between beginning of flowering – end of flowering) in hazel was on average 25 days in lowlands and 15.8 days in mountains. The pollen season in alder was on average 16.8 in lowlands and 18.6 in mountains. The average number of days between flower buttons visible and end of flowering (the period, which is very important for allergy sensitive persons) in hazel was 41.6 days at Lednice station and 22.6 days at Horní Rokytnice station. The average number of days between flower buttons visible and end of flowering in alder was 38.2 at Lednice station and 23 days at Horní Rokytnice station.

Conclusions

Phenological observations allow us to recognise the life cycle of plants in dependence on external conditions, and they give us valuable information about duration of vegetation season in different climatic regions. This case study manifests the dependence of seasonal events

in the examined hazel and alder species on altitude and aspect of the locality. The temporal variability of timing of the first occurrence of phenophase in its annual cycle is considerable, and it depends on climatic conditions, locality and weather conditions in the current year. Duration of snow cover and variability of weather have influence on timing the phenophase entrance in mountain areas. For the studied period 1992–2007, there was found bigger variance for values obtained at the mountain station, which indirectly confirms the results of statistical processing of phenophases-related observation data. For example, EMBERLIN et al. (2006) found that pollen seasons in *Alnus* spp. and *Corylus* spp. have changed in the Worcester area over the last 10 years, becoming longer and more severe in the recent years, but long term trends cannot be discerned based on this relatively small data set (EMBERLIN et al., 2006). Although the analyses are based on the Worcester data, the results can have a wider application, and they also can be used for other regions. The results of this study are also consistent with previous works declaring that the temperature is the main factor affecting the phenology of early flowering trees.

The mean date of beginning of flowering in European hazel in Slovakia is considered March 15 (evaluated period 1987–2006) (REMIŠOVÁ and VINCEOVÁ, 2007), for the Czech Republic we obtained February 19 to March 20 (evaluated period 1992–2007).

The analysis of the flowering data variability in hazel and alder in the Slovak Republic suggests their association with the air temperature variability towards the end of winter (LUKNÁROVÁ and BRASLAVSKÁ, 1999). Consequently, the next case study should address phenophase entrance in relation to air temperature, precipitation, sun hours and synoptic situation – with the aim to forecast the following phenophase entrance (especially flower buttons visible and beginning of flowering) in the current year. The results presented in this case study provide a basic outline of the temporal patterns of phenophases entrance in *Alnus glutinosa* and *Corylus avellana* in the Czechia over the recent years, and also statistical comparison between localities situated at noticeably different altitudes.

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Časová a prostorová variabilita alergologicky významných fenologických fází lísky a olše v Česku

Souhrn

V uvedené práci byly zpracovávány nástupy alergologicky významných fenofází (butonizace, počátek a konec kvetení) u lísky obecné a olše lepkavé. Výsledky jsou uvedeny jak ve formě statistických tabulek se statistickými charakteristikami průměr, směrodatná odchylka, rozptyl, nejranější a nejpozdější datum nástupu, variační rozpětí (u dvou vybraných stanic – nížinné a horské za období 1992–2007), tak ve formě map za využití geografických informačních systémů (aplikace Clidata-GIS s horizontálním rozlišením 500 m a se závislostí na nadmořské výšce) z celkem 34 fenologických stanic. Jako vstupní data byla použita průměrná data nástupů zvolených fenofází za období 1992–2007.

Vzhledem k tomu, že líska a olše jsou velmi významnými alergeny (po bříze bradavičnaté), zaměřili jsme se v práci rovněž na statistické zhodnocení počtu dní mezi nástupy alergologicky významných fenofází, výsledky jsou rovněž uvedeny v tabulkové podobě.

Ve výsledcích srovnání nástupu fenofází v odlišných podmínkách byla prokázána závislost nástupu fenofází na nadmořské výšce i na poloze, vzhledem k orientaci ke světovým stranám.

Časová variabilita nástupu fenofází je velmi velká a závisí na klimatických podmínkách dané lokality a na průběhu počasí v daném roce. V horských polohách má na časový nástup fenofází vliv délka trvání sněhové pokrývky a variabilita počasí. V budoucnosti je vhodné věnovat se dalšímu studiu nástupu fenofází ve spojení s teplotou vzduchu, sumou srážek, slunečním svitem a synoptickými situacemi pro možnost prognózy nástupu fenofáze (zejména butonizace a počátku kvetení) v aktuálním roce. Výzkum těchto druhů rozšířit o další detailní rozbor fenologických stanic v jiných polohách a nadmořských výškách a zároveň o další alergologicky významné rostlinné druhy sledované ve fenologické síti stanic ČHMÚ. Uvedené výsledky poskytují čtenáři základní představu o vývoji nástupu alergologicky významných fenofází u lísky obecné a olše lepkavé v Česku v posledních letech a statistické porovnání lokalit s výrazně odlišnou nadmořskou výškou.

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An interesting case of phoresy in mite associates of *Hylurgops palliatus* (Gyll.) (Coleoptera: Scolytidae)

Branislav Kršiak, Peter Zach, Rastislav Jakuš

Institute of Forest Ecology, Slovak Academy of Sciences, Štúrova 2, 960 53 Zvolen, Slovak Republic,
E-mail: zach@savzv.sk

Abstract

KRŠIAK, B., ZACH, P., JAKUŠ, R. 2009. An interesting case of phoresy in mite associates of *Hylurgops palliatus* (Gyll.) (Coleoptera: Scolytidae). *Folia oecol.*, 36: 20–22.

The first record of phoresy in the two mite taxa of the family Trematuridae (Acarina: Mesostigmata) and Histiostomatidae (Acarina: Astigmata) has been documented from the larval galleries of the bark beetle *Hylurgops palliatus* (Gyll.) (Coleoptera: Scolytidae) in Norway spruce forest in West Carpathians, Central Europe. The interesting and rare case of phoresy is briefly discussed.

Key words

Central Europe, *Hylurgops palliatus*, Norway spruce, phoretic mites, West Carpathians

Introduction

Phoresy is a phenomenon where one animal actively seeks out and attaches to the body of another animal to disperse (ATHIAS-BINCHE, 1993). Phoretic hosts of mites, known as vectors or phoronts, can be insects and numerous other animals occurring in habitats of phoretic mites. Not rarely, phoresy may be observed in the mite associates of beetles (Coleoptera), bark beetles (Scolytidae) included (PFEFFER, 1955; HIRSCHMANN, 1971; KIELCZEWSKI et al., 1983; KACZMAREK et al., 1992; KOFLER and SCHMÖLZER, 2000; MAŠÁN, 2001).

This study gives the first evidence of phoresy in the representatives of the two mite taxa of the family Trematuridae (Acarina: Mesostigmata) and Histiostomatidae (Acarina: Astigmata) documented from the larval galleries of *Hylurgops palliatus* (Coleoptera: Scolytidae) in Norway spruce forest in Central Europe.

Material and methods

Uropodine mites were collected in Norway spruce forest near Detvianska Huta in Veporske vrchy Mountains, West Carpathians, Central Europe, altitude 850 m,

in August 2006. Uropodids were hand-sampled from the larval galleries of *Hylurgops palliatus* (Coleoptera: Scolytidae) constructed under the bark of moist log of Norway spruce [*Picea abies* (L.) Karst.]. The log (0.2 m thick and 4.0 m long) was positioned on the forest floor. It was completely shaded.

In the laboratory, the uropodids sampled were mounted into permanent microscopic slides using the Liquido de Swan and identified according to MAŠÁN (2001). The material has been deposited in the mite collections of the Institute of Forest Ecology, Slovak Academy of Sciences, in Zvolen.

Results and discussion

A total of 14 individuals of the uropodid *Trichouropoda obscura* (Koch), all deutonymphs, were collected from the larval galleries of *Hylurgops palliatus* under the bark of spruce log. Of them, a single deutonymph of *T. obscura* was carrying another mite identified as the tritonymph (hypopus) of the genus *Histiostoma* Kramer (Acarina: Astigmata). The tritonymph was found attached to the dorsal side of the body of *T. obscura* (Figs 1, 2). Both the deutonymph and tritonymph were

living individuals. The described case of phoresy clearly shows that the tiny representatives of the genus *Histiostoma* can be passively dispersed by their somewhat larger mite associates.

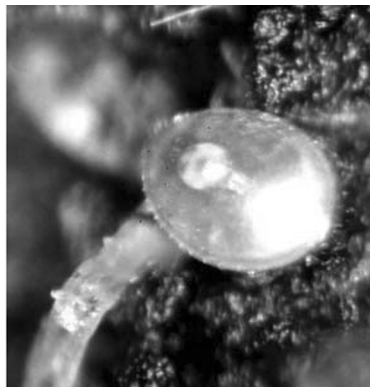


Fig 1. A specimen of *Histiostoma* sp. phoretic on the deutonymph of *Trichouropoda obscura*



Fig 2. A tritonymph of the genus *Histiostoma*

The uropodid *T. obscura* is the most frequent uropodine mite associate of *Hylurgops palliatus* in West Carpathians (KRŠIAK and ZACH, 2007). Spruce logs checked for the presence of the bark beetle and its mite associates (>50 logs) gave no evidence of *T. obscura* transferring another mite species. Also, a total of 280 individuals of *Hylurgops palliatus* collected by flight window trapping in Tatra Mountains, vectored one or more deutonymphs of *T. obscura* but none of these deutonymphs was carrying the tritonymph of *Histiostoma*. This indicates that phoresy in mite associates of *Hylurgops palliatus* is rare in nature.

Transfers of the tritonymphs of the genus *Histiostoma* may occur in populations of other bark beetle species too. For example, the tritonymphs of the genus *Histiostoma* were found attached to the scolytid *Hylastes cunicularius* Er. (B. Kršiak, personal observation). In this particular case, the tritonymphs formed small aggregations of closely-packed individuals on the

lateral side of the prothorax of the bark beetle vector. Rarely, they were found as associates of the deutonymphs of the uropodid *Trichouropoda pecinai* (Hirschmann and Wiśniewski). The cases of hyperphoresy (BAJERLEIN and BŁOSZYK, 2003) were not documented.

The observations on phoretic mites contribute to better understanding the ties among mite species in Norway spruce forests in Central Europe.

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Zaujímavý prípad forézie u roztoča viazaného na *Hylurgops palliatus* (Gyll.) (Coleoptera: Scolytidae)

Súhrn

Z požerkov *Hylurgops palliatus* (Coleoptera: Scolytidae) v ležiacom, zatienenom a vlhkom smrekovom polene (hrúbka – 0,2 m, dĺžka 4,0 m) bolo získaných 14 jedincov uropodného roztoča *Trichouropoda obscura* (Koch), všetky v štádiu deutonymfy. Jedna z deutonymf *T. obscura* prenášala tritonymfu (hypopus) jedinca roztoča z rodu *Histiostoma* (Acarina: Astigmata). Tritonymfa bola prichytená na dorzálnej časti deutonymfy *T. obscura*. Oba jedince roztočov, tritonyma i deutonymfa, boli živé. Tento a podobné prípady forézie sú medzi foretickými roztočmi zriedkavé až vzácne. Prezentované výsledky prispievajú k poznaniu ekológie a rozptylových stratégií foretických roztočov.

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Mycoflora of beech forests in the Kremnické vrchy Mts (Central Slovakia)

Ivan Mihál, Katarína Bučinová, Jana Pavlíková

Institute of Forest Ecology, Slovak Academy of Sciences, Zvolen, Štúrova 2, 960 53 Zvolen,
Slovak Republic, E-mail: mihal@savzv.sk

Abstract

MIHÁL, I., BUČINOVÁ, K., PAVLÍKOVÁ, J. 2009. Mycoflora of beech forests in the Kremnické vrchy Mts (Central Slovakia). *Folia oecol.*, 36: 23–31.

The results of myco-inventory research from the Ecological-Experimental Stationary (EES) Kremnické vrchy mountains (Central Slovakia) are presented. The locality is situated within the beech forests. Total 353 species of fungi were determined on the EES locality. The species eg *Coenococcum geophilum*, *Habrostictis rubra*, *Nectria punicea*, *Sphaerostibella aureonitens* (Ascomycota) as well as *Hymenogaster olivaceus*, *Mycena stipata*, *Phaeocollybia festiva*, *Pseudotomentella tristis* (Basidiomycota) and *Cryptococcus podzolicus* (Cystofilobazidiales) are rare and endangered. Both of thermophilous and typical mountain species of macromycetes were found. The ecotropical distribution of species spectrum is presented. A few species were found as the lignicolous parasites, herboparasites or mycoparasites.

Key words

beech forests, Central Slovakia, Kremnické vrchy mountains, mycocoenology, mycoflora

Introduction

The Kremnické vrchy Mts, with their varied geology and geo-morphology, are an important volcanic mountain range belonging to the unit Slovenské stredohorie Mts. Forest complexes in the Kremnické vrchy Mts have a much diversified species composition, and they represent almost all vegetation tiers. All up-to-date recognised specific properties of this area also reflect the very high diversity of the local biota. In the Kremnické vrchy Mts, we can meet a number of members of thermophilous Pannonian flora as well as members preferring cold conditions. It is undisputable that the species diversity of biota in the Kremnické vrchy Mts is also manifested by the mycoflora over this mountain range. We studied mycoflora in beech forest ecosystems in a selected locality situated in southern part of the Kremnické vrchy Mts.

The history of mycological research in area of the Kremnické vrchy Mts points out a lack of systematic study – in contrast to the close Štiavnické vrchy Mts. From the far past, we have the first records of

mycoflora in the Kremnické vrchy Mts registered by HAZSLINSKÝ (1886), who studied here a selected group of ascomycetous fungi. SVRČEK (1965) in his survey of mycofloristic research in individual phyto-geographical districts reports in case of the Kremnické vrchy Mts two authors only: KOTLABA – Poštárka u Zvolena (September 1954, Aphylloporales) and ČERNÝ – Budča (Polyporales). More interest in mycoflora in the Kremnické vrchy Mts can be dated to 80s of the past century. KOTLABA (1984) presents about 50 species of polyporous fungi recorded in the Kremnické vrchy Mts. KOTLABA (1991-in litt.) collected fungi in this region also in years 1973 (National Nature reserve Badínsky prales, virgin forest) and in 1986 (National Nature Reserve Mláčik). Also other published works of this author (KOTLABA, 1995; KOTLABA and POUZAR, 1963) mention several macromycetes species collected in the Kremnické vrchy Mts. Several other authors also included in their works fungal species recorded in the Kremnické vrchy Mts, eg HAGARA (1987, 1992), KUBIČKA and LIZOŇ (1982), LIZOŇ (1991), ŠKUBLA (1995).

Since 1990 we have been carrying out a research on mycoflora in southern part of the Kremnické vrchy Mts. From the examined area we have collected a large number of the newest mycofloristic records, and we have also published several mycocoenological papers (eg MIHÁL, 1993, 1996a, b, 1998, 2002; MIHÁL and BUČINOVÁ, 2005, 2007). In this paper we summarise the species diversity of hitherto recorded macromycetes in beech stands in southern part of the Kremnické vrchy Mts.

Materials and methods

We studied mycoflora in beech stands in south part of the Kremnické vrchy Mts. The research ran at the Ecological Experimental Stationary (EES) Kováčová – Kremnické vrchy Mts, from 1990 to 2008. The research station was established in year 1989, by investigators working at the Institute of Forest Ecology SAS in Zvolen. The aim was long-term monitoring of changes in biotic and abiotic components of fir-beech ecosystems subjected to human-induced load at different levels. We visited the locality once-monthly, at least, in vegetation season – from April to November. The short description of the locality EES Kremnické vrchy Mts is in Table 1.

During each visit to the locality we made records about the species diversity of macromycetes. Material that had not been determined directly in field was

determined in the laboratory, following the literature: ČERVENKA et al. (1972), MOSER (1983), JULICH (1984), BREITENBACH and KRÄNZLIN (1986), HAGARA (1987, 1992), VESELÝ et al. (1972), PAPOUŠEK (2004), and other sources. Several species were determined in laboratory *in vitro* conditions, by cultivation on substrates and by using sequencing analysis of sequences obtained from clones cultivated from nrDNA templates. From DNA templates isolated from soil samples, we amplified fragments of nuclear ribosomic acid nrDNA, by means of polymerase chain reaction – PCR in presence of primers specific for fungi (GRYNDLER et al., 2004). More detailed description of this method can be found in BUČINOVÁ (2008).

Herbarium items for most species are deposited by the first author in the Institute of Forest Ecology SAS in Zvolen. For assessment of mycocoenological situation, the species diversity was divided in two basic ecotrophic groups: 1. wood-decaying fungi (parasites and saprophytes), growing in wood substrate only, 2. terrestrial species (mycorrhizal and saprophytic), growing from soil horizons and forest litter. Apart from these two basic ecological trophic groups, we classified certain species in separate group of myco-parasitic species (species parasitizing on other fungi) and phyto-parasitic species (parasitizing on leaves of herbs and woody plants). In the group of epiphytic fungi we classified one single species (*Ascodichaena rugosa*).

Table 1. Basic characteristics of the locality EES Kremnické vrchy Mts

Orographic unit	Kremnické vrchy Mts
Permanent research plot	Ecological – Experimental Stationary Kováčová
Localisation	N 48°38'10", E 19°04'08"
Altitude [m asl.]	470–490
Exposition	WSW
Slope [°]	20
Geological substrate	Andesite, tuffaceous agglomerates
Soil type	Cambisol modale saturated
Throughfall *[mm]	653
Temperature * [°C]	8.3
Forest type groups	<i>Fagetum pauper inferiora</i>
Vegetal association	<i>Dentario bulbiferae</i> – Fagetum Zlatník, 1936 <i>Carici pilosae</i> – Fagetum Oberd. 1958
Tree composition [%]	Beech 95, fir 2, hornbeam 2, oak 1
Age of stand [years]	105
Stocking of stand **	0.0–0.3–0.5–0.7–0.9
Crown canopy [%]	0.0–100
Area of EES [ha ⁻¹] **	1.61

*Throughfall and Temperature: average values from 2003–2005 (Source: SHMÚ 2007)

**Stocking and Area of individual Partial research plots (PP): PP: H (clear cut) – 0.0–0.41 ha⁻¹, PP: I (intensive cutting operation) – 0.3–0.35 ha⁻¹, PP: S (mediate cutting operation) – 0.5–0.35 ha⁻¹, PP: M (moderate cutting operation) – 0.7–0.35 ha⁻¹, PP: K (control plot – without cutting operation) – 0.9–0.15 ha⁻¹

Results and discussion

In the following overview list we describe all hitherto determined fungal species confirmed for the EES Kremnické vrchy Mts. The species are ordered alphabetically: Ascomycota, Basidiomycota, Deuteromycota – Fungi imperfecti and Cystofilobasidiales. The nomenclature and author's abbreviations for taxons have been presented by LIZOŇ and BACIGÁLOVÁ (1998) and ŠKUBLA (2003).

Ascomycota: (46 species)

Aleuria aurantia (Pers.) Fuckel, *Ascocoryne sarcoides* (Jacq.) J.W. Groves et D.E. Wilson, *Ascodichaena rugosa* (L.) Butin, *Bisporella citrina* (Batsch) Korf et S.E.Carp., *Cenococcum geophilum* Fr., *Dasyscyphus ciliatus* (Schrad.) Sacc., *Diatrype disciformis* (Hoffm.) Fr., *D. stigma* (Hoffm.) Fr., *Durella commutata* Fuckel, *Eutypella quaternata* (Pers.) Rappaz, *Gyromitra esculenta* (Pers.) Fr., *Habrostictis rubra* Fuckel, *Helvella elastica* Bull., *H. lacunosa* Afzel., *Humaria hemisphaerica* (F.H.Wigg.) Fuckel, *Hymenoscyphus fagineus* (Pers.) Dennis, *Hypomyces chrysospermus* Tul. et C.Tul., *H. luteovirens* (Fr.) Tul. et C.Tul., *Hypoxylon fragiforme* (Pers.) J.Kickx f., *H. multifforme* (Fr.) Fr., *Kretzschmaria deusta* (Hoffm.) P.M.D.Martin, *Lachnum roseum* (Rehm) Rehm, *Leotia lubrica* (Scop.) Pers., *Melanopsamma pomiformis* (Pers.) Sacc., *Microsphaera alphitoides* Griffiths et Maubl., *Nectria cinnabarina* (Tode) Fr., *N. cosmariospora* Ces. et De Not., *N. ditissima* Tul. et C.Tul., *N. episphaeria* (Tode) Fr., *N. galligena* Bres. apud Strasser, *N. peziza* (Tode) Fr., *N. purtonii* (Grev.) Berk., *N. radiculicola* Gerlach & L.Nilsson, *Orbilbia curvatispora* Boud., *O. luteorubella* (Nyl.) P. Karst., *Peziza arvernensis* Boud., *P. succosa* Berk., *Pseudoplectania melaena* (Fr.) Sacc., *Pseudovalsa spinifera* (Wallr.) E.M.Barr., *Rhytisma acerinum* (Pers.) Fr., *Scutellinia scutellata* (L.) Lambotte, *Spathularia flavida* Pers., *Sphaerostibella aureonitens* (Tul. et C.Tul.) Seifert et al., *Valsa ambiens* (Pers.) Fr., *Xylaria hypoxylon* (L.) Grev., *X. polymorpha* (Pers. ex Mérat) Grev.

Basidiomycota: (300 species)

Agaricus arvensis Schaeff., *A. silvaticus* Schaeff., *Agrocybe praecox* (Pers.) Fayod, *Amanita eliae* Quél., *A. pantherina* (DC.) Krombh., *A. phalloides* (Fr.) Link, *A. rubescens* Pers., *A. vaginata* (Bull.) Lam., *Armillaria ostoyae* (Romagn.) Herink, *Auricularia mesenterica* (Dicks.) Pers., *Basidioradulum radula* (Fr.) Nobles, *Bjerkandera adusta* (Willd.) P. Karst., *Boletus betulicola* (Vasilkov) Pilát et Dermek, *B. edulis* Bull., *B. erythropus* Pers., *B. regius* Krombh., *B. reticulatus* Schaeff., *B. subappendiculatus* Dermek et al., *Bovista pussilla* (Batsch) Pers., *Calocera cornea* (Batsch) Fr., *C. viscosa* (Pers.) Fr., *Calvatia excipuliformis* (Scop.) Perdeck,

Cantharellus cibarius Fr., *C. pallens* Pilát, *C. tubaeformis* Fr., *Chondrostereum purpureum* (Pers.) Pouzar, *Chrysomphalina chrysophyllum* (Fr.) Cléménçon, *Clavariadelphus pistillaris* (L.) Donk., *Clavicornona pyxidata* (Pers.) Donk, *Clavulina cinerea* (Bull.) J. Schröt., *C. coralloides* (L.) J. Schröt., *Climacocystis borealis* (Fr.) Kotl. et Pouzar, *Clitocybe alba* (Bat.) Sing., *C. fragrans* (Sowerby) P.Kumm., *C. gibba* (Pers.) P.Kumm., *C. metachroa* (Fr.) P.Kumm., *C. nebularis* (Batsch.) P.Kumm., *C. odora* (Bull.) P.Kumm., *C. phyllophila* (Pers.) P.Kumm., *Clitopilus prunulus* (Scop.) P.Kumm., *Coleosporium tussilaginis* (Pers.) Berk., *Collybia cookei* (Bres.) J.D.Arnold, *Conocybe aporos* Kits van Waw., *Coprinus comatus* (O.F.Müll.) Gray, *C. disseminatus* (Pers.) Gray, *C. domesticus* (Bolton) Gray, *C. micaceus* (Bull.) Fr., *C. plicatilis* (Curt.) Fr., *C. silvaticus* Peck, *C. xanthothrix* Romagn., *Cortinarius anomalus* (Fr.) Fr., *C. brunneus* (Pers.) Fr., *C. bulliardii* (Pers.) Fr., *C. duracinus* Fr., *C. multifformis* (Fr.) Fr., *C. venetus* var. *montanus* M.M.Moser, *Craterellus cornucopioides* (L.) Pers., *Creolophus cirrhatus* (Pers.) P.Karst., *Cyathus striatus* (Huds.) Willd., *Cystoderma carcharias* (Pers.) Fayod, *C. cinnabarinum* (Alb. et Schwein. ex Fr.) Fayod, *C. granulosum* (Batsch) Fayod, *Dacrymyces stillatus* Nees., *Daedalea quercina* (L.) Fr., *Daedaleopsis confragosa* (Bolton) J.Schröt., *Entoloma rhodopolium* f. *nidosum* (Fr.) Noordel., *E. sinuatum* (Bull. ex Fr.) P.Kumm., *Exidia glandulosa* (Bull.) Fr., *E. saccharina* (Alb. et Schwein.) Fr., *E. pithya* (Alb. et Schwein.) Fr., *Flammulina velutipes* (M.A.Curtis) Singer, *Fomes fomentarius* (L.) J.Kickx f., *Fomitopsis pinicola* (Sw.) P.Karst., *Galerina badipes* (Fr.) Kühner, *G. pumila* (Pers.) Singer, *Ganoderma lipsiense* (Batsch) G.F.Atk., *G. lucidum* (M.A.Curtin) P.Karst., *Geastrum fimbriatum* Fr., *Gloeophyllum abietinum* (Bull.) P. Karst., *G. odoratum* (Wulfen) Imazeki, *Gymnopilus junonius* (Fr.) P.D.Orton, *G. penetrans* (Fr.) Murrill, *G. sapineus* (Fr.) Maire, *Gymnopus acervatus* (Fr.) Murrill, *G. aquosus* (Bull.) Antonín et al., *G. confluens* (Pers.) Antonín et al., *G. dryophilus* (Bull.) Murrill, *G. fusipes* (Bull.) Gray, *G. peronatus* (Bolton) Antonín et al., *Hapalopilus nidulans* (Fr.) P.Karst., *Hebeloma radicosum* (Bull.) Ricken, *H. sinapizans* (Paulet) Gillet, *Hericium clathroides* (Pall.) Pers., *H. coralloides* (Scop.) Gray, *Heterobasidion annosum* (Fr.) Bref., *Hirneola auricula-judae* (Bull.) Berk., *Hohenbuehelia petaloides* (Bull.) Schulzer, *Hydnum repandum* L., *H. rufescens* Fr., *Hydropus subalpinus* (Höhn.) Singer, *Hygrophoropsis aurantiaca* (Wulfen) Maire, *Hygrophorus chrysodon* (Batsch) Fr., *H. eburneus* (Bull.) Fr., *H. penarius* Fr., *H. poetarum* R.Heim, *H. olivaceoalbus* (Fr.) Fr., *Hymenochaete rubiginosa* (J.Dicks.) Lév., *Hymenogaster olivaceus* Vittad., *Hypholoma fasciculare* (Huds.) P.Kumm., *H. sublateritium* (Schaeff.) Quél., *Inocybe asterospora* Quél. *I. geophylla* (Fr.) P.Kumm., *I. rimoso* (Bull.) P.Kumm., *Inonotus nodulosus* (Fr.) P.Karst., *Kuehneromyces*

mutabilis (Schaeff.) Singer et A.H.Sm., **Laccaria** *amethystina* (Huds.) Cooke, *L. laccata* agg., *L. proxima* (Boud.) Pat., **Lacrymaria** *lacrymabunda* (Bull.) Pat., **Lactarius** *azonites* (Bull.) Fr., *L. blennius* (Fr.) Fr., *L. chrysorrheus* Fr., *L. fuliginosus* (Fr.) Fr., *L. mitissimus* (Fr.) Fr., *L. pallidus* (Pers.) Fr., *L. piperatus* (L.) Gray, *L. pterosporus* Romagn., *L. quietus* (Fr.) Fr., *L. salmonicolor* R.Heim et Leclair, *L. torminosus* (Scaeff.) Gray, *L. vellereus* (Fr.) Fr., *L. volemus* (Fr.) Fr., *L. zonarius* (Bull.) Fr., **Leccinum** *carpini* (R.Schulz) M.M.Moser ex D.A.Reid, *L. scabrum* (Bull.) Gray, **Lentaria** *mucida* (Pers.) Corner, **Lentinus** *strigosus* (Schwein.) Fr., *L. torulosus* (Pers.) Lloyd, **Lenzites** *betulina* (L.) Fr., **Lepiota** *clypeolaria* (Bull.) P.Kumm., *L. cristata* (Alb. et Schwein.) P.Kumm., **Lepista** *flaccida* (Sowerby) Pat., *L. irina* (Fr.) H.E.Bigelow, *L. nuda* (Bull.) Cooke, *L. panaeolus* (Fr.) P. Karst., **Leucopaxillus** *giganteus* (Sibth.) Singer, **Lycoperdon** *echinatum* Pers., *L. perlatum* Pers., *L. pyriforme* Schaeff., *L. umbrinum* Pers., **Lycophyllum** *connatum* (Schumach.) Singer, *L. deliberatum* (Britzelm.) Kreisel, *L. fumosum* (Pers.) P.D.Orton, *L. loricatum* (Fr.) Kühner, **Macrocyttidia** *cucumis* (Pers.) Joss., **Macrolepiota** *procera* (Scop.) Singer, **Marasmiellus** *foetidus* (Sowerby) Antonín et al., **Marasmius** *alliaceus* (Jacq.) Fr., *M. bulliardii* Quél., *M. cohaerens* (Pers.) Cooke et Quél., *M. epiphyllus* (Pers.) Fr., *M. rotula* (Scop.) Fr., *M. wynnei* Berk et Broome, **Megacollybia** *platyphylla* (Pers.) Kotl. et Pouzar, **Mycena** *acicula* (Schaeff.) P.Kumm., *M. alcalina* (Fr.) P.Kumm., *M. citrinomarginata* Gillet, *M. crocata* (Schrad.) P.Kumm., *M. epipterygia* (Scop.) Gray, *M. fagetorum* (Fr.) Gillet, *M. filopes* (Bull.) P.Kumm., *M. galericulata* (Scop.) Gray, *M. galopus* (Pers.) P.Kumm., *M. haematopus* (Pers.) P. Kumm., *M. maculata* P.Karst., *M. polygramma* (Bull.) Gray, *M. pura* (Pers.) P.Kumm., *M. renati* Quél., *M. rosea* (Bull.) Gramberg, *M. rosella* (Fr.) P.Kumm., *M. stipata* Maas Geest. & Schwöbel, *M. stylobates* (Pers.) P.Kumm., **Oligoporus** *subcaesius* (A.David) Ryvarden et Gilb., *O. fragilis* (Fr.) Gilb. et Ryvarden, *O. stipticus* (Pers.) Gilb. et Ryvarden, *O. tephroleucus* (Fr.) Gilb. et Ryvarden, **Omphalina** *epichysium* (Pers.) Quél., **Oudemansiella** *mucida* (Schrad.) Höhn., **Panaeolus** *retirugis* (Fr.) Quél., **Panellus** *serotinus* (Pers.) Kühner, *P. stipticus* (Bull.) P.Karst., **Paxillus** *involutus* (Batsch) Fr., **Peniophora** *incarnata* (Pers.) P.Karst., **Phaeocollybia** *festiva* (Fr.) Heim., **Phaeolus** *schweinitzii* (Fr.) Pat., **Phaeomarasmius** *erinaceus* (Fr.) Kühner, **Phallus** *impudicus* L., **Phanerochaete** *laevis* (Pers.) J. Erikss. et Ryvarden, **Phellinus** *conchatus* (Pers.) Quél., *P. hartigii* (Allesch. et Schnabl) Pat., **Phlebia** *radiata* Fr., **Phlebiella** *sulphurea* (Pers.) Ginus et M.N.L. Lefébvre, **Pholiota** *adiposa* (Batsch) P. Kumm., *P. aurivella* (Batsch) P.Kumm., *P. flammans* (Batsch) P.Kumm., *P. lenta* (Pers.) Singer, *P. squarrosa* (Weigel) P.Kumm., **Phragmidium** *rubi-idaei* (DC.) P.Karst., **Pleurotus** *ostreatus* (Jacq.) P.Kumm., *P. pulmonarius* (Fr.) Quél., **Plicaturopsis** *crispa* (Pers.) D.A.Reid, **Pluteus**

atromarginatus (Konrad) Kühner, *P. cervinus* (Schaeff.) P.Kumm., *P. pellitus* (Pers.) P.Kumm., *P. romellii* (Britzelm.) Sacc., *P. salicinus* (Pers.) P.Kumm., **Polyporus** *arcularius* (Batsch) Fr., *P. brumalis* (Pers.) Fr., *P. ciliatus* Fr., *P. melanopus* (Sw.) Fr., *P. squamosus* (Huds.) Fr., *P. varius* (Pers.) Fr., **Psathyrella** *candolleana* (Fr.) Maire, *P. piluliformis* (Bull.) P.D.Orton, *P. spadiceogrisea* (Schaeff.) Maire, **Pseudoclitocybe** *cyathiformis* (Bull.) Singer, **Pseudocraterellus** *undulatus* (Pers.) Rauschert, **Pseudohydnum** *gelatinosum* (Scop.) P.Karst., **Pseudotomentella** *tristis* (P.Karst.) M.J.Larsen, **Psilocybe** *inquilina* var. *crochula* (Fr.) Høil., **Puccinia** *violae* DC., **Pycnoporus** *cinnabarinus* (Jacq.) P.Karst., **Ramaria** *botrytis* (Pers.) Ricken, *R. fennica* var. *fumigata* (Peck) Schild, **Rhodocollybia** *butyracea* f. *asema* (Fr.) Antonín et al., *R. maculata* (Alb. et Schwein.) Singer, **Rickenella** *fibula* (Bull.) Raithelth., **Russula** *aeruginea* Lindbl., *R. albonigra* (Krombh.) Fr., *R. alutacea* (Pers.) Fr., *R. amoenolens* Romagn., *R. aurea* Pers., *R. chloroides* (Krombh.) Bres., *R. cyanoxantha* (Schaeff.) Fr., *R. farinipes* Romell, *R. fellea* (Fr.) Fr., *R. firmula* Jul. Schäff., *R. foetens* (Pers.) Fr., *R. galochroa* (Fr.) J.E.Lange, *R. heterophylla* (Fr.) Fr., *R. integra* (L.) Fr., *R. laurocerasi* Melzer, *R. lepida* Fr., *R. nigricans* (Bull.) Fr., *R. nobilis* Velen., *R. olivacea* (Schaeff.) Pers., *R. risigallina* (Batsch) Sacc., *R. undulata* Velen., *R. vesca* Fr., *R. violeipes* Quél., **Sarcodon** *imbricatus* (L.) P.Karst., **Schizophyllum** *commune* Fr., **Schizopora** *flavipora* (Berk. et M.A.Curtis ex Cooke) Ryvarden, *S. radula* (Pers.) Hallenb., **Scleroderma** *citrinum* Pers., **Simocybe** *centunculus* (Fr.) P.Karst., **Stereum** *gausapatum* (Fr.) Fr., *S. hirsutum* (Willd.) Gray, *S. rugosum* (Pers.) Fr., *S. sanguinolentum* (Alb. et Schwein.) Fr., **Stropharia** *aeruginosa* (Curtis) Quél., **Thelephora** *terrestris* Ehr., **Trametes** *gibbosa* (Pers.) Fr., *T. ochracea* (Pers.) Gilb. et Ryvarden, *T. velutina* (Planer) G.Cunn., *T. versicolor* (L.) Pilát, **Trechispora** *cohaerens* (Schwein.) Jülich et Stalpers, **Tremella** *foliacea* Pers., *T. mesenterica* Retz., **Trichaptum** *abietinum* (J.Dicks.) Ryvarden, *T. bifforme* (Fr.) Ryvarden, **Tricholoma** *acerbum* (Bull.) Vent., *T. album* (Schaeff.) P.Kumm., *T. flavobrunneum* (Fr.) Quél., *T. imbricatum* (Fr.) P.Kumm., *T. sejunctum* (Sowerby) Quél., *T. sulphureum* (Bull.) P.Kumm., *T. terreum* (Schaeff.) P.Kumm., *T. ustale* (Fr.) P.Kumm., *T. vaccinum* (Pers.) P.Kumm., *T. virgatum* (Fr.) P.Kumm., **Tricholomopsis** *rutilans* (Schaeff.) Singer, **Tubaria** *conspersa* (Pers.) Fayod, *T. romagnesiana* Arnolds, **Xerocomus** *chrysenteron* (Bull.) Quél., *X. ferrugineus* (Schaeff.) Bon, *X. subtomentosus* (L.) Quél., **Xerula** *melanotricha* Dörfelt, *X. pudens* (Pers.) Singer, *X. radicata* (Relhan) Dörfelt

Deuteromycota – Fungi imperfecti:

(6 species)

Bispora *antennata* (Pers.:Fr.) E.W. Mason, **Cylindrocarpon** *willkommii* (Lind.) Wollenw., **Cytospora** *ambiens* Sacc.,

Libertella faginea Desm., *Melasmia acerina* Lév.,
Tubercularia vulgaris (Tode: Fr.) Fr.

Cystofilobasidiales: (1 species)

Cryptococcus podzolicus (Babeva & Reshetova) Golubev

From this species spectrum we provide here short descriptions for some rarely or very rarely occurring and endangered species:

Ascomycota:

Cenococcum geophilum

An ectomycorrhizal species, growing in soil in mixed and coniferous forest stands. The presence of this species in the EES Kremnické vrchy Mts was only confirmed under *in vitro* conditions – using soil samples and sequencing analysis of clones cultivated from nrDNA templates (BUČINOVÁ, 2008; GRYNDLER et al., 2004).

Habrostictis rubra

Small reddish fruiting bodies of *H. rubra* grow very rarely in bark fissures on dying broadleaved woody plants. Perhaps due to their very small size, *H. rubra* fruiting bodies are often unnoticed. In Slovakia, this species was found only in the EES Kremnické vrchy Mts (ŠKUBLA, 2003).

Nectria peziza

A rare species, growing in decomposing wood of broadleaved and coniferous species. KEIZER (1998) reports its occurrence also in decomposing fruiting bodies of *Polyporus squamosus* (Huds.) Fr. In Slovakia, the species *N. peziza* has been reported from a single locality – Kopčany, Záhorie region (ŠKUBLA, 2003). Apart from the record of *N. peziza* at EES Kremnické vrchy Mts, the species was in year 2005 also registered in surroundings of the magnesite plant in Lubeník in the Revúcka vrchovina Mts (MIHÁL and BLANÁR, 2007), in 2001 in the locality National Nature Reserve Šarkanica in the National Park Muránska planina Plateau (leg. D. BLANÁR, det. I. MIHÁL, non-published), as well as in 2008 in the locality Zámčisko in the Chvojnická pahorkatina Hills and in the locality Michalková in the Javorie Mts (leg et det. I. MIHÁL, non-published).

Nectria purtonii

A species belonging to the family Nectriaceae. *N. purtonii* is a very rare species, parasiting on several fungi from the order Pyrenomycetales, eg *Diatrype disciformis* (Hoffm.) Fr., *D. stigma* (Hoff.) Fr., *Eutypella quaternata* (Pers.) Rappaz, *Valsa* sp. Apart from the Kremnické vrchy Mts, the occurrence of *N. purtonii* has only been confirmed in two geographical units of Slovakia (ŠKUBLA, 2003).

***Nectria radiciala* (anamorphs: *Cylindrocarpon destructans*)**

Fungus parasitizing on roots of broadleaved woody plants, occurring mostly in asexual form of *C. destructans*. In case of EES Kremnické vrchy Mts, the presence of this species was proved in conditions *in vitro* in soil samples, using the method of sequencing analysis of clones cultivated from nrDNA templates (BUČINOVÁ, 2008; GRYNDLER et al., 2004).

Pseudoplectania melaena

A very rare discomycetous species, growing in fir wood (VESELÝ et al., 1972). In Slovakia, this interesting species has been included among the threatened macrofungi (LIZOŇ, 1995). Occurrence of *P. melaena* has been, apart from the Kremnické vrchy Mts confirmed from four geographical units in Slovakia (ŠKUBLA, 2003). In the Czech Republic, the species belongs to the most severely endangered ones (ANTONÍN and BIEBEROVÁ, 1995).

Sphaerostibella aureonitens

A rare ascomycetous species, more known under the synonym of *Nectriopsis aureonitens* (Tul. et C.Tul) Maire. It grows as a sapro-parasite on aphyllorhous macrofungi. At the EES Kremnické vrchy Mts, the species was found growing on old fruiting bodies of *Stereum rugosum* (Pers.) Fr. In Slovakia, this species has hitherto been known from the EES Kremnické vrchy Mts, only (ŠKUBLA, 2003).

Basidiomycota:

Conocybe aporos

A saprophytic, humicolous species, rarely occurring in appropriate substrates in broadleaved forests. Due to its gracility and very small dimensions of fruiting bodies, the fungus is frequently unnoticed. Apart from the Kremnické vrchy Mts, the occurrence of *C. aporos* has been confirmed in five geographical units of Slovakia (ŠKUBLA, 2003).

Hymenogaster olivaceus

A rarely occurring mycorrhizal gasteromycetous fungus with fruiting bodies developing and growing partially immersed in soil. The occurrence of *H. olivaceus* has been, apart from the Kremnické vrchy Mts, confirmed only in two other geographical units of Slovakia (ŠKUBLA, 2003).

Mycena stipata

A saprophytic fungus, growing in clusters on dead and decomposing wood in broadleaved and mixed forests. The fungus is frequently confused with relative ones belonging to the range of *Mycena alcalina* agg. Occurrence of *M. stipata* has been, apart from the Kremnické vrchy Mts, confirmed only for two geographical units of Slovakia (ŠKUBLA, l.c.).

Phaeocollybia festiva

A rare species, occurring especially in coniferous forests, at higher altitudes. In Slovakia, the species belongs to the endangered macromycetes (LIZOŇ, 1995). Occurrence of *P. festiva* has been, apart from the Kremnické vrchy Mts, confirmed from four units of Slovakia (ŠKUBLA, l.c.).

Pseudotomentella tristis

A rarely occurring saprophytic species, belonging to the family of Thelephoraceae. It grows in moist forest soil, in decomposing plant debris or among stones. Apart from the Kremnické vrchy Mts, the occurrence of *P. tristis* has been confirmed from the Sitno Mountain in the Štiavnické vrchy Mts (ŠKUBLA, l.c.).

Russula amoenolens

An ectomycorrhizal symbiotic fungus, rarely growing in broadleaved forests. Apart from the Kremnické vrchy Mts, the occurrence of *R. amoenolens* has been reported from seven geographical units of Slovakia (ŠKUBLA, l.c.).

Trechispora cohaerens

A lignicolous fungus, forming resupinate fruiting bodies coloured cream to yellowish on dead branches, primarily in broadleaved woody plants. Together with several relative species of genus *Trechispora*, it is frequently unnoticed in nature. Apart from the Kremnické vrchy Mts, *T. cohaerens* has been recorded in the Bukovské vrchy Mts in eastern Slovakia (ŠKUBLA, l.c.).

Cystofilobasidiales:

Cryptococcus podzolicus

An interesting species, associated with forest soils in which it represents a very rich-in-species group of yeast fungi. It is necessary to note that some mycologists classify this species rather in the taxonomic group of yeasts (Endomycota), order Cystofilobasidiales or Trichosporonales (FELL et al., 2000; SCORZETTI et al., 2002). Other authors consider the species *C. podzolicus* relative to the taxonomic order of Tremellales (Basidiomycota), and describe it here as a species manifesting mitosporic yeast phase within its development (UNIPROT CONSORTIUM, 2008; RHODE, 2005). For the EES Kremnické vrchy Mts, the occurrence of this species was proved in conditions *in vitro* from soil samples, by using sequencing analysis of clones obtained from nrDNA templates (BUČINOVÁ, 2008; GRYNDLER et al., 2004).

Among macromycetes with rare or very rare occurrence in Slovakia we can also include: *Helvella lacunosa*, *Hymenoscyphus fagineus*, *Orbilina luteorubella*, *Cortinarius venetus* var. *montanus*, *Chrysomphalina chrysophyllum*, *Hericium coralloides*, *Lentaria mucida*, *Pluteus salicinus*, *Sarcodon imbricatus*, *Tricholoma virgatum*, *Xerula pudens* and others

From macromycetes characteristic for thermophilous or Pannonian flora, we report here: *Amanita vaginata*, *Basidioradulum radula*, *Boletus regius*, *B. subapplendiculatus*, *Entoloma sinuatum*, *Hirneola auricula-judae*, *Marasmiellus foetidus*, *Phallus impudicus*, *Polyporus arcularius*, *Russula aurea*, *Scleroderma citrinum*, *Tricholoma acerbum*, and *Xerocomus subtomentosus*. Analogically, we can document the species having its occurrence optimum in highly situated fir-beech, fir and spruce vegetation zones: *Armillaria ostoyae*, *Climacocystis borealis*, *Dacrymyces stillatus*, *Fomitopsis pinicola*, *Gloeophyllum abietinum*, *Heterobasidion annosum*, *Lepista flaccida*, *Mycena rosea*, *Oligoporus subcaesius*, *Omphalina epichysium*, *Pholiota flammans*, *Pseudohydnum gelatinosum*, *Rickenella fibula*, *Trichaptum abietinum*, and others. In case of these species, it is necessary to note that the presence of fir trees in the locality substituted, to a certain extent, ecotopic and ecotrophic conditions characteristic for fir and spruce stand situated at higher altitudes. In spite of a low percent share of fir in the forest stand at the EES Kremnické vrchy Mts, there occurred rather high numbers of macromycetes closely associated with fir or with by-fir-created environment.

Abundance of macromycetes classified to the individual eco-trophic groups is illustrated in Table 2. We can see that markedly dominant were saprophytic species (LS – 127 and TS – 102 species), and lower dominant mycorrhizal species (MS – 97 species), and we can conclude that the studied mycocoenosis in the beech stand at the EES Kremnické vrchy Mts has a conspicuous symbiotic-saprophytic character. At the same time, we also recorded several parasitic species (phyto-, myco-, and lingo-parasites), having in the given ecosystem an important role, mainly in terms of their influence on health state of forest woody plants (Table 3). The most important lignicolous parasites are, for example the species: *Armillaria ostoyae*, *Fomes fomentarius*, *Fomitopsis pinicola*, *Heterobasidion annosum*, *Kretzschmaria deusta*, species of the genus *Nectria*, *Pholiota adiposa*, *Phellinus hartigii*, and others. In the saprophytic species *Armillaria ostoyae* growing at the EES Kremnické vrchy Mts, we monitored dynamics of abundance and biomass production in its fruiting bodies (MIHÁL, 1995, 1996b). As parasitic ones were also recorded several species parasitizing on leaves of herbs and woody plants, eg *Coleosporium tussilaginis*, *Puccinia violae*, *Rhytisma acerinum*, and others. From the fungi parasitizing on other fungi we recorded several species belonging to the genera *Hypomyces* and *Nectria*, and the species *Sphaerostibella aureonitens*.

Apart from determination of species diversity of macromycetes in beech stands at the EES Kremnické vrchy Mts, we also conducted research on abundance and distribution of their fruiting bodies. Providing with the results of evaluation of dynamics of the species dominance, we also assessed succession dynamics of the

macromycetes, and quantified biomass production in fruiting bodies of selected macromycetes species (MIHÁL, 1993, 1995, 1996b, 1998; MIHÁL and BUČINOVÁ, 2005, 2007). We do not consider our mycofloristic and mycocoenological research in beech stands at the EES Kremnické vrchy Mts as complete. For obtaining results relevant for describing appropriately the succession dynamics of the mycocoenosis at the EES Kremnické vrchy Mts, long-term monitoring of the mycoflora is, according to our opinion, inevitable.

Table 2. Number of species within individual ecotrophic groups

Ecotrophic groups							Total
LP	HP	MP	LS	TS	MS	E	
14	6	6	127	102	97	1	353

LP, lignicolous parasites; HP, herbivorous parasites; MP, mycoparasites; LS, lignicolous saprophytes; TS, terrestrial saprophytes; MS, mycorrhizal symbionts; E, epiphytes

Table 3. Enumeration of fungal parasites

Species	LP	HP	MP
<i>Armillaria ostoyae</i>	×		
<i>Coleosporium tussilaginis</i>		×	
<i>Cylindrocarpon willkommii</i>	×		
<i>Fomes fomentarius</i>	×		
<i>Fomitopsis pinicola</i>	×		
<i>Ganoderma lipsiense</i>	×		
<i>Heterobasidion annosum</i>	×		
<i>Hypomyces chrysospermus</i>			×
<i>Hypomyces luteovirens</i>			×
<i>Inonotus nodulosus</i>	×		
<i>Kretzschmaria deusta</i>	×		
<i>Melasmia acerina</i>		×	
<i>Microsphaera alphitoides</i>		×	
<i>Nectria cosmariospora</i>			×
<i>Nectria ditissima</i>	×		
<i>Nectria episphaeria</i>			×
<i>Nectria galligena</i>	×		
<i>Nectria purtonii</i>			×
<i>Nectria radicularia</i>	×		
<i>Phellinus hartigii</i>	×		
<i>Pholiota adiposa</i>	×		
<i>Phragmidium rubi-idaei</i>		×	
<i>Pleurotus ostreatus</i>	×		
<i>Puccinia violae</i>		×	
<i>Rhytisma acerinum</i>		×	
<i>Sphaerostibella aureonitens</i>			×
Total	14	6	6

LP, HP, MP – see Table 2

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Mykoflóra bukových lesov Kremnických vrchov (stredné Slovensko)

Súhrn

Počas rokov 1990 až 2008 sme skúmali mykoflóru bukových lesných porastov na Experimentálnom a ekologickom stacionári (EES) v južnej časti Kremnických vrchov. Počas doby výskumu sme v poraste EES determinovali celkovo 353 druhov húb. Medzi vzácné sa vyskytujúce a ohrozené huby zistené v poraste EES môžeme zaradiť napr. druhy: *Coenococcum geophilum*, *Habrostictis rubra*, *Nectria punicea*, *Sphaerostibella aureonitens* (Ascomycota), *Hymenogaster olivaceus*, *Mycena stipata*, *Phaeocollybia festiva*, *Pseudotomentella tristis* (Basidiomycota) a *Cryptococcus podzolicus* (Cystofilobazidiales). V bukovom poraste EES sa vyskytovali druhy typické pre podmienky teplomilnej, panónskej flóry a zároveň sa tu vyskytovali aj druhy charakteristické pre horské jedľobučiny a smrečiny. Z rozdelenia početnosti druhov do jednotlivých ekotrofických skupín vidno výrazný symbioticko-saprofytický charakter mykocenózy lesného porastu EES. Z celkovej druhovej diverzity makromycétov sa pomerne málo druhov vyskytovalo paraziticky. Z mykofloristického hľadiska je potrebné územiu Kremnických vrchov venovať v budúcnosti viac pozornosti.

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Occurrence of species of the *Nectria* s.l. (Bionectriaceae, Nectriaceae, Hypocreales, Ascomycetes) in Central and South-eastern Europe

Ivan Mihál, Alojz Cicák¹, Hristo Tsakov², Petar Petkov²

¹Institute of Forest Ecology, Slovak Academy of Sciences, Štúrova 2, 960 53 Zvolen, Slovak Republic,
E-mail: mihal@sav.savzv.sk

²Forest Research Institute, Bulgarian Academy of Sciences, St. Kliment Ohridski Blvd. 132,
1756 Sofia, Bulgaria,
E-mail: forestin@bulnet.bg

Abstract

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Recent data on the occurrence of species of *Nectria* s.l. (Bionectriaceae, Nectriaceae, Hypocreales, Ascomycetes) in the Czech Republic, Poland, Slovakia, Hungary, Romania and Bulgaria (Central and South-eastern Europe) are presented, including some notes on their ecological characteristics. Eight species were found in the five countries outside Slovakia (*Cosmospora coccinea*, *C. purtonii*, *Nectria aurantiaca*, *N. cinnabarina*, *N. coryli*, *Neonectria coccinea*, *N. galligena*, *N. punicea*). Due to long-term investigations in a large number of localities, we found six additional species in Slovakia (*Cosmospora episphaeria*, *Hydropisphaeria peziza*, *Nectria berolinensis*, *N. cucurbitula*, *Neonectria ditissima*, *N. radicolica*). *Nectria aurantiaca* (one locality in Bulgaria), *N. coryli* (one locality in Slovakia and Bulgaria) and *Neonectria punicea* (three localities in Slovakia and one in Bulgaria) can be considered as rare. The records of these three species in Bulgaria can be regarded as the first ones for this country. The data were collected mainly in the course of a long-term study of the necrotic bark disease of beech (*Fagus sylvatica* L.) focused on Slovakia. The disease is apparently mainly caused by some species of *Neonectria* (*N. coccinea*, *N. ditissima*, *N. galligena*). It has spread in the last decades and often provokes epiphytycias.

Key words

Ascomycetes, Central Europe, fungi, *Nectria* s.l., Nectriaceae, South-eastern Europe

Introduction

The genus *Nectria* s.l. belongs to the significant genera of ascomycetous fungi. Species of this genus occur mostly as saproparasites of herbs and wooden plants, in form of sexual stage (telemorpha) and asexual stage (anamorpha), for example genera *Cylindrocarpon* Wallenw., *Fusarium* Link., *Tubercularia* Tode or *Verticillium* Nees. The genus *Nectria* s.l. includes species that are significant vascular parasites of forest trees. In contrast to the original tracheomycotic fungi, for example those of the genus *Ophiostoma* Syd. et P. Syd., some species of the genus *Nectria* are considered to evoke secondary disease of tracheomycotic type, which is mani-

festated by creation of necrotic wounds on the tree barks (JANČAŘÍK, 2000).

Occurrence and distribution of the fungi of the families Bionectriaceae and Nectriaceae, but especially of the genus *Nectria* is in focus of many mycologists and phytopathologists in Central and South-eastern Europe. In the Czechia these families were studied, for example by ANTONÍN and VÁGNER (2001), JANČAŘÍK (2000), NOVOTNÝ (2003), in Poland MAŃKA (2005), ROZYCKI (1993), RYKOWSKI et al. (1989), in Slovakia by CICAČ and MIHÁL (2002), MIHÁL (2002), MIHÁL et al. (2007), in Hungary by MIHÁL and CICAČ (2005), STANDOVÁR and KEREKES (2003), in Romania by CHIRA and CHIRA (1997, 1998), CHIRA et al. (1996), MIHÁL and CICAČ (2007),

MIHALCIUC et al. (2001), in Bulgaria by CÍČÁK et al. (2006), ROSNEV and PETKOV (1996). Important for the control and possible elimination of dangerous effects of the fungi of the genus *Nectria* in forests stands is deeper knowledge of biology and ecology of these fungi.

It is to be stressed, that few data about the occurrence, distribution and ecological requirements of representatives of the genus *Nectria* in Central and South-eastern Europe are recorded. For this reason, when studying the necrotic disease of beech in Czech Republic, Poland, Slovakia, Hungary, Romania and

Bulgaria we focused on the evidence of the present occurrence of some species of the genus *Nectria* s.l. Their occurrence together with ecological characteristics and taxonomical notes are presented in this study.

Material and methods

Occurrence of the fungi of different genera of the families Bionectriaceae and Nectriaceae was recorded in

Table 1. Basic characteristics of research localities in the individual countries

Country	Orographic unit	Locality	Date of research	Altitude [m asl]	Exposition	Beech composition [%] / Age of stand [years]
CZ	Moravsko-sliezské Beskydy	Šance	2. 4. 2001	650	SW	90.0 / 60
	Moravsko-sliezské Beskydy	Hukvaldy	3. 4. 2001	450	E	38.0 / 90
	Moravsko-sliezské Beskydy	Pustevny	3. 4. 2001	680	SE	74.0 / 115
PL	Beskid Sądecki	Kiczera	17. 4. 2007	695	W	80.0 / 60–70
	Beskid Nizki	Przełecz Zebrak	18. 4. 2007	825	W	95.0 / 90–110
	Bieszczady	Połanki	19. 4. 2007	500	NE	30.0 / 60–80
	Bieszczady	Przysłop	19. 4. 2007	610	S	80.0 / 70
SK*	35 in total	77 in total	1990–2008	280–1,025	all	25–100 / 20–250
H	Börzöny	Diosjenő	17. 4. 2001	500	N	80.0 / 100
	Bükk	Öserdő	18. 4. 2001	800	SW	92.0 / 20–200
	Zempéni-Hegység	Telkibánya	18. 4. 2001	300	SE	50.0 / 65
RO	Munții Stânișoarei	Crucea	17. 10. 2006	690	SW	90.0 / 30–100
	Munții Bistriței	Holda	17. 10. 2006	655	NE	95.0 / 30–120
	Munții Bărgau	Piatra Fântânele	18. 10. 2006	1,017	E	98.0 / 80
	Munții Tibleș	Telciu	19. 10. 2006	420	E	90.0 / 70
BG	Vitosha	Dragalevski monastir	18. 4. 2005	1,080	NE	100 / 70–130
	Stara planina	Petrohan	20. 4. 2005	1,400	NE	100 / 100–110
	Stara planina	Barzia	20. 4. 2005	1,150	NW	100 / 100–120
	Stara planina	Etropole	21. 4. 2005	720	NE	99.0 / 120–130
	Stara planina	Ribaritsa	24. 4. 2006	1,100	NW	100 / 70
	Stara planina	Shipkovo	25. 4. 2006	650	NE	100 / 70
	Stara planina	Troyan	25. 4. 2006	480	N	100 / 80
	Stara planina	Balkanets	26. 4. 2006	1,250	N	100 / 100–120
	Stara planina	Shipka	28. 4. 2006	1,100	NE	90.0 / 65
	Stara planina	Kotel	24. 10. 2007	700	N	100 / 120
	Stara planina	Ticha	25. 10. 2007	750	SW	90.0 / 70
	Stara planina	Ichera	26. 10. 2007	700	NW	100 / 80
	Stara planina	Karandila	26. 10. 2007	1,000	SE	100 / 135
	Strandzha	Silkosia	25. 4. 2009	305	N	100 / 98

SK*, nomenclature of the basic characteristics of Slovakia's localities is given by CÍČÁK and MIHÁL (2002) and MIHÁL (2002); CZ, Czech Republic; PL, Poland; SK, Slovakia; H, Hungaria; RO, Romania; BG, Bulgaria

countries mentioned above during evaluation of the degree of the necrotic disease in 2001, 2005–2009. In Slovakia this investigation was running longer, since 1990 until 2008. The basic characteristic of the study sites in individual countries are given in the Table 1.

The samples of fruiting bodies *in vivo* in the form of teleomorpha were collected from beech bark as well as from other woody trees and various substrates. In the laboratory the species were identified under the microscope. The identification keys by BREITENBACH and KRÄNZLIN (1986), BUTIN (1995), ČERVENKA (1971), ROSSMAN et al. (1999), SAMUELS and BLACKWELL (2001) were used. The species *Neonectria ditissima* and *Neonectria radiculicola* were identified by cultivation *in vitro* (*N. ditissima* – det. G. JUHÁSOVÁ, *N. radiculicola* – det. K. BUČINOVÁ). Samples of fruiting bodies were collected and identified by the authors of this study and they have been deposited in the form of exicates in the collection of the first author in the Institute of Forest Ecology of SAS in Zvolen (Slovakia).

Data on the distribution, validity of taxonomical names as well as ecotrophy (ie nutrition requirement to substrate) of the species of both families included in this study were taken from the works by ČERVENKA (1971), ROSSMAN et al. (1999), ŠKUBLA (2003) and from the CABI BIOSCIENCE (2008), as well as from the existing papers of the authors of this study (MIHÁL, 2002; MIHÁL et al., 2007). The nomenclature and taxonomical classification of the identified species mainly by ROSSMAN et al. (1999) as well as by CASTLEBURY et al. (2006), MANTIRI et al. (2001) and SAMUELS et al. (2006) were used.

Results and discussion

During the investigation of the beech necrotic disease in the selected localities in individual Central and South-eastern countries the occurrence of several species of the families Bionectriaceae and Nectriaceae were recorded. Their survey in individual localities is given in the Table 2.

As shown in this table, in these countries, outside of Slovakia except, we recorded the occurrence of 8 species. Due to a long-term investigation in Slovakia, which was carried out in many localities, we recorded occurrence of further 6 species, which we have not found outside of Slovakia, viz. *Cosmospora episphaeria*, *Hydropisphaeria peziza*, *Nectria berolinensis*, *N. cucurbitula*, *Neonectria ditissima* and *N. radiculicola* (see Table 2). However, many of them may also occur in other Central and South-eastern European countries. For example, we have no doubts about the occurrence of the generally distributed species like *Nectria cucurbitula* or *Neonectria ditissima*. How-

ever, we have a few data on the occurrence of other target species in the adjacent countries.

The data on the occurrence of Bionectriaceae and Nectriaceae in the adjacent countries found in the available literature are given in the Table 3. When compared with the findings given in the Table 2, we see that also in these countries some species were recorded in the past, which in recent study we have found only in Slovakia (*Cosmospora episphaeria*, *Hydropisphaeria peziza*, *Neonectria ditissima* and *N. radiculicola*). Therefore the data from the Table 3 can be considered as complementary data to the species we recorded in those countries during our investigations. According to BREITENBACH and KRÄNZLIN (1986), among all species given in Tables 2 and 3 the species *Nectria coryli* and *Neonectria punicea* can be considered as rare. However, from the point of view *Cosmospora purtonii*, *Hydropisphaeria peziza* and *Nectria berolinensis* can be included in the group of rare fungi. For example, in Slovakia *Nectria coryli* was recorded in only one locality, *Neonectria punicea* in three localities, while *Hydropisphaeria peziza* in four localities (MIHÁL et al., 2007; MIHÁL, 2008 – unpubl.). In the adjacent countries the occurrence of these species is not known and in the literature (ANTONÍN and VÁGNER, 2001) we have found only one record of *Hydropisphaeria peziza* occurrence. For this reason, the rarer our data of *Cosmospora purtonii* occurrence in Hungary, whereas the *Nectria aurantiaca*, *N. coryli* and *Neonectria punicea* occurrence in Bulgaria can be considered as the first record for the Hungary and Bulgaria.

All species given in the Tables 2 and 3 can be classified, according to the newest taxonomical concepts (ROSSMAN et al., 1999), into 2 families and 4 genera:

- o Bionectriaceae Samuels et Rossman *fam. nov.* (genus: *Hydropisphaeria* Dumort.)
- o Nectriaceae Tul et C. Tul. (genera: *Cosmospora* Rabenh., *Nectria* (Fr.) Fr., *Neonectria* Wollenw.).

According to the most recent literature, the fungi of the families Bionectriaceae and Nectriaceae have a relatively stabilized taxonomical status. Similarly as the other macromycetes, also these species were subjected to different taxonomical nomenclature in the past. According to ROSSMAN et al. (1999), more than 200 species related to the genus *Nectria* have been described up to day. Among the complex works presenting the newest knowledge on the biology and taxonomy of the genus *Nectria* s.l. and other related genera, the works of BRAYFORD et al. (2004), CASTLEBURY et al. (2006), MANTIRI et al. (2001), ROSSMAN et al. (1999), SAMUELS (1976), SAMUELS and BLACKWELL (2001) and SAMUELS et al. (2006) should be mentioned. The overview of the current taxonomical validity of the nomenclature within the genus *Nectria*

s.l., in the sexual stage (teleomorpha) as well as the asexual stage (anamorpha) is presented in the Table 4. However, the anamorphic developmental stages of several species of the genus *Nectria* and related genera have not been identified with certainty. They are also an objective of different studies (for example BRAY-

FORD et al., 2004; ROSSMAN et al., 1999). Absence of the described anamorphs of some species of *Nectria* s.l., especially in older literatures is understandable because of the demanding field and laboratory studies of the asexual developmental stage of the fungi of the genus *Nectria*.

Table 2. Findings of species of Bionectriaceae and Nectriaceae in selected localities in individual countries of Central and South-eastern Europe

Country	Locality	<i>C. coc.</i>	<i>C. pur.</i>	<i>N. aur.</i>	<i>N. cin.</i>	<i>N. cor.</i>	<i>Neo. pun.</i>	<i>Neo. coc.</i>	<i>Neo. gal.</i>
CZ	Šance							*	
	Hukvaldy							*	
	Pustevny				*				
PL	Kiczera								*
	Przełecz Zebrak	*							
	Połanki								*
	Przysłop								*
SK*	77	6	4	0	36	1	3	29	39
H	Diosjenő		*					*	
	Öserdő	*			*				*
	Telkibánya								*
RO	Crucea				*				
	Holda							*	*
	Piatra Fântânele				*			*	
	Telciu								*
BG	Dragalevski monastir	*							
	Petrohan	*							*
	Barzia								*
	Etropole							*	
	Ribaritsa								*
	Shipkovo							*	
	Troyan							*	
	Balkanets	*							*
	Shipka	*							
	Kotel					*			*
	Ticha							*	
	Ichera								*
	Karandila						*	*	
	Silkosia			*					
Total	102	12	5	1	40	2	4	39	52

C. coc., *Cosmospora coccinea* Rabenh.; *C. pur.*, *Cosmospora purtonii* (Grev.) Rossman & Samuels; *N. aur.*, *Nectria aurantiaca* (Tul. et C. Tul.) Jacz.; *N. cin.*, *Nectria cinnabarina* (Tode: Fr.) Fr.; *N. cor.*, *Nectria coryli* Fuckel; *Neo. pun.*, *Neonectria punicea* (Kuntze et J.C. Schmidt) Fr.; *Neo. coc.*, *Neonectria coccinea* (Pers.: Fr.) Rossman & Samuels; *Neo. gal.*, *Neonectria galligena* (Bres.) Rossman & Samuels

SK*: We found altogether 13 species of Bionectriaceae and Nectriaceae on 77 localities in Slovakia. Besides listed species (see Table 2) have been determined further six species in Slovakia: *Cosmospora episphaeria* (Tode: Fr.) Rossman et Samuels (on 19 localities), *Hydropisphaeria peziza* (Tode: Fr.) Dumort. (on four ones), *Nectria berlinensis* (Sacc.) Cooke (two ones), *Nectria cucurbitula* (Tode: Fr.) Fr. (four ones), *Neonectria ditissima* Tul. et C. Tul. (three ones) and *Neonectria radicolata* Gerlach & L. Nilsson (on one locality).

Table 3. Occurrence of species of Bionectriaceae and Nectriaceae in the individual countries of Central and South-eastern Europe by selected literature sources

Country	Literature source	Species
CZ	ANTONÍN and VÁGNER (2001)	<i>Cosmospora episphaeria</i> , <i>Hydropisphaeria peziza</i>
	JANČAŘÍK (2000)	<i>Neonectria ditissima</i> , <i>Neonectria coccinea</i> , <i>Neonectria galligena</i>
	NOVOTNÝ (2003)	<i>Neonectria radiculicola</i>
PL	MAŃKA (2005)	<i>Neonectria ditissima</i> , <i>Neonectria coccinea</i> , <i>Neonectria galligena</i>
	ROZYCKI (1993)	<i>Neonectria radiculicola</i>
	RYKOWSKI et al. (1989)	<i>Neonectria coccinea</i>
H	MIHÁL and CÍČÁK (2005)	<i>Cosmospora coccinea</i> , <i>Cosmospora purtonii</i> , <i>Nectria cinnabarina</i> , <i>Neonectria coccinea</i> , <i>Neonectria galligena</i>
	STANDOVÁR and KEREKES (2003)	<i>Neonectria ditissima</i> , <i>Neonectria galligena</i>
RO	CHIRA and CHIRA (1997)	<i>Neonectria ditissima</i>
	CHIRA and CHIRA (1998)	<i>Nectria cinnabarina</i> , <i>Neonectria ditissima</i> , <i>Neonectria coccinea</i>
	CHIRA et al. (1996)	<i>Neonectria ditissima</i> , <i>Neonectria galligena</i>
	MIHALCIUC et al. (2001)	<i>Nectria cinnabarina</i> , <i>Neonectria ditissima</i> , <i>Neonectria coccinea</i>
BG	CÍČÁK et al. (2006)	<i>Cosmospora coccinea</i> , <i>Neonectria coccinea</i> , <i>Neonectria galligena</i>
	ROSNEV and PETKOV (1996)	<i>Neonectria ditissima</i> , <i>Neonectria coccinea</i>

Table 4. Current status of taxonomy of species of the family Bionectriaceae and Nectriaceae according to selected literature sources

Teleomorpha (ROSSMAN et al., 1999)	Teleomorpha CABI BIOSCIENCE, 2008)	Anamorpha (ROSSMAN et al., 1999)
<i>Cosmospora coccinea</i>	<i>Cosmospora coccinea</i>	<i>Verticillium olivaceum</i> W. Gams
<i>Cosmospora episphaeria</i>	<i>Nectria episphaeria</i>	<i>Fusarium aquaeductum</i> var. <i>medium</i> (Radlk. et Rabenh.) Lagerh.
<i>Cosmospora purtonii</i>	<i>Cosmospora purtonii</i>	<i>Fusarium aquaeductum</i> var. <i>aquaeductum</i> (Radlk. et Rabenh.) Lagerh.
<i>Neonectria radiculicola</i> ¹⁾	<i>Neonectria radiculicola</i>	<i>Cylindrocarpon destructans</i> (Zins.) Scholten ²⁾
<i>Hydropisphaeria peziza</i>	<i>Nectria peziza</i>	<i>Acremonium</i> sp. ³⁾
<i>Nectria aurantiaca</i>	<i>Nectria aurantiaca</i>	<i>Tubercularia aurantiaca</i> (Babington) Seifert
<i>Nectria berolinensis</i>	<i>Thyronectria berolinensis</i>	<i>Tubercularia berolinensis</i> (Wollenw.) Rossman
<i>Nectria cinnabarina</i>	<i>Nectria cinnabarina</i>	<i>Tubercularia vulgaris</i> (Tode: Fr.) Fr.
<i>Nectria coryli</i>	<i>Nectria coryli</i>	<i>Tubercularia</i> sp.???
<i>Nectria cucurbitula</i>	<i>Neonectria fuckeliana</i>	<i>Zythiostroma pinastri</i> (P. Karst.) Höhn. ex Weese
<i>Neonectria ditissima</i> ⁴⁾	<i>Neonectria ditissima</i>	<i>Cylindrocarpon willkommii</i> (Lindau) Wollenw. ²⁾
<i>Neonectria punicea</i> ⁵⁾	<i>Neonectria punicea</i>	<i>Cylindrocarpon album</i> (Sacc.) Wollenw. ⁶⁾
<i>Neonectria coccinea</i>	<i>Nectria coccinea</i>	<i>Cylindrocarpon candidum</i> (Link) Wollenw.
<i>Neonectria galligena</i>	<i>Neonectria galligena</i>	<i>Cylindrocarpon heteronema</i> (Berk. et Broome) Wollenw.

¹⁾Nomenclature of species and literature source by MANTIRI et al. (2001); ²⁾nomenclature of species and literature source by BUTIN (1995); ³⁾nomenclature of species and literature source by SAMUELS (1976); ⁴⁾nomenclature of species and literature source by SAMUELS et al. (2006); ⁵⁾nomenclature of species and literature source by CASTLEBURY et al. (2006); ⁶⁾nomenclature of species and literature source by DEUTSCHE SAMMLUNG VON MIKROORGANISMEN UND ZELLKULTUREN (2001)

The species of both families grow as saprophytes or parasites on forest trees. More species are able to occupy substrate of both broadleaved and coniferous trees. The species *Nectria aurantiaca*, *N. cinnabarina*, *N. coryli*, *Neonectria punicea*, *N. galligena* and *N. coccinea* are typical for broadleaved trees, especially for beeches. However, they can be also found on untypical substrates. For example, in some cases in Slovakia we found *Nectria cinnabarina* on the wood of oaks, Norway spruces, firs or even vine (MIHÁL et al., 2007). In our collections we have also species that grow as saproparasites on old fruiting bodies of the pyrenomycetic fungi (Pyrenomycetales, Ascomycetes) or on the fruiting bodies of polyporous tinder fungi (Polyporales, Basidiomycetes). The species of *Cosmospora coccinea*, *C. episphaeria* and *C. purtonii* also belong to such species. On the other hand, the species *Nectria cucurbitula* is typical for coniferous trees and *Nectria berolinensis* occurs on bark of the *Ribes* sp.

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Výskyt húb rodu *Nectria* s.l. (Bionectriaceae, Nectriaceae, Hypocreales, Ascomycetes) v strednej a juhovýchodnej Európe

Súhrn

Autori uvádzajú aktuálne údaje o výskyte húb rodu *Nectria* s.l. (Bionectriaceae, Nectriaceae, Hypocreales, Ascomycetes) v Českej republike, Poľsku, Slovensku, Maďarsku, Rumunsku a Bulharsku, ako aj niektoré ekologické a taxonomické poznámky k determinovaným druhom. Mimo územia Slovenska bolo zistených osem druhov (*Cosmospora coccinea*, *C. purtonii*, *Nectria aurantiaca*, *N. cinnabarina*, *N. coryli*, *Neonectria coccinea*, *N. galligena*, *N. punicea*). Vďaka dlhotrvajúcemu výskumu na veľkom počte lokalít na Slovensku, autori zistili výskyt ďalších šiestich druhov (*Cosmospora episphaeria*, *Hydropisphaeria peziza*, *Nectria berolinensis*, *N. cucurbitula*, *Neonectria ditissima*, *N. radicola*). Ako vzácne huby boli zistené druhy *Nectria aurantiaca* (na jednej lokalite v Bulharsku), *N. coryli* (na jednej lokalite na Slovensku a v Bulharsku) a *Neonectria punicea* (tri lokality na Slovensku a jedna v Bulharsku). Všetky tri uvedené druhy boli ako prvonálezy zistené takisto aj v Bulharsku. Údaje autorov o výskyte druhov rodu *Nectria* s.l. v krajinách strednej a juhovýchodnej Európy pochádzajú najmä z nálezov týchto húb na kôre bukov (*Fagus sylvatica* L.), pričom niektoré druhy spôsobujú epifyticiu nekrotického ochorenia kôry buka (napr. druhy *Neonectria coccinea*, *N. ditissima* a *N. galligena*).

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Forest vegetation of the northern part of the Štiavnické vrchy Mts

Michal Slezák, Ján Kukla

Institute of Forest Ecology, Slovak Academy of Sciences, Zvolen, Štúrova 2, 960 53 Zvolen, Slovak Republic,
E-mail: slezak@savzv.sk, kukla@savzv.sk

Abstract

SLEZÁK, M., KUKLA, J. Forest vegetation of the northern part of the Štiavnické vrchy Mts. *Folia oecol.*, 36: 39–49.

The article presents first results of vegetation research of the forest plant communities in the north part of the Štiavnické vrchy Mts. Research was carried out by traditional Zürich-Montpellier (Braun-Blanquet) approach during the vegetation period 2008. The data set of 21 original phytosociological relevés was sampled and analysed using numerical divisive classification (TWINSPAN) and detrended correspondence analysis (DCA). Five different communities within four alliances were distinguished and characterised – *Carici pilosae-Fagetum*, *Dentario bulbiferae-Fagetum*, *Mercuriali-Fraxinetum*, *Poo nemoralis-Quercetum petraeae* and *Luzulo albidae-Quercetum petraeae*. Information about their species composition and ecology is presented. The main ecological gradients responsible for the variability of the forest vegetation are light conditions, temperature and moisture with nutrients together.

Key words

classification, forest vegetation, gradient analysis, Štiavnické vrchy Mts

Introduction

In frame of the floristic region *Praecarpaticum*, the vegetation of the Štiavnické vrchy Mts has a special status. The localisation, geological substrate and soils, together with N-S aspect of this mountain unit provide a background for parallel occurrence of thermophilous – Pannonian as well as submountain – Carpathian species. The phytosociological research in forest communities of the Štiavnické vrchy Mts started in the 30s of the last century with publishing works discussing vegetation conditions of the massives Skalka, Anderloch (by Banský Studenec village) and surveys of forest vegetation of the Slovenské stredohorie Mts (MIKYŠKA, 1929, 1930, 1937, 1939). A special care was devoted to the plant communities of the Sitno Mt, especially to its beech phytocoenosis (MIKYŠKA, 1932). Forest communities of the SE promontories and foothills of the Štiavnické vrchy Mts were treated in NEUHÄUSL and NEUHÄUSLOVÁ-NOVOTNÁ (1964) and NEUHÄUSLOVÁ-NOVOTNÁ (1965). These works analysed floristic composition and soil conditions in selected syntaxonomical

units in this area. Vegetation description of the Nature Reserve Holík with its forest stands can be found in MIKYŠKA (1933) and DAVID (1999). Several phytosociological relevés obtained on northern slopes of the Štiavnické vrchy Mts have also been published by KONTRIŠOVÁ (1980). The knowledge of ecology of forest stands in the NW part of the Štiavnické vrchy Mts has been contributed by BALKOVIČ (2001) and ČIRIAKOVÁ and HEGEDŮŠOVÁ-KUČEROVÁ (2003). This paper should contribute to better understanding of the forest communities in N part of the Protected Landscape Area (PLA) Štiavnické vrchy Mts, their species compositions, ecological links and distribution of the relevant syntaxa.

Material and methods

The Štiavnické vrchy Mts are a neovolcanic mountain unit situated in Central Slovakia (Fig 1). They mainly consist of pyroclastic rocks, primarily andesite (in NW part also rhyolite) tuff agglomerates, in ridge zones also



Fig 1. Localisation of the Štiavnické vrchy Mts

andesites and rhyolites. In surroundings of Sklené Teplice occur also carbonate rocks.

FUTÁK (1984) classifies the Štiavnické vrchy Mts as belonging to the phytogeographical district Slovenské stredohorie Mts – in frame of which they have status of a separate sub-district.

The local forest communities were studied in field research running over the growing season 2008, to the north of the line connecting the villages Voznica, Svätý Anton and Babiná. Phytosociological relevés were recorded by implementing the generally used methods of the Zürich-Monpellier approach (BRAUN-BLANQUET, 1964), with using the extended 9-point Braun-Blanquet scale for species abundance and dominance (BARKMAN et al., 1964). In Table 2, the degrees 2a and 2b are listed in shortened form (a, b). At first, the relevés were saved in database programme TURBOVEG (HENNEKENS and SCHAMINÉE, 2001), and then they were exported to the programme JUICE 6.5 (TICHÝ, 2002). The vegetation was classified with using the method for divisive polythetic classification TWINSpan (HILL, 1979). The final form of this classification takes in consideration also the results of detrended correspondence analysis (DCA) which we used for analysing the principal gradients of variability in the species composition of the studied forest vegetation. The analysis ran in the programme Canoco for Windows (TER BRAAK and ŠMILAUER, 2002). For interpreting the ordination axes in DCA, we provided with selected environmental factors (slope, altitude) and plant indicator values (calculated as weighted arithmetic mean for each relevé) sensu ELLENBERG et al. (1992) as supplementary variables. Before the analysis, the data were subjected to logarithmic transformation. The phytosociological table presents the data for separate layers, ranked according to decreasing constancy. For each syntaxonomical unit, we distinguished diagnostic species (MORAVEC, 1994),

constant (permanent in the given vegetation unit by >60%) and dominant species (reaching cover values 3–5 at least in one relevé). The diagnostic species were determined only based on our data set (Table 2).

The nomenclature of flowering plants follows MARHOLD and HINDÁK (1998). The names of syntaxa are according to MORAVEC et al. (2000) and JAROLÍMEK et al. (2008), in case of the first appearance, the author's name and year of description are attached.

For determining altitude and geographical coordinates, we used a GPS appliance (Garmin GPSmap 60 CSx) working with an accuracy less than 15 m. In the following text, we use these abbreviations: ass. – association, c – constant species, dif. – differential species, dom. – dominant species, rel. – relevé. The subspecies (without the species name) are provided with asterisks (*).

Results and discussion

Survey of vegetation units

Five forest communities within four alliances were found out in northern part of the Štiavnické vrchy Mts.

Quercus-Fagetum Br.-Bl. et Vlieger in Vlieger 1937

Fagetalia Pawlowski in Pawlowski et al. 1928

Tilio-Acerion Klika 1955

Mercuriali-Fraxinetum (Klika 1942) Husová in Moravec et al. 1982

Fagion sylvaticae Luquet 1926

Eu-Fagenion Oberd. 1957 em. R. Tx. in Oberd. et R. Tx. 1958

Carici pilosae-Fagetum Oberd. 1957

Dentario bulbiferae-Fagetum Zlatník 1938

Pulsatillo-Pinetea sylvestris Oberd. 1992

Pulsatillo-Pinetalia Oberd. in Th. Müller 1966
Cytiso ruthenici-Pinion Krausch 1962
Poo nemoralis-Quercetum petraeae J. Michalko 1980
Quercetea robori-petraeae Br.-Bl. et R. Tx. ex Oberd. 1957
Quercetalia roboris R. Tx. 1931
Genisto germanicae-Quercion Neuhäusl et Neuhäuslová-Novotná 1967
Luzulo albidae-Quercetum petraeae Hiltzer 1932

Main environmental gradients

The first DCA ordination axis explains 18.6% of variability in the species data. Along this axis, the species are ordered from left to right, from shade-tolerating

mesotrophic to heliophilous, hemioligotrophic ones (Fig 2). The spatial distribution of the relevés in the Štiavnické vrchy Mts in relation to the main environmental gradients is illustrated in Fig 3. The values of correlation between ordination scores of the relevés and of environmental variables (Table 1) show that the first DCA axis expresses the relation between the type of phytocoenosis and light together with temperature. Negative correlation was found for relation to soil moisture and nutrient content. From the cluster of more-hygrophilous beech phytocoenosis (ass. *Carici pilosae-Fagetum*, *Dentario bulbiferae-Fagetum*) and heminitrophilous debris phytocoenosis (ass. *Mercuriali-Fraxinetum*), the first axis separated cluster of more-drought-tolerating mesotrophic oak stands (ass. *Poo nemoralis-Quercetum petraeae*) and acidophilous oak stands (ass. *Luzulo albidae-Quercetum petraeae*).

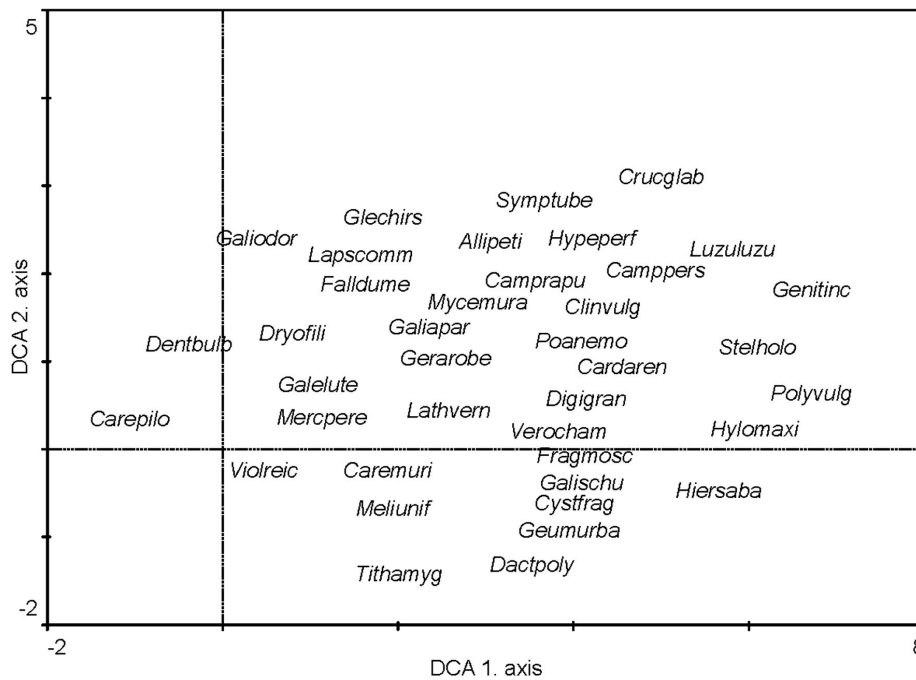


Fig 2. Detrended correspondence analysis (DCA) ordination diagram of the species. Eigenvalues: 1st axis 0.793; 2nd axis 0.240; Lengths of gradient: 1st axis 6.361; 2nd axis 1.978. Total inertia: 4.266 (Ordination scores of the species that occur at least in 4 relevés.)

Allipeti – *Alliaria petiolata*, *Camppers* – *Campanula persicifolia*, *Camprapu* – *Campanula rapunculoides*, *Cardaren* – *Cardaminopsis arenosa*, *Caremuri* – *Carex muricata*, *Carepilo* – *Carex pilosa*, *Clinvulg* – *Clinopodium vulgare*, *Crucglab* – *Cruciata glabra*, *Cystfrag* – *Cystopteris fragilis*, *Dactpoly* – *Dactylis polygama*, *Dentbulb* – *Dentaria bulbifera*, *Digigran* – *Digitalis grandiflora*, *Dryofili* – *Dryopteris filix-mas*, *Falldume* – *Fallopia dumetorum*, *Fragmosc* – *Fragaria moschata*, *Galelute* – *Galeobdolon luteum*, *Galiapar* – *Galium aparine*, *Galiodor* – *Galium odoratum*, *Galischu* – *Galium schultesii*, *Genitinc* – *Genista tinctoria*, *Gerarobe* – *Geranium robertianum*, *Geumurba* – *Geum urbanum*, *Glechirs* – *Glechoma hirsuta*, *Hiersaba* – *Hieracium sabaudum*, *Hylomaxi* – *Hylotelephium maximum*, *Hypeperf* – *Hypericum perforatum*, *Lapscomm* – *Lapsana communis*, *Lathvern* – *Lathyrus vernus*, *Luzuluzu* – *Luzula luzuloides*, *Meliunif* – *Melica uniflora*, *Mercpere* – *Mercurialis perennis*, *Mycemura* – *Mycelis muralis*, *Poanemo* – *Poa nemoralis*, *Polyvulg* – *Polypodium vulgare*, *Stelholo* – *Stellaria holostea*, *Symptube* – *Symphytum tuberosum*, *Tithamyg* – *Tithymalus amygdaloides*, *Verocham* – *Veronica chamaedrys*, *Violreic* – *Viola reichenbachiana*

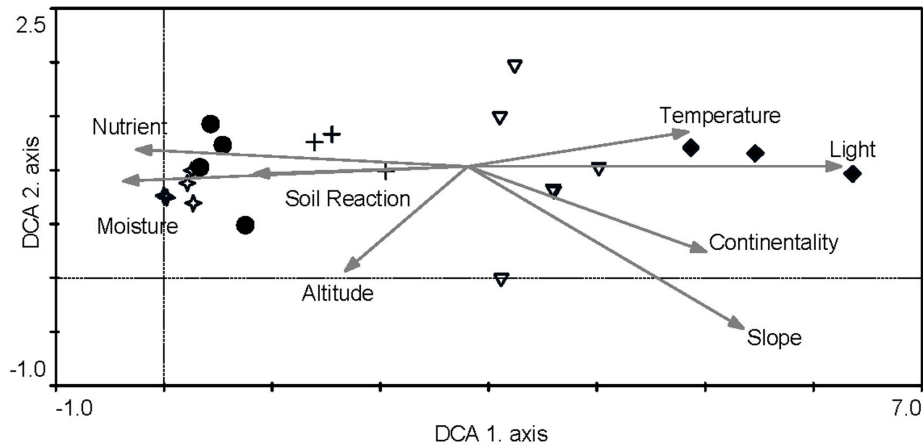


Fig 3. Detrended correspondence analysis (DCA) ordination diagram of 21 relevés of forest vegetation from Štiavnické vrchy Mts with Ellenberg indicator values, altitude and slope as supplementary environmental variables (◊ – *Carici pilosae-Fagetum*; ● – *Dentario bulbiferae-Fagetum*; + – *Mercuriali-Fraxinetum*; ▽ – *Poo nemoralis-Quercetum petraeae*; ◆ – *Luzulo albidiae-Quercetum petraeae*)

Table 1. Spearman's rank correlation matrix between environmental variables and ordination scores of plots for the first two DCA axis. Correlation significant on the level of $p < 0.05$ is in grey

Environmental variables	1 st axis	2 nd axis
Altitude	-0.3172	-0.2775
Slope	0.6925	-0.3517
Light	0.9551	0.0835
Temperature	0.6815	0.0983
Continentiality	0.4857	-0.2519
Moisture	-0.9087	-0.0713
Soil Reaction	-0.5366	-0.0478
Nutrients	-0.8403	-0.0076

Characteristics of forest communities

Carici pilosae-Fagetum (Table 2, rel. 1–5)

Diagnostic species: *Carex pilosa* (c, dif., dom.), *Dentaria bulbifera* (c), *Fagus sylvatica* (E₃; c, dom., E₂; c), *Galium odoratum* (c).

This association, in general occurring on well developed modal cambisols, belongs to beech communities typical for the submountain vegetation belt. It is characterised by presence of the oceanic species *Fagus sylvatica* (E₃, E₂) as determining edificator species, and by species-poor, to some extent uniform, herbal understorey with dominant *Carex pilosa*. As the result, the overall physiognomy of herb layer looks typical grassy. The shrub layer has been developed in patches only, and it consists only of trees of the tree layer present in different developmental phases and

exhibiting low cover. Species composition of the herb layer is supplemented with species occurring with higher frequencies – forest sciophytes *Dentaria bulbifera* and *Galium odoratum*, from the species tolerating strong shadowing, it is *Dryopteris filix-mas* and *Viola reichenbachiana*, from mesotrophic mesophytes, locally occur *Lathyrus vernus* and *Scrophularia nodosa*.

Phytocoenosis of this association have been developed on moderate slopes (5–15°), their foothills or flat ridge areas, situated at 510–770 m asl. In case when exposition is southern, however, these communities can descend down to the area of oak-hornbeam forests.

Dentario bulbiferae-Fagetum (Table 2, rel. 6–9)

Diagnostic species: *Dentaria bulbifera* (c), *Dryopteris filix-mas* (dif.), *Fagus sylvatica* (E₃; c, dom.), *Galium odoratum* (c).

These, floristically least differentiated community in the study area is characterised by a lower species diversity (on average 8 species in herb layer of a relevé), by dominance of *Fagus sylvatica*, and by simple vertical structure. The shrub layer is practically absent. The tree layer with low cover variability (90–95%) mainly consists of *Fagus sylvatica*, with isolated *Acer pseudoplatanus*, *Fraxinus excelsior* and *Picea abies*. In presence of very dense crown canopy, limited light supply and litter accumulation, the cover of herb layer in this community is low (20–30%), too. The herbal understorey shows a strongly dominant presence of heliophilous *Dentaria bulbifera*, primarily in spring. The species composition is supplemented by constant *Dryopteris filix-mas*, *Galium odoratum* and mesotrophic sciophyte *Mercurialis perennis*. The other diagnostic species for the alliance *Fagion sylvaticae* are lacking – with small exceptions.

The stands of this association meet their ecological distribution optimum on moderate (10–35°), mostly N-oriented slopes with colder and more humid microclimate. They have been developed on deep soils with high retention capacity, at altitudes 610–810 m.

Over the studied area, beech stands are relatively abundant primarily in case of north-oriented sites (CIRIAKOVÁ and HEGEDŮŠOVÁ-KUČEROVÁ, 2003). In submountain parts of volcanic mountains, presence of analogical communities (ass. *Carici pilosae-Fagetum* and *Dentario bulbiferae-Fagetum*) with similar structure and species composition is not a rarity. Their occurrence documented with phytosociological relevés has been reported from the Javorie Mts (MIKYŠKA, 1939), S-E part of the Kremnické vrchy Mts (KUKLA et al., 1998) and from the Cerová vrchovina Mts (UJHÁZY et al., 2004).

Mercuriali-Fraxinetum (Table 2, rel. 10–12)

Diagnostic species: *Acer platanoides* (E₃; c), *A. pseudoplatanus* (E₃; c), *Alliaria petiolata* (c, dif.), *Carpinus betulus* (E₃; c), *Cerasus avium* (E₃; c), *Dentaria bulbifera* (c), *Fagus sylvatica* (E₃; c, dom.), *Fallopia dumetorum* (c), *Fraxinus excelsior* (E₃; c, dom.), *Galeobdolon luteum* (c, dif.), *Galium aparine* (dif.), *G. odoratum* (c, dom.), *Geranium robertianum* (c, dif.), *Lilium martagon* (c), *Melica uniflora* (c), *Mercurialis perennis* (c, dif., dom.), *Mycelis muralis* (c), *Symphytum tuberosum* (c), *Viola reichenbachiana* (c).

This association represents edaphically and topographically conditioned heminitrophilous community, in most cases present in small-sized fragments in the beech forest belt. For the tree layer is characteristic a considerable species diversity. The edicator species is *Fraxinus excelsior*, in case of rel. 11 also with subdominant *Fagus sylvatica*; presence of *Acer platanoides* and *A. pseudoplatanus* is in general lower. *Cerasus avium*, *Quercus polycarpa* and *Ulmus glabra* occur with varying frequency and cover. Shrub layer is totally absent.

In the herb layer, *Mercurialis perennis*, associated with thin forests on skeletal and debris soils, is dominant with a high cover. Apart from subdominant species of the order *Fagetalia* and alliance *Fagion sylvaticae* (*Dentaria bulbifera* and *Galium odoratum*), there are also present *Campanula rapunculoides*, *Galium aparine* and *Geranium robertianum*. Typical feature of the herb layer is presence of heminitrophilous and nitrophilous species with wide temperature amplitude, indicating favourable humification (*Alliaria petiolata*, *Galeobdolon luteum* and *Glechoma hirsuta*). The moss layer is concentrated on rocks in the surface debris.

The community is associated with rough-rocky or bouldery slopes covered with debris, more rarely with ridge or sub-ridge bouldery localities on neutral, in-minerals-richer rocks. It has been developed on mineral-rich moderately humid soils, at altitudes from 530–870 m. Their relation to site exposition is indifferent.

As for floristic composition, the stands of the studied association are to some extent similar to phytocoenosis of the Biele Karpaty Mts (FAJMONOVÁ, 1984). The occurrence of debris phytocoenosis of the alliance *Tilio-Acerion* in the Štiavnické vrchy Mts has not been mentioned either by BALKOVIČ (2001), or CÍRIKOVÁ and HEGEDŮŠOVÁ-KUČEROVÁ (2003).

Poo nemoralis-Quercetum petraeae

(Table 2, rel. 13–18)

Diagnostic species: *Campanula persicifolia* (c), *C. rapunculoides* (c, dif.), *Clinopodium vulgare* (c, dif.), *Carpinus betulus* (E₃; c), *Cruciata glabra* (c), *Dactylis polygama* (c, dif.), *Dentaria bulbifera* (c), *Digitalis grandiflora* (c), *Fragaria moschata* (c), *Galium schultesii* (c, dif.), *Geum urbanum* (c), *Hieracium sabaudum* (c), *Hypericum perforatum* (c, dif.), *Lathyrus vernus* (c), *Melica uniflora* (c), *Poa nemoralis* (c, dif., dom.), *Quercus polycarpa* (E₃; c, dom.), *Veronica chamaedrys* (c).

This community is the richest in species (22 to 41 species in the herb layer of a relevé), and in general it is characterised by *Quercus polycarpa* dominance in the tree and mesophilous *Poa nemoralis* dominance in the herb layer. In stands with lower cover variability (70–80%), apart from oak, *Carpinus betulus* occurs regularly, but with a low cover. In the sporadically developed shrub layer grow isolated trees of the natural regeneration or bushes of *Rosa* sp. (rel. 15 and 16). Species composition of the herb layer mainly consists of differential species (*Campanula rapunculoides*, *Clinopodium vulgare*, *Dactylis polygama*, *Galium schultesii*, *Hypericum perforatum*, *Poa nemoralis*), species belonging to the alliance *Carpinion betuli* (*Campanula persicifolia*, *Lathyrus vernus*, *Melica uniflora*) and contact communities of penetrating mesotrophic species of the order *Fagetalia* (*Dentaria bulbifera*, *Galium odoratum*).

Phytocoenosis of this association have colonised climax, moderately undulated parts of ridges at 380–775 m asl. They are associated with warmer and drier localities situated on shallower soils on moderate, mostly S-oriented slopes.

Floristic composition, including presence of acidophilous species (*Calmagrostis arundinacea*, *Luzula luzuloides*) and mesophilous taxons of the alliance *Carpinion betuli*, of these phytocoenosis in the Štiavnické vrchy Mts corresponds to an ass. *Poo nemoralis-Quercetum petraeae* in the Popradská basin described based of one relevé, by MICHALCO (1980). Analogous communities were also recorded in the Spišská basin ŠMARDÁ (1961) and in the Tríbeč Mts, ELIÁŠ (1986). Stands with similar species composition are known under the name of *Quercus petraeae-Carpinetum poetosum nemoralis* from surroundings of the town of Zvolen by MIKYŠKA (1939), from the Vihorlat Mts by MICHALCO (1957), and from the territory of

the Štiavnické vrchy Mts by BALKOVIČ (2001) and CIRIAKOVÁ and HEGEDŮŠOVÁ-KUČEROVÁ (2003). Relative communities: ass. *Poo nemoralis-Quercetum dalechampii* Šomšák et Háberová 1979 described in the Silická plateau show certain differences – for the last one is characteristic higher presence of oligotrophic (*Genista tinctoria*, *Veronica officinalis*) and thermophilous species (*Astragalus glycyphyllos*, *Galium verum*, *Lactuca quercina*, *Trifolium sarosiense*) (ŠOMŠÁK and HÁBEROVÁ, 1979).

Luzulo albidae-Quercetum petraeae

(Table 2, rel. 19–21)

Diagnostic species: *Asplenium trichomanes* (c), *Avenella flexuosa* (c, dif.), *Calamagrostis arundinacea* (c, dif.), *Campanula persicifolia* (c), *Cardaminopsis arenosa* (c), *Dianthus carthusianorum* (c), *Fagus sylvatica* (E₃; c, E₂; c), *Galium odoratum* (c), *G. schultesii* (c), *Genista tinctoria* (c, dif.), *Hieracium sabaudum* (c), *H. sp.* (c), *Hylotelephium maximum* (c), *Hypericum perforatum* (c), *Lembotropis nigricans* (c, dif.), *Luzula luzuloides* (c, dom.), *Poa nemoralis* (c), *Polypodium vulgare* (c, dif.), *Quercus polycarpa* (E₃; c, dom., E₂; c), *Steris viscaria* (c, dif.), *Vaccinium myrtillus* (dif., dom.), *Veronica chamaedrys* (c).

This community, in which are present acidophilous species, has a simple vertical structure, and it is floristically poorer. In the tree layer is dominant *Quercus polycarpa*, in general with a low admixture of *Fagus sylvatica*. Phytocoenosis on steeper slopes have lower stocking, thinner crown canopy and smaller overall growth. Higher amounts of light penetrating through the stand have been reflected on higher cover values in the herb layer. Qualitatively poorer shrub layer lacks a conspicuous dominant species. Floristically composition of this association in the study area is relatively homogeneous. The main constituent of the

herb layer is a group of acidophilous species *Luzula luzuloides*, *Hieracium sabaudum* and *Calamagrostis arundinacea*. Consequently, the overall physiognomy of this layer looks grassy. The species composition is completed with the alliance species *Avenella flexuosa*, *Genista tinctoria*, thermophilous *Lembotropis nigricans*, *Steris viscaria*, mesotrophic *Cardaminopsis arenosa* and *Galium schultesii*, tolerating more oligotrophic character of the site.

The area with this association is not large. The stands represent only small patches, primarily in ridge parts and in convex spots. The associations have been developed on shallow soils with minimum water retention capacity.

The community recorded in the N part of the Štiavnické vrchy Mts is floristically more similar to the ones recorded in East Slovakia by JURKO (1975). Comparing the species composition between them, we can see only a lower presence of *Vaccinium myrtillus* and absence of xerophilous *Festuca ovina*. In contrast to the relevés obtained in the Malé Karpaty Mts (NEUHÄUSLOVÁ-NOVOTNÁ, 1970), higher floristic diversity as well as higher dominance of species belonging to the alliance *Carpinion betuli* in the herb layer is evident. The above mentioned deviations evidently result from the nature of site conditions of the community and from the size of the analysed data set (SLEZÁK and KUKLA, 2009).

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Table 2. Phytosociological table of forest communities in the north part of the Štiavnické vrchy Mts (*Cp-F* – *Carici pilosae-Fagetum*, *Db-F* – *Dentario bulbiferae-Fagetum*, *L-Q* – *Luzulo albidae-Quercetum petraeae*, *M-F* – *Mercurialis-Fraxinetum*, *Pn-Q* – *Poo nemoralis-Quercetum petraeae*)

Number of relevé:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Species in herb layer:	12	3	8	8	10	9	1	8	12	19	18	24	39	22	41	24	29	39	25	25	17
Community	<i>Cp-F</i>			<i>Db-F</i>			<i>M-F</i>			<i>Pn-Q</i>			<i>L-Q</i>								
Tree layer (E3)																					
<i>Fagus sylvatica</i>	4	5	5	5	5	5	5	5	5	.	3	b	+	.	.	.	r	.	+	1	.
<i>Quercus polycarpa</i>	.	a	.	r	.	.	.	.	.	.	.	a	4	4	4	4	4	4	4	4	4
<i>Carpinus betulus</i>	.	r	.	.	.	.	.	.	.	.	r	r	+	r	.	r	+	a	.	.	.
<i>Fraxinus excelsior</i>	.	.	.	.	.	.	.	.	1	4	3	4	.	.	.	.	.	.	.	.	.
<i>Acer pseudoplatanus</i>	.	.	.	.	.	.	.	.	1	1	.	+	.	.	.	.	.	.	.	.	.
<i>Acer platanoides</i>	.	.	.	.	.	.	.	.	.	+	1	+	.	.	.	.	.	.	.	.	.

Table 2. Continued

Number of relevés:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		
<i>Abies alba</i>	.	.	1	.	.	r	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.
<i>Quercus cerris</i>	b	a	.	.	r	.	.	.		
<i>Ulmus glabra</i>	r	1	.	.	.	.	.	.	.	.	.	.	.
<i>Cerasus avium</i>	r	.	r	.	.	.	.	.	.	.	.	.
<i>Acer campestre</i>	r	.	.	.	.	r	.	.	.	.	.	.
<i>Tilia cordata</i>	+	r		
Shrub layer (E2)																							
<i>Fagus sylvatica</i>	1	.	1	1	r	.	.	.	a	.	.	.	r	.	.	.	.	.	r	1	.
<i>Carpinus betulus</i>	r	r	1	.	.	.	.
<i>Rosa sp.</i>	+	+	.	.	+	.	.		
<i>Quercus polycarpa</i>	+	.	1		
Herb layer (E1)																							
Diagnostic species																							
<i>Carex pilosa</i>	4	a	b	4	4	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Dryopteris filix-mas</i>	.	.	r	.	+	r	.	+	+	+	.	.	r	r	.	.	.	.	.	.	r
<i>Mercurialis perennis</i>	+	.	.	r	1	b	b	3	r	.	+	.	.	.	.	.	.
<i>Alliaria petiolata</i>	a	1	+	r	.	+	r	+	1	.	.	.		
<i>Galium aparine</i>	a	+	1	.	.	r	.	.	+	.	.	r		
<i>Geranium robertianum</i>	r	.	.	.	.	.	.	.	.	+	.	r	.	.	.	.	+	r	.	.	.
<i>Glechoma hirsuta</i>	+	1	a	.	a	.	.	.	.	.	.	.
<i>Galeobdolon luteum</i>	r	a	+	+	.	.	.	.	.	.	.	.
<i>Poa nemoralis</i>	r	.	.	r	r	.	.	.	.	1	.	.	3	4	4	4	4	4	b	1	.
<i>Hypericum perforatum</i>	r	.	.	.	.	.	.	.	.	.	.	.	+	.	r	r	r	+	r	.	r
<i>Campanula rapunculoides</i>	a	.	.	+	1	1	+	+	1	.	.	.		
<i>Galium schultesii</i>	1	1	b	1	1	1	+	1	.		
<i>Dactylis polygama</i>	+	r	1	r	1	.	r	.	.		
<i>Clinopodium vulgare</i>	+	+	+	+	+	+	.	.		
<i>Polypodium vulgare</i>	r	.	.	.	+	+	a	1	
<i>Genista tinctoria</i>	+	+	a	1
<i>Steris viscaria</i>	+	+	1	.
<i>Lembotropis nigricans</i>	1	a	+	
<i>Calamagrostis arundinacea</i>	r	.	.	1	1	.	.	
<i>Avenella flexuosa</i>	+	1	b	.	
<i>Vaccinium myrtillus</i>	4	
Genisto germanicae-Quercion, Quercetalia roboris																							
<i>Luzula luzuloides</i>	r	.	r	r	.	.	.	.	.	.	.	.	.	+	.	.	r	a	3	4	+
<i>Hieracium sabaudum</i>	r	r	+	+	.	.	1	+	.		
<i>Melampyrum pratense</i>	+	+		
Carpinion betuli																							
<i>Lathyrus vernus</i>	.	.	.	+	.	.	r	.	.	r	.	r	.	+	+	+	+	.	r	.	.		
<i>Melica uniflora</i>	r	.	.	.	.	a	.	1	1	+	1	+	+	r	.	.	.		
<i>Campanula persicifolia</i>	1	+	r	+	.	+	+	r	r	.		
<i>Fallopia dumetorum</i>	+	r	.	+	.	r	.	.	+	.	.	.		
<i>Stellaria holostea</i>	r	.	.	1	+	r	.	.	.	1		
<i>Symphytum tuberosum</i>	+	.	+	+	+	.	.	.		
<i>Melittis melissophyllum</i>	r	.	+	r	.	.	.		
Fagion sylvaticae, Fagetalia																							
<i>Dentaria bulbifera</i>	1	b	a	+	a	b	b	b	a	a	a	a	+	+	1	.	.	1	.	.	.		
<i>Galium odoratum</i>	1	r	+	1	b	1	.	1	+	.	3	3	.	1	r	.	.	1	+	r	.		

Table 2. Continued

Number of relevé:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
<i>Viola reichenbachiana</i>	+	.	+	r	+	r	.	r	.	.	.	.	.	r	.	.	.
<i>Tithymalus amygdaloides</i>	+	.	.	r	.	+	l	.	.	.	.	.	.
<i>Pulmonaria obscura</i>	r	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.	r	.	.	.	.
<i>Scrophularia nodosa</i>	.	.	.	+	.	r	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.
<i>Prenanthes purpurea</i>	r	+	.	.	.	.	.	.	.	.	.	.	.	.
<i>Lilium martagon</i>	r	.	r	.	.	.	.	.	.	.	.	.
<i>Campanula trachelium</i>	r	.	.	.	.	.	r	.	.	.	.
<i>Polygonatum multiflorum</i>	+	r	.	.	.	.	.	.	.
<i>Quercion confertae-cerris, Quercetalia pubescenti-petraeae</i>																					
<i>Hylotelephium maximum</i>	r	.	.	+	.	.	.	.	.	+	r	+
<i>Fragaria moschata</i>	+	+	+	r	+	.	.	.
<i>Astragalus glycyphyllos</i>	r	+	r	.	.	.	.	.	.
<i>Lathyrus niger</i>	r	r	+	.	.	.	.
<i>Pyrethrum corymbosum</i>	r	.	+	+	.	.
<i>Securigera varia</i>	+	+
<i>Verbascum *austriacum</i>	+	.	.	r	.	.
<i>Quercio-Fagetea</i>																					
<i>Cruciata glabra</i>	+	+	+	l	.	+	.
<i>Mycelis muralis</i>	r	r	.	.	.	.	.	r	r	.	.	.
<i>Convallaria majalis</i>	+	+	.	r
<i>Bromus benekenii</i>	+	.	.	.	l	.	.	.	.	.	.
<i>Hedera helix</i>	+	r	.	.	.	.	.	.
<i>Other species</i>																					
<i>Veronica chamaedrys</i>	+	r	+	+	+	+	+	r	.
<i>Lapsana communis</i>	.	.	.	r	r	.	.	.	.	.	.	.	r	.	.	.	r	r	.	.	.
<i>Digitalis grandiflora</i>	r	a	+	+	.	+	+	.	+	.	.	r
<i>Cardaminopsis arenosa</i>	+	+	.	+	+	r
<i>Carex muricata</i>	r	.	.	.	.	.	r	+	.	r	.	.	.	.	.	.
<i>Cystopteris fragilis</i>	r	.	.	r	.	r	.	+	.	.	.	.
<i>Geum urbanum</i>	+	.	+	.	r	r	.	.	.
<i>Rubus hirtus</i>	+	r	.	.	.	.	.	l	.	.	.	.	.	.
<i>Dianthus carthusianorum</i>	r	.	.	.	.	.	+	r	.
<i>Asplenium trichomanes</i>	r	.	.	.	.	.	.	+	r
<i>Hieracium murorum</i>	r	.	.	r	.	.	r	.	.
<i>Veronica officinalis</i>	r	.	.	r	.	r	.
<i>Epipactis helleborine</i>	r	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.
<i>Athyrium filix-femina</i>	.	.	r	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Epilobium montanum</i>	r	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Carex sylvatica</i>	r	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.
<i>Sanicula europaea</i>	r	.	.	r	.	.	.	.	.	.	.	.	.
<i>Heracleum sphondylium</i>	r	.	.	.	.	.	.	r	.	.	.
<i>Genista pilosa</i>	r	.	.	+	.	.	.	.	.
<i>Dalanum ladanum</i>	r	.	.	r	.	.	.	.	.
<i>Viola tricolor</i>	+	r
<i>Cephalanthera longifolia</i>	r	l	.	.	.	.	.
<i>Vicia sepium</i>	r	.	.	r	.	.	.
<i>Vicia hirsuta</i>	+	.	.	r	.	.	.
<i>Hieracium sp.</i>	l	r

Species present in one relevé only:

E_3 : *Betula pendula* 6 (relevé): r; *Picea abies* 6: 1; *Quercus dalechampii* 6: r; *Sorbus aucuparia* 20: r; *S. torminalis* 15: r; *Tilia platyphyllos* 10: 2.

E_2 : *Abies alba* 21: +; *Acer platanoides* 1: r; *Cornus mas* 14: +; *Corylus avellana* 15: 1; *Crataegus laevigata* 15: 1; *C. sp.* 13: +; *Fraxinus excelsior* 19: r; *Picea abies* 20: 1; *Sorbus aucuparia* 21: +.

E_1 : *Anthericum ramosum* 18: r; *Anthriscus cerefolium* 15: +; *Arctium sp.* 12: r; *Brachypodium pinnatum* 15: 1; *Cardamine impatiens* 16: r; *Carex montana* 18: +; *Cephalanthera damasonium* 6: r; *C. rubra* 11: r; *Chelidonium majus* 11: r; *Cirsium sp.* 13: r; *Clematis vitalba* 11: r; *Daphne mezereum* 1: r; *Dryopteris dilatata* 8: r; *Festuca heterophylla* 18: +; *F. pallens* 21: +; *Fragaria vesca* 18: +; *Galeopsis tetrahit* 20: r; *Galium glaucum* 19: r; *Impatiens noli-tangere* 10: r; *I. parviflora* 11: 1; *Isopyrum thalictroides* 12: +; *Linaria vulgaris* 13: r; *Melica nutans* 3: r; *Moehringia trinervia* 18: 1; *Myosotis arvensis* 15: r; *Origanum vulgare* 19: r; *Paris quadrifolia* 12: +; *Pimpinella saxifraga* 20: r; *Platanthera bifolia* 18: +; *Polygonatum odoratum* 10: +; *Primula veris* 13: r; *Pulmonaria officinalis* 13: r; *Senecio germanicus* 18: r; *Silene nutans* 20: r; *S. vulgaris* 18: r; *Stachys alpina* 12: r; *Tithymalus cyparissias* 19: 1; *T. epithymoides* 15: r; *Urtica dioica* 12: +; *Vincetoxicum hirundinaria* 15: r; *Viola collina* 14: +; *V. mirabilis* 15: 1.

The header data of relevés:

Relevé number, village (locality); altitude (m); aspect; slope (°); relevé area (m²); cover of tree layer (E_3); cover of shrub layer (E_2); cover of herb layer (E_1); cover of mosses and lichens (E_0); longitude; latitude; date (day/month/year); author of the relevé (Ms – M. Slezák, Jk – J. Kukla).

1. Močiar (Štálová); 770 m; NW; 10°; 400; E_3 80%; E_2 5%; E_1 80%; E_0 0%; 18°56'51.1"; 48°31'36.2"; 29. 7. 2008; Ms.

2. Kozelník; 510 m; E-SE; 5°; 400; E_3 95%; E_2 0%; E_1 30%; E_0 0%; 18°59'88.6"; 48°31'51.9"; 6. 6. 2008; Ms, Jk.

3. Vyhne; 620 m; SE; 15°; 400; E_3 90%; E_2 5%; E_1 30%; E_0 0%; 18°50'27.5"; 48°29'92.5"; 3. 6. 2008; Ms, Jk.

4. Banská Belá (Veľký vrch); 660 m; NE; 10°; 400; E_3 85%; E_2 3%; E_1 80%; E_0 0%; 18°57'98.4"; 48°27'86.5"; 8. 7. 2008. Ms.

5. Šášovské Podhradie (Sut'); 695 m; NW; 15°; 400; E_3 90%; E_2 1%; E_1 90%; E_0 0%; 18°55'49.5"; 48°34'27.5"; 25. 6. 2008; Ms, Jk.

6. Kozelník; 625 m; N-NE; 15°; 400; E_3 95%; E_2 0%; E_1 30%; E_0 0%; 18°58'68.3"; 48°31'29.2"; 6. 6. 2008; Ms, Jk.

7. Babiná (Holý vrch); 695 m; NW; 10°; 400; E_3 90%; E_2 0%; E_1 20%; E_0 0%; 19°01'90.9"; 48°26'84.9"; 11. 6. 2008; Ms, Jk.

8. Kozelník (Strela); 810 m; NW; 25°; 400; E_3 95%; E_2 0%; E_1 25%; E_0 0%; 18°59'72.0"; 48°29'02.9"; 9. 6. 2008; Ms, Jk.

9. Repište; 610 m; NW; 35°; 400; E_3 95%; E_2 10%; E_1 30%; E_0 0%; 18°51'92.0"; 48°30'32.1"; 5. 6. 2008; Ms, Jk.

10. Banský Studenec (Skalka); 870 m; E-NE; 25°; 400; E_3 85%; E_2 0%; E_1 75%; E_0 0%; 18°59'73.1"; 48°27'42.5"; 13. 6. 2008; Ms, Jk.

11. Repište; 530 m; SSW; 25°; 400; E_3 80%; E_2 0%; E_1 90%; E_0 0%; 18°51'98.2"; 48°30'83.7"; 5. 6. 2008; Ms, Jk.

12. Kozelník (Strela); 835 m; W; 10°; 400; E_3 90%; E_2 0%; E_1 90%; E_0 0%; 18°59'72.7"; 48°28'90.8"; 9. 6. 2008; Ms, Jk.

13. Banská Belá (Vtáčnik); 775 m; S; 30°; 400; E_3 70%; E_2 3%; E_1 70%; E_0 0%; 18°57'95.2"; 48°28'99.2"; 10. 7. 2008; Ms.

14. Voznica; 380 m; SW; 25°; 400; E_3 80%; E_2 5%; E_1 80%; E_0 0%; 18°43'20.8"; 48°27'39.0"; 16. 6. 2008; Ms, Jk.

15. Kozelník; 695 m; SW; 30°; 400; E_3 70%; E_2 10%; E_1 95%; E_0 0%; 18°58'47.6"; 48°31'08.6"; 6. 6. 2008; Ms, Jk.

16. Hronská Breznica (Kamenné); 470 m; S; 20°; 400; E_3 75%; E_2 3%; E_1 70%; E_0 0%; 18°59'30.1"; 48°33'31.2"; 22. 8. 2008; Ms.

17. Hronská Breznica; 610 m; W; 25°; 400; E_3 70%; E_2 3%; E_1 70%; E_0 0%; 19°01'02.3"; 48°33'11.0"; 6. 8. 2008; Ms.

18. Babiná (Holý vrch); 630 m; SW; 10°; 400; E_3 80%; E_2 0%; E_1 80%; E_0 0%; 19°01'65.6"; 48°27'20.5"; 11. 6. 2008; Ms, Jk.

19. Hronská Breznica (Kamenné); 440 m; SW; 25°; 400; E_3 70%; E_2 5%; E_1 70%; E_0 0%; 18°59'45.9"; 48°33'34.7"; 22. 8. 2008; Ms.

20. Kozelník; 490 m; NW; 40°; 400; E_3 70%; E_2 10%; E_1 85%; E_0 20%; 19°00'07.8"; 48°30'00.9"; 9. 6. 2008; Ms, Jk.

21. Vyhne (Jelenia Skala); 750 m; NW; 45°; 400; E_3 60%; E_2 5%; E_1 95%; E_0 50%; 18°49'49.0"; 48°29'46.7"; 10. 6. 2008; Ms, Jk.

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Lesná vegetácia severnej časti Štiavnických vrchov

Súhrn

Predkladaný príspevok sa venuje syntaxonómii lesných spoločenstiev severnej časti Štiavnických vrchov, dopĺňa údaje o rozšírení a druhovom zložení príslušných vegetačných jednotiek. Fytocenologický výskum realizovaný tradičnými metódami zürišsko-montpelliarskej školy sa uskutočnil počas vegetačného obdobia roku 2008. Na vyhodnotenie snímkového materiálu sme využili metódu divíznej polytetickej klasifikácie TWINSPAN. Finálna podoba klasifikácie zohľadňuje aj výsledok nepriamej gradientovej analýzy (DCA). Pomocou Ellenbergových indikačných hodnôt boli zisťované hlavné faktory prostredia zodpovedné za variabilitu vo fytoocenologických dátach.

Zaznamenali sme prítomnosť piatich lesných spoločenstiev – *Carici pilosae-Fagetum*, *Dentario bulbiferae-Fagetum*, *Mercuriali-Fraxinetum*, *Poo nemoralis-Quercetum petraeae* a *Luzulo albidae-Quercetum petraeae*. Hlavným gradientom prostredia sa ukázali byť svetelné a teplotné podmienky v kombinácii s vlhkosťou a obsahom živín.

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Suitable parameters for soil organic matter changes evaluation in agro-ecosystems

Vladimír Šimanský, Anton Zaujec

Department of Pedology and Geology, Faculty of Agrobiological and Food Resources, Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, 949 76 Nitra, Slovak Republic, E-mail: Vladimír.Simansky@uniag.sk

Abstract

ŠIMANSKÝ, V., ZAUJEC, A. 2009. Suitable parameters for soil organic matter changes evaluation in agro-ecosystems. *Folia oecol.*, 36: 50–57.

In period 1999–2003, we studied suitability of new parameters for determination of soil organic matter (SOM) changes in ecological (ES) and integrated (IS) farming systems established in 1990 in the experimental station Slovak University of Agriculture in Nitra. The lability of carbon (L_C) was higher in spring (0.183) than in autumn (0.158) in both systems. The lability of nitrogen (L_N) was higher in IS (0.080) than in ES (0.074). Carbon management index (CMI) values were increasing more intensively in IS (from 108.7 to 118) than in ES (from 109.3 to 113.3). Higher percentage portions of potentially mineralizable nitrogen (N_L) from total (N_T) were in IS than in ES. It means that higher SOM sources are in ES than IS, but according to parameters L_C , CMI, L_N , more intensive changes in SOM sources can be supposed in IS than in ES. We recorded influence of average annual temperature on parameters of labile carbon ($r = -0.79$, $P < 0.01$), non-labile nitrogen ($r = 0.76$, $P < 0.01$), as well as the year precipitation sum on CMI ($r = -0.58$, $P < 0.01$), labile nitrogen ($r = 0.72$, $P < 0.01$) and L_N ($r = 0.61$, $P < 0.01$). From the point of sustainable development the parameters labile carbon, L_C and non-labile nitrogen (N_{NL}) were the most suitable for the assessment of SOM changes in farming systems.

Key words

carbon sequestration, farming systems, labile carbon and nitrogen, soil organic matter

Introduction

Soil fertility is closely linked to soil organic matter whose status depends on biomass input and management, mineralization, leaching and erosion. Soil organic matter (SOM) improves the productivity and physical properties of soils. The quantity and quality of SOM are the most important characteristics influencing the sustainable development. In natural conditions soils have their characteristic humus contents. This equilibrium state is disturbed by soil cultivation when inputs of organic matter to soil are lower, and decomposition of present organic matter is higher. Its quantity is determined through carbon and nitrogen. SCHJONNING et al. (2007) recorded changes in soil organic matter fractions in differentiated soil management after 5–6 years. It means that much more sensitive indicators of dynamic changes in C and N are their fractions, labile carbon or

potentially mineralizable nitrogen. The most common fractionations of SOM are based on differences in solubility of organic constituents in acid and alkali. The complexity of these fractions means that each of them represents a wide range of chemical forms with very different turnover rates. These fractions are not either conceptual pools or related to their rate of turnover. They are procedurally defined fractions, based largely on their solubility, and thus with limited value in studies of SOM dynamics. Techniques for isolation individual carbon fractions are different. LOGINOW et al. (1987) developed a fractionating method for SOM and fractions or substrates of SOM based on the susceptibility to oxidation by permanganate. Modification and standardization of $KMnO_4$ oxidation technique by BLAIR et al. (1995) has increased the precision and simplified the technique to use only one concentration $KMnO_4$, thereby dividing soil carbon into labile (C_L) and non-labile (C_{NL}) car-

bon. These measurements of labile carbon have been used, in combination with similar data from soil of an uncropped, reference area, to calculate carbon management index (CMI), as a measure of relative sustainability of different agricultural systems. This index compares the changes that occur in the total and labile carbon as a result of agricultural practice, with increased importance assigned to changes in labile, as opposed to non-labile, component of the SOM. Through these parameters, some scientists tried to observe smaller changes and changes in short time period. CONTEH et al. (1998) used parameters as lability (L), lability index (LI), carbon pool index (CPI) and CMI for the complex evaluation of differences in soil organic matter between natural ecosystems and agro-ecosystems. These parameters were used in our study for evaluating the influence of farming systems on the quantity and quality of SOM and on carbon sequestration. Our research has been focused on: i) possibilities how to evaluate changes in soil organic matter through total and labile fractions of SOM, ii) selection of parameters suitable for sensitive detection of organic matter changes in agro-ecosystems, iii) comparison between ecological (ES) and integrated farming systems (IS) through these parameters. This comparison can enable a faster and more sensitive response to negative changes in soil parameters that are very important for sustainable development.

Materials and methods

Experimental site

The studied territory of Dolná Malanta (lat. 48°19'00"; lon. 18°09'00") is located in the lower part of the basin of Selenec creek and its tributaries which belong to the central part of the Nitra river basin. It is located eastwards from the town of Nitra (Slovakia) in the Žitavská Upland. The geological substratum consists of little rocks with high contents of fine materials. Young Neogene deposits are composed

of various clays, loams, sands, gravels covered with loess deposited in the Pleistocene (HRNČIAROVÁ and MIKLÓS, 1991). The soil is Orthic Luvisol (FAO, 1998) containing on average 318.8 g kg⁻¹ of sand, 567.0 g kg⁻¹ of silt and 114.3 g kg⁻¹ of clay. Total soil carbon content was 13.9 ± 1.8 g kg⁻¹, total nitrogen content was 1348 ± 108 mg kg⁻¹, sorptive capacity was 157.7 ± 11.2 mmol kg⁻¹ and base saturation percentage was 88.9 ± 2.3 %. On average, exchangeable soil pH was 5.16 ± 0.31. Mean maximum and minimum air temperatures (1999–2003) were 21.1 °C (from July to August) and -2.1 °C (from December to January). The mean annual temperature of air is 10.7 °C. During the years 1999–2003 the mean annual precipitation was 487 mm, with about 48% of this amount falling from March to July.

Experimental details

The project with ecological (ES) and integrated (IS) farming systems was established in autumn 1990. All plots had the following size: width 10 m, length 10 m, in 4 replications. The plots were separated with 1 m insulation strips. The crop rotation in IS was: winter wheat (*Triticum aestivum* L.), silage corn (*Zea mays* L.), spring barley (*Hordeum vulgare* L.), bean (*Faba vulgaris* M.) + alfalfa (*Medicago sativa*); in ES there were: winter wheat (*Triticum aestivum* L.), pea (*Pisum sativum* L. subsp. *Hortense* (Neitr.)), silage corn (*Zea mays* L.), spring barley (*Hordeum vulgare* L.), bean (*Faba vulgaris* M.) + alfalfa (*Medicago sativa*). Farmyard (FYM) was added in a dose of 40 Mg ha⁻¹ to silage corn. In ES, FYM was added in a dose of 40 Mg ha⁻¹, supplementary nitrogen was provided through leguminous crops fixating nitrogen. The soil cultivation in both systems is based on conventional tillage. Crop rotations, fertilization and crop yields on plots 5 and 7 of both farming systems are shown in Table 1. In both farming systems, control variants without fertilization were included. In IS, the average annual doses of fertilizers were: N – 80 kg ha⁻¹, P (P₂O₅) – 40 kg ha⁻¹

Table 1. Schedule of field experiment, farming systems, crop rotation, FYM application and crop yields

Farming system			1999		2000		2001		2002		2003					
	Plot	Crop Rotation	Yield (Mg ha ⁻¹)		Yield (Mg ha ⁻¹)		Yield (Mg ha ⁻¹)		Yield (Mg ha ⁻¹)		Yield (Mg ha ⁻¹)					
			Control	Fertilized	Crop Rotation	Control	Fertilized	Crop Rotation	Control	Fertilized	Crop Rotation	Control	Fertilized			
IS	5	SB	5.1	7.2	WW	5.9	5.9	pea	3.9	3.4	WW	5.65	5.9	SC	18.6	22.9
	7	WW	6.9	8.3	SC+40tFYM	29.2	29.1	SB	3.2	4.6	B+AA	4.95	5.4	AA	12.9	10.0
ES	5	pea	4.9	4.6	SC+40tFYM	48.2	53.2	SB	3.1	3.6	B+AA	4.76	5.0	AA	10.5	8.8
	7	WW	6.0	6.2	pea	1.9	2.0	SC+40tFYM	48.2	53.2	SB	4.40	6.6	B+AA	5.7	5.4

SC, silage corn; AA, alfalfa; WW, winter wheat; SB, spring barley; B, bean; IS – plot 5 – 1990–2003 dose of FYM 100 Mg ha⁻¹, plot 7 dose of FYM 120 Mg ha⁻¹; ES – plot 5 – 1990–2003 dose of FYM 140 Mg ha⁻¹, plot 7 dose of FYM 120 Mg ha⁻¹

and K (K_2O) – 75 kg ha⁻¹. All treatments in IS were protected against detrimental effect of weeds, diseases and pests and in ES only physical protection was permitted.

Soil sampling and analysis

We collected soil samples from layer 0–0.3 m in spring and autumn in years 1999–2003. For each sampled zone, three different locations were chosen randomly. On each location, soil samples were collected and mixed up to an average sample. Soil samples were dried at the laboratory temperature and grinded. We determined the amounts of total organic carbon C_T (FIALA et al., 1999), labile carbon C_L (LOGINOV et al., 1987), total nitrogen N_T (FIALA et al., 1999) and potentially mineralizable nitrogen N_L (STANDFORD and SMITH, 1978) in soil samples. We calculated non-labile carbon (C_{NL}) as difference between C_T and C_L , and CMI according to BLAIR et al. (1995). We also used this procedure for evaluation of changes in soil nitrogen. We calculated values of the nitrogen parameters determined in soil: lability of soil nitrogen (L_N), lability index of nitrogen (LI_N), nitrogen pool index (NPI) and the nitrogen management index (NMI). The obtained data were analyzed by using the statistic software Statgraphic Plus. Data for each farming system, sampling time and years were prepared by analysis of variance. Differences were considered significant at $P < 0.05$, and differences between treatments means were calculated using the Duncan test. We used correlation analysis to determination of relationships between SOM quality and quantity and climatic conditions (temperature and precipitation).

Results and discussion

Carbon parameters in evaluation of SOM changes

The fluctuation of total organic carbon content (C_p) was the highest in year 2000 from 10.6 g kg⁻¹ to 15.8 g kg⁻¹ in variants. On average, a higher C_T content was in ES (14.5 g kg⁻¹) than in IS (13.1 g kg⁻¹) and in autumn than in spring (13.7 g kg⁻¹ and 11.9 g kg⁻¹) during the testing period (TOBIAŠOVÁ and PAČUTA, 2006). In ES, there was a higher portion of forage crops and lower portion of cereals than in IS. The reason of higher C_T content in autumn is accumulation of crop residues. Considering this fact it is not possible to predict quality of organic substances as source of SOM. The carbon content is higher in elemental composition of cereals, but the decomposition rate of crop residues is higher in case of forage crops (TOBIAŠOVÁ, 2001; TOBIAŠOVÁ, 2006; JURČOVÁ and TOBIAŠOVÁ, 2002). Another reason can be nitrogen fertilizer, which might be a result of increased organic carbon mineralization after autumnal application

of mineral nitrogen where there may be no crop present to utilize the fertilizer, resulting in adverse changes in SOM quality. The mineral fertilization contributes significantly to the formation of labile humic substances at the expense of Ca-forms of SOM which are more resistant to microbial decomposition (SHEVTSOVA et al., 2003). In summary, a higher average C_T content was in fertilized variants (13.3 g kg⁻¹) than in control variants (11.3 g kg⁻¹). BHATTACHARYYA et al. (2007) described considerable accumulation of total C_T in the 0.0–0.15 m soil layer in conditions with regular application of FYM in combination with NPK or N alone. The differences between fertilized and non-fertilized variants were higher in IS. The cause is in added inorganic fertilizers influencing nutrient ratios and next transformation processes (TOBIAŠOVÁ and KARABINOVÁ, 2002). We determined statistically significant influences of farming system and sampling time on C_T (Table 2). The labile carbon content (C_L) is much more sensitive parameter from the view point of study of short-term changes. The main reason of organic matter losses is the high rate of mineralization. Therefore, the values of C_L more sensitively reflected oxidative processes. ZOU et al. (2005) defined the soil labile organic carbon as the fraction of soil organic carbon degradable during microbial growth. Its oxidation drives the flux of CO_2 between soil and atmosphere. According to BELL et al. (1998), labile easy oxidizable carbon plays an important role in soil fertility. Therefore, the increase in content of this carbon fraction is decisive for the sustainable farming system. Generally, higher average contents of labile carbon were determined in spring than autumn in both farming systems. The differences in contents of C_L and C_T were observed between the individual years. In the multi-year studies, the type of interaction varied between years, suggesting that seasonal events, rather than soil type, determine the type of interaction. The greatest benefits of applying organic and mineral fertilizers together, LINQUIST et al. (2007) observed in years when soil-water conditions were unfavorable (fluctuating anaerobic-aerobic conditions). The highest contents of C_L were in 2001 and the lowest in 2002. Before 2001, a very dry year was year 2000 (added FYM positively affected on crop yields, mainly in ES). This manifests decreasing of soil organic matter transformation processes. Variability in temperature and precipitation during the years very intensively influenced transformation processes. We determined statistically significant influences of farming system, fertilization and sampling time on C_L . The lability of carbon (L_C) was the highest in 2001. This indicated the highest amount of active carbon in labile form, which was probably the result of FYM application in dry year 2000. BLAIR et al. (2006) proved that C_T , C_{NL} and C_L were greater with addition of FYM than without it and the application of N with FYM increased C_L but not C_T or C_{NL} compared to just FYM. Statistically significant influence of time of sampling on L_C values was determi-

ned. Their average values were higher in spring (0.183) than in autumn (0.158). Lower values of this parameter in autumn were the result of increased mineralization during the vegetative period with decreasing content of labile carbon, but also increasing of contents C_T by intensive humification of crop residues. With relation to farming system, on average higher value of L_C was in IS (0.172) than in ES (0.169). The lability index of carbon (LI_C) was the highest in 2000 (autumn), which was a very dry year. Just dryness could be the limiting factor of stabilization of the produced organic substances. Markedly lower values of LI_C in spring than in autumn were the result of a longer period of dryness in summer. On average, LI_C values were lower in spring than in autumn during the whole monitored period. In effect, the intensity of decomposition was higher in spring than in autumn. There were optimal conditions for growth and activity of microorganism. The temperature was the limiting factor in winter and the dryness was the limiting factor in summer. More pronounced changes among variants were not observed in carbon pool index (CPI) values. CONTEH et al. (1998) obtained similar values of CPI parameter in soil with and without crop residues. CPI values fluctuated from 0.855 to 1.346, but most of them were above 1. The stable forms of organic carbon are less available for microorganisms. On the other hand, they are important for the production of stabilized condensed humus substances as a potential resource of organic matter in soils. The stabilized humus substances play an important role in optimal soil structure and they also influence other physical, chemical and biological parameters of soils. And that is reason why it is better to consider C_T content together with carbon labile forms and CMI is better for the evaluation of these changes. CMI was designed to express C dynamics of the system. Although the value itself was not important, the changes, as a result of different management strategies, gave an indication of ecosystem response (BLAIR et al., 1995). On average, the highest value was in 2003 and the lowest in 2000. CMI values showed whether to consider as dominant processes of carbon losses or processes of new organic substances production. Usually, CMI values are strongly influenced by N fertilization. With regard to CMI, it may be stated that simultaneous mineral fertilization and organic manure cause an accumulation of SOM and the rate of these processes is proportional to the fertilizer doses (JANOWIAK et al., 2001). There is not an ideal CMI value. CMI is suitable for the comparison of carbon changes in different soils and farming systems. The lower CMI value, the higher amount of carbon from soil reserve is changed as a reason of cultivation (BLAIR et al., 1995). CMI average values were lower in spring than in autumn. They were increasing more intensively in IS (from 108.7 to 118), than ES (from 109.3 to 113.3), which focused on higher intensity of carbon transformation. Fluctuation of CMI values was higher in integrated than in ecological farming system.

Table 2. Mean values of parameters of soil organic matter quality in different farming systems, time sampling and years

	Parameters													
	L_C	LI_C	CPI	CMI	L_N	LI_N	NPI	NMI	C_T	C_L	C_{NL}	N_T	N_L	N_{NL}
									[g kg ⁻¹]			[mg kg ⁻¹]		
Farming system	ES ^{a)}	0.169a ^{e)}	1.072a	111.30a	0.074a	102.52a	1.073a	109.33a	14.06b ^{b)}	2.01b	12.05b	1541.9b	104.6a	1432.3b
	IS ^{b)}	0.172a	1.134a	113.36a	0.080a	94.96a	1.083a	101.36a	12.54a	1.83a	10.71a	1393.1a	97.2a	1290.9a
Sampling time	Spring	0.183b	1.109a	108.99a	0.074a	95.34a	1.084a	102.49a	12.77a	1.97a	10.80a	1489.5a	101.3a	1388.2a
	Autumn	0.158a	1.097a	115.67a	0.080a	102.14a	1.071a	108.20a	13.83b	1.87a	11.95b	1445.5a	100.5a	1335.0a
Years	1999	0.168ab	1.077ab	114.85a	0.079ab	100.43a	1.037ab	101.65a	14.38a	2.06a	12.32b	1364.8a	99.3abc	1265.5a
	2000	0.156a	0.959a	106.03a	0.060a	91.18a	0.970a	88.70a	13.69a	1.81a	11.87ab	1591.0c	88.0ab	1502.8c
	2001	0.194b	1.138b	107.93a	0.082ab	106.83a	1.107ab	116.80a	12.75a	2.06a	10.69a	1520.0bc	113.0bc	1394.8bc
	2002	0.172ab	1.147b	106.43a	0.094b	102.65a	1.144b	116.25a	12.63a	1.85a	10.78ab	1473.8ab	125.5c	1348.3ab
	2003	0.162a	1.194b	126.43a	0.071ab	92.63a	1.131b	103.33a	13.06a	1.81a	11.25ab	1387.9a	78.8a	1296.8ab

^{a)}Ecological farming system; ^{b)}Integrated farming system; ^{c)}Values followed by the same letter within each column are not significantly different at $P < 0.05$; C_T , total organic carbon; C_L , labile carbon; C_{NL} , non-labile carbon; L_C , lability index of soil organic carbon; LI_C , lability index of carbon; CPI, carbon pool index; CMI, carbon management index; N_T , total nitrogen; N_L , potentially mineralizable nitrogen; N_{NL} , non-labile nitrogen; L_N , lability index of soil nitrogen; LI_N , lability index of nitrogen; NPI, nitrogen pool index; NMI, nitrogen management index

Nitrogen parameters in evaluation of SOM changes

The farming system and the fertilization had statistically significant influence on total nitrogen content (N_T). On average, the nitrogen content was higher in ES than in IS (about 149 mg kg⁻¹). Noticeable differences of N_T contents were also between the years. On average, the lowest N_T content was in 1999 (1,365 mg kg⁻¹) and the highest in 2000 (1,591 mg kg⁻¹). Higher percentage portions of potentially mineralizable nitrogen (N_L) from N_T were in IS than in ES. Their portions in control variants were higher, but the differences between spring and autumn sampling were not observed. Differences in their percentage portions were between the years. On average, the lowest value of N_L portion from N_T 5.9% was denoted in 2000. The measurement of potentially mineralizable carbon and nitrogen represents a bioassay of labile organic matter using the indigenous microbial community to release labile organic fractions of carbon and nitrogen. The mineralizable nitrogen is also an important indicator of soil capacity to supply the nitrogen for crop. It is concluded that individual labile organic matter fractions are sensitive to changes in soil management and have specific effects on soil function (ZAUJEC et al., 2005). According to WESTERHOF et al. (1998) NMI is a good indicator of N availability but it gives no information about the total amount of N. In land use system analysis, N_T and N_L can be used together as a simple and rapid tool for evaluation the nitrogen status of the soil. Nitrogen evaluation changes are also more sensitive through the lability of nitrogen (L_N), lability index of nitrogen (LI_N) or nitrogen pool index (NPI). L_N fluctuated from 0.046 to 0.107 in both farming systems. The lowest values were obtained in 2000 and the highest in 2002. FISSORE et al. (2008) found that both soil organic matter quantity and quality decreased with increasing mean annual temperature. Soil moisture is also one of the key factors influencing soil microbial activity and SOM decomposition, but presence of plants can not be ignored in SOM decomposition studies (DIJKSTRA and CHENG, 2007). Crops with bigger root systems in topsoil were in 2000 than in 2002. Year 2000 was not only dry, but there were also mainly cereals, which decreased soil moisture. Higher value of L_N indicates higher amount of available nitrogen. Differences were also between years, with the highest value in 2002, and the lowest in 2000. In 2002, average annual temperature and annual sum of precipitation were the highest. It is interesting that marked differences were not observed between fertilized and control variants. Average values of L_N were higher in autumn than in spring. Parameter LI_N confirmed, that nitrogen organic substances were less resistant in ES than in IS. They were least stable in the dry year 2000. NMI pointed to the most intensive changes of nitrogen content just in year 2000, where this average value was the lowest. It means that in case

of year 2000, the nitrogen organic substances were the least stable and they underlay the most intensive changes. More sensitive parameter of nitrogen content evaluation was nitrogen pool index (NPI). The amount of organic matter inputs statistically significantly influenced the parameters of CPI, CMI and NPI. Their amount was higher in control variant in ES and in fertilized variants in IS (Table 2).

Correlations between climatic changes and soil organic matter parameters

Statistical assessment (Table 3) showed that significant linear dependence was between precipitation and C_L , but not C_T . It can be the reason of the higher accumulation of organic matter in topsoil, but in lower part of soil profile stabilized organic substances are dominant. This also indicated that soil labile carbon was relatively more sensitive to environmental changes than soil organic carbon. CMI, CPI, NMI and NPI indexes were more suitable for comparison of SOM changes between individual years. It was probably the reaction on climatic changes (temperature and precipitation). In our experiment, the average temperatures in July and August influenced statistically significantly values of CPI and NPI (Table 3). HOMANN et al. (2007) recorded that the organic carbon pool is negatively related to a temperature/precipitation index in studied regions and negatively related to mean annual temperature. These relations are consistent with concepts of moisture and temperature controls on detrital production, differential effects of temperature on detrital production and decomposition, and stabilization of organic matter by clay and silt. In our study, the average annual temperature had statistically significant influence on C_L ($r = -0.79$, $P < 0.01$) and N_{NL} ($r = 0.76$, $P < 0.01$). Average temperatures in July and August significantly influenced C_L ($r = -0.50$, $P < 0.05$), C_{NL} ($r = -0.74$, $P < 0.01$) and CPI ($r = 0.61$, $P < 0.01$), NPI ($r = 0.63$, $P < 0.01$). Average temperatures from April to October had statistically significant influence on N_{NL} ($r = 0.63$, $P < 0.01$) and L_N ($r = -0.60$, $P < 0.01$). Annual sum of precipitation had statistically significant influence on CMI ($r = -0.58$, $P < 0.01$), N_L ($r = 0.72$, $P < 0.01$), L_N ($r = 0.61$, $P < 0.01$). Sum of precipitation in July and August significantly influenced C_L ($r = -0.50$, $P < 0.05$), N_{NL} ($r = -0.72$, $P < 0.01$), L_N ($r = 0.59$, $P < 0.01$). Sum of precipitation from April to October significantly influenced LI_C ($r = -0.54$, $P < 0.05$), N_L ($r = 0.72$, $P < 0.01$), N_{NL} ($r = -0.59$, $P < 0.01$), L_N ($r = 0.68$, $P < 0.01$), LI_N ($r = 0.57$, $P < 0.01$), NMI ($r = 0.58$, $P < 0.01$). Temperature and precipitation play important role in SOM changes. It is important not only for annual characteristics, but also their distribution during the year.

Table 3. Correlation coefficients between soil organic matter parameters and climatic conditions and variants of farming systems

	C _T	C _L	C _{NL}	L _C	LI _C	CPI	CMI
Year average (temperature)	-0.38	-0.79**	-0.25	-0.40	-0.04	-0.41	-0.46
Average temp. (April–October)	-0.34	-0.25	-0.31	0.10	0.15	-0.12	0.03
Average temp. (July–August)	-0.34	-0.50*	-0.74**	0.13	-0.30	0.61**	0.37
Year sum (precipitation)	0.12	0.16	0.10	0.01	-0.38	-0.18	-0.58**
Sum of precipitation (April–October)	-0.07	-0.25	-0.11	0.21	-0.54*	0.37	-0.15
Sum of precipitation (July–August)	0.41	-0.50*	0.35	0.02	-0.30	0.17	-0.15
IS – fertilized variant	0.39	-0.29	0.46*	-0.52*	0.24	0.83**	-0.64**
IS – control	-0.08	-0.06	-0.07	-0.05	-0.46*	-0.08	-0.54*
ES – fertilized variant	-0.68**	-0.41	-0.63**	0.19	-0.31	-0.13	-0.43
ES – control	-0.20	-0.41	-0.13	-0.32	-0.09	0.67**	0.63**
	N _T	N _L	N _{NL}	L _N	LI _N	NPI	NMI
Year average (temperature)	0.76**	0.01	0.78**	-0.28	-0.43	-0.20	-0.29
Temperature av. (April–October)	0.59**	-0.43	0.63**	-0.60**	-0.30	-0.15	-0.22
Temperature av. (July–August)	0.09	-0.16	0.07	0.01	-0.14	0.63**	0.31
Year sum (precipitation)	-0.03	0.72**	-0.12	0.61**	0.41	-0.00	0.24
Sum of precipitation (April–October)	-0.48*	0.72**	-0.59**	0.68**	0.57*	0.47	0.58**
Sum of precipitation (July–August)	-0.68**	0.39	-0.72**	0.59**	0.38	0.14	0.25
IS – fertilized variant	0.48*	0.12	0.53*	-0.22	-0.29	-0.67*	-0.53*
IS – control	0.02	0.73**	-0.08	0.64**	0.33	0.14	0.29
ES – fertilized variant	0.65**	0.09	0.81**	-0.21	-0.06	0.03	0.07
ES – control	-0.71**	-0.06	-0.70**	0.38	-0.17	0.64**	0.23

Sum of samples = 19, * $P < 0.456$; ** $P < 0.575$

Conclusions

The results showed on the necessity of application, predominantly, of carbon and nitrogen fractions in the evaluation of soil organic matter quality and its losses. Because the changes in these fractions are observed in shorter time periods, it is possible to respond to them more flexibly and to assess together the quantity and quality of soil organic matter. In this case, longer time of dryness strongly influenced processes of soil organic matter transformation. It means that temperature and precipitation play important role in soil organic matter changes and it is important to monitor not only mean annual temperature and sum of precipitation, but also their distribution over the year.

According to statistical assessment, suitable parameters for sensitive response to changes of organic matter in agro-ecosystems are mainly parameters labile carbon, carbon lability and non-labile nitrogen. They are the most suitable for assessment of soil organic matter changes in conditions of different farming systems. New approach to the evaluation of contents and changes in soil organic matter presented possibilities in complex assessment of carbon and nitrogen forms, total and labile, not only for different ecosystems but also for farming systems.

According to total organic carbon content, higher values were in average in ecological than in integrated system. But according to carbon lability on average higher values were in IS than in ES, which indicates higher amount of active carbon in labile form. Carbon management index values were increasing more intensively in integrated than ecological system, which showed on higher intensity of carbon transformation and microorganism activity. Higher percentage portions of potentially mineralizable nitrogen from total nitrogen were in integrated than in ecological system. It means that higher soil organic matter sources are in ecological than integrated system, but according to parameters carbon lability, carbon management index, labile nitrogen from total nitrogen, more intensive changes in soil organic matter sources we can await in integrated than in ecological system.

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Vhodné parametre pre hodnotenie zmien v organickej hmote pôdy v agroekosystémoch

Súhrn

Vo vybraných agro-ekosystémoch (ES – ekologický systém hospodárenia, IS – integrovaný systém hospodárenia), ktoré boli založené v roku 1990 na experimentálnej báze SPU – Nitra, sme v rokoch 1999–2003 študovali vhodnosť nových ukazovateľov pre určenie zmien v organickej hmote pôdy. Zistili sme, že labilita uhlíka (L_C) v oboch systémoch hospodárenia bola vyššia na jar (0,183) ako na jeseň (0,158). Labilita dusíka (L_N) bola vyššia v IS (0,080) v porovnaní s ES (0,074). Hodnoty uhlíkového radiaceho indexu (CMI) sa výraznejšie zvýšili v IS (z 108,7 do 118) ako v ES (z 109,3 do 113,3), čo poukazovalo na vyššiu intenzitu transformácie uhlíka. Vyššie percentuálne zastúpenie potenciálne mineralizovateľného dusíka z celkového dusíka bolo v IS ako v ES, čo znamená, že vyššie zdroje organickej hmoty pôdy sú v ES ako v IS. Na druhej strane na základe hodnôt L_C , CMI, L_N , intenzívnejšie zmeny v zdrojoch organickej hmoty pôdy môžeme očakávať v IS ako v ES. Vstupy organickej hmoty ovplyvnili tieto parametre: veľkosť zdroja uhlíka (CPI), CMI a veľkosť zdroja dusíka (NPI). Zvyšovanie ich priemerných hodnôt bolo výraznejšie v IS v porovnaní s ES počas celého sledovaného obdobia od jari do jesene. Zvýšenie hodnôt v období experimentu bolo od jari do jesene v priemere vyššie v IS ako v ES. To znamená, že zmeny v dynamike pôdnej organickej hmoty boli vyššie v IS, s jej nižším obsahom, teda reakcia na vstupy organickej hmoty bola oveľa citlivejšia. Zaznamenali sme vplyv priemernej ročnej teploty na parametre C_L ($r = -0,79$; $P < 0,01$), nelabilného dusíka (N_{NL}) ($r = 0,76$; $P < 0,01$), a taktiež vplyv ročného úhrnu zrážok na CMI ($r = -0,58$; $P < 0,01$), labilný dusík (N_L) ($r = 0,72$; $P < 0,01$) a L_N ($r = 0,61$; $P < 0,01$). Z pohľadu trvalej udržateľnosti agroekosystémov sa parametre labilného uhlíka (C_L), L_C a N_{NL} javia oveľa vhodnejšími pre hodnotenie zmien v pôdnej organickej hmote jednotlivých systémov hospodárenia.

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Structure of root branches in Norway spruce with respect to soil drainage

Peter Štofko¹, Milan Kodrík²

¹National Forest Centre – Forest Research Institute, T. G. Masaryka 22, 960 92 Zvolen, Slovak Republic

²Technical University in Zvolen, Faculty of Forestry, T. G. Masaryka 20, 960 53 Zvolen, Slovak Republic,
E-mail: kodrik@vsld.tuzvo.sk

Abstract

ŠTOFKO, P., KODRÍK, M. 2009. Structure of root branches in Norway spruce with respect to soil drainage. *Folia oecol.*, 36: 58–66.

We studied root branch structure in uprooted spruce trees (*Picea abies* [L.] Karst.) in the localities Hnilé Blatá (the High Tatra Mts.) (waterlogged) and Zemská (the Low Tatra Mts) (well-drained). After cleaning the root plates, we measured the number, diameter and length of individual root branches. Individual root branches were classified in twelve diameter classes – according to their diameter measured in the middle of root branch length. Mean values of absolute frequency of root branches in the first eight root-diameter classes (0.2–12.0 cm) were higher in spruce trees growing on well-drained sites, but for the same sites, we found out lower mean values of absolute frequencies of root branches in the last four root-diameter classes (12.1–30.0 cm). We found out unproportionally higher mean values of root branch length in all root-diameter classes in spruce trees growing on waterlogged sites. The mean value of total length of root branches was two times higher in the first root-diameter class (0.2–1.0 cm); and, similarly, mean values of total length of root branches were noticeably higher in the last four root-diameter classes (12.1–30.0 cm) in spruce trees growing on waterlogged sites. Based on our results, it seems that there is practically no difference in total mean length of root branches (all root-diameter classes together) with diameter exceeding 1 cm between spruce trees growing on waterlogged and well-drained sites. According to our results, spruce trees growing on well-drained sites form shorter root branches in the thinner root-diameter classes, but the frequency of these root branches is higher in comparison with spruce trees growing on waterlogged sites. Therefore, the total length of root branches (with diameter exceeding 1 cm) in spruce trees growing in waterlogged and well-drained sites is almost the same.

Key words

Picea abies, root branch, waterlogged sites

Introduction

The morphology and size of tree root system is predetermined by the genetic properties of particular tree species, as manifested through inter-specific differences. However, the environment (especially soil conditions) can influence root system features considerably (COUTTS, 1987). In case of undisturbed development, the spruce forms a typical shallow root system characterised by presence of large, horizontal, lateral roots just

below the soil surface and small roots branching down vertically from the first ones. A high groundwater table can also reduce maximum depth of root penetration. KODRÍK (1998) mentions that the level of underground water considerably influences the root system formation. KÖSTLER et al. (1968) report that spruce forms extreme shallow root system on poorly drained sites. According to KONŮPKA (2003), the roots do not need or cannot penetrate through deeper soil horizons, and shallow and unstable root systems are formed on waterlogged sites.

¹Current address: Neulogy, Pribinova 25, 811 09 Bratislava, Slovak Republic, E-mail: peter.stofko@post.sk

CROW (2005) mentions that poor gas exchange in waterlogged soils causes depleting these soils of oxygen and brings about anaerobic conditions resulting in root death. In general, soils with permanently high water tables cause trees to develop very shallow, widespread rooting systems.

The main problem in belowground biomass research is equivalent to the basic problem – how to obtain the roots from the soil substrate or how to get into the soil substrate up to their near proximity. Overcoming this obstacle is a necessary condition for the correct study. In preliminary research on tree roots, the excavation method when the roots are obtained from the soil by digging is the most common. Using trees which are naturally uprooted from the soil, eg by wind or by a winch, is also effective.

The aim of this paper is to compare the diameter and length structure of root branches between spruce trees growing in waterlogged and well-drained sites.

Material and methods

The structure of root branches was measured on Norway spruce (*Picea abies* [L.] Karst.) in the locality Hnilé Blatá (the High Tatra Mts) (waterlogged site) and the locality Zemská (the Low Tatra Mts) (well-drained site). The forest stand 396A (waterlogged) is uneven-aged, with the dominant stand layer 90 years old, south aspect, 5–10% slope, altitude is about 950 m asl. The stand consists of three forest biotopes (see Table 1). The properties of soil are given in Table 2. Spruce is the do-

minant woody plant on the site, but the birch and alder are also quite abundant. The soil is rather waterlogged, with low incidence of peat.

The forest stand 47A (well-drained site) is uneven-aged, with the over storey 80 years old, north exposure, 40% slope, altitude is about 950 m asl. The stand consists of one forest biotope (see Table 1). The soil properties are given in Table 2. The forest stand 47A consists of Norway spruce with 100% proportion.

The study ran on 22 uprooted spruce trees on waterlogged site and 9 uprooted spruce trees on well-drained site. The examined trees were selected by random sampling from uprooted spruces scattered across the stand. The root plates of the measured spruce trees were cleared of soil up to the soil surface, by using hand tools. It means that we did not excavate the whole root plates. We only cleared visible surface of root plates up to the hinge (see Fig 1). After cleaning the root plates, the parameters of root branches were measured. The number, length and diameter of the individual root branches were measured as illustrates Fig 2. An individual root branch is defined as the most vigorous unbroken root branch forking into other smaller individual root branches. The length of an individual root branch was measured as the actual distance from its forking point up to the tip of its thickest (strongest) sub-branch. Individual root branches were classified in twelve diameter classes according to their diameter measured at the middle of root branch length: 0.2–1.0 cm, 1.1–2.0 cm, 2.1–3.0 cm, 3.1–4.0 cm, 4.1–5.0 cm, 5.1–6.0 cm, 6.1–9.0 cm, 9.1–12.0 cm, 12.1–15.0 cm, 15.1–20.0 cm, 20.1–25.0 cm and

Table 1. Habitat classification of the analysed stands (according to STANOVÁ and VALACHOVIČ, 2002)

Stand	Stand area [%]	Forest type according to Slovak forest typology		CORINE ¹⁾		EUNIS ²⁾	
		Code	Name	Code	Name	Code	Name
396A (waterlogged)	50	0023	Peaty fir-spruce	44.A4	<i>Sphagnum</i> spruce woods	G3.E6	Nemoral bog <i>Picea</i> woods
	40	0012	Birch-alder on a fluvio-glacial substrate	44.21	Montane grey alder galleries	G1.121	Montane <i>Alnus incana</i> galleries
	10	6124	Bilberry-spruce with fir	42.1	Fir forests	G3.1	[<i>Abies</i>] and [<i>Pinus</i>] woodland
47A (well-drained)	100	6232	Nutritive spruce-firs of higher degree	42.1	Fir forests	G3.1	[<i>Abies</i>] and [<i>Pinus</i>] woodland

¹⁾According to classification by Commission of European Communities

²⁾According to EUNIS Habitat classification

Table 2. Soil characteristics of the analysed forest stands

Stand	Soil type ¹⁾	Soil skeleton / average size	Proportion of skeleton
396A (waterlogged)	Haplic Stagnosols	Stony / 20 cm	20%
47A (well-drained)	Dystric Cambisols	Gravel / 4 cm	50%

¹⁾According to classification of WRB (World Reference Base for Soil Resources, 1994)

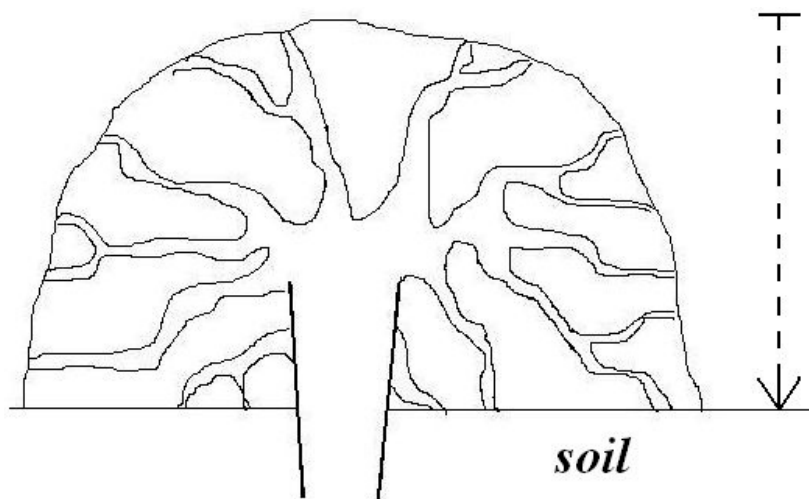


Fig 1. Root-plate surface containing the analysed root branches – cleaning of the visible part of the root plate up to the soil surface (up to the hinge)

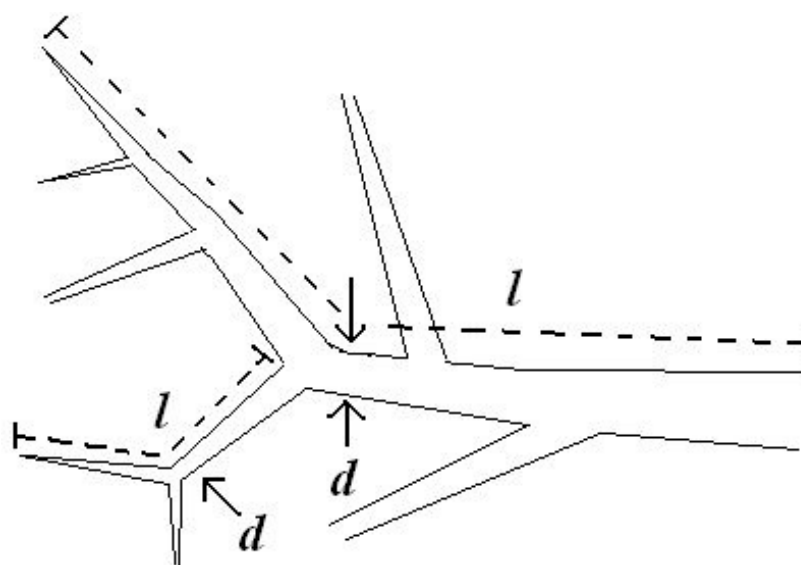


Fig 2. Measurement of diameter (d) and length (l) of individual root branches

25.1–30.0 cm. Number and length of the individual root branches in the first root-diameter class (0.2–1.0 cm) were only estimated, consequently, these data are only approximate. Mean values of the number and length of root branches were calculated for each root-diameter class.

Results

Mean values of aboveground parameters of analysed spruce trees are given in Table 3. Mean values of frequency and length of root branches according to individu-

al root-diameter classes are given in Table 4. We found out differences in the diameter and length structure of root branches between spruce trees growing on water-logged and well-drained sites. Average values of absolute frequencies of root branches in the first eight root-diameter classes (0.2–12.0 cm) were higher for spruce trees growing on well-drained sites. Moreover, these values were more than two times higher in the first four root-diameter classes. On the contrary, in the last four root-diameter classes (12.1–30.0 cm), we found out lower mean values of absolute frequencies of root branches in spruce trees growing on well-drained sites (Figs 3 and 4). The differences in the relative frequencies of

root branches in individual root-diameter classes were not such significant, and higher mean values of relative frequency of root branches were found out in the last four root-diameter classes (12.1–30.0 cm) on waterlogged sites. After having excluded the roots belonging to the first diameter class – the frequency of which was only estimated, we found out that the relative frequency of root branches was higher especially in the second (1.1–2.0 cm) root-diameter class – 57.12% in spruce trees growing on well-drained sites and 49.51% in spruce trees growing on waterlogged sites. On the other hand, after having excluded the roots belonging to the first diameter class, the mean values of relative frequency of root branches in the last four root-diameter classes (12.1–30.0 cm) were unproportionally higher for spruce trees growing on waterlogged sites.

We found unproportionally higher mean values of length of root branches in all root-diameter classes in spruce trees growing on waterlogged sites (Figs 5 and 6). These values were approximately two times higher in the first eighth root-diameter classes in spruce trees growing on waterlogged sites. Interestingly, on waterlogged sites, the mean value of length of root branches was four times higher in the first root-diameter class in comparison to well-drained sites. The differences in the relative values of length of root branches between waterlogged and well-drained sites were not so noticeable. Only in the first (0.2–1.0 cm) root-diameter class, the mean value of relative length of root branches was 2.5 times higher in spruce trees growing on waterlogged sites.

Table 3. Mean values of aboveground parameters of the analysed spruce trees

Stand	Stem diameter at breast height	Stem diameter 20 cm from the ground level	Tree height	Crown width	Crown length	Crown proportion index
	DBH [cm]	D _{0.2} [cm]	H [m]	CW [m]	L [m]	L / H × 100 [%]
396A (waterlogged)	31.2	40.6	22.3	5.3	17.2	76.8
47A (well-drained)	45.5	62.5	32.2	6.9	18.5	57.6

Table 4. Mean values of frequency and length of root branches corresponding to the individual root-diameter classes in Norway spruce

Parameter	Site	Diameter class (cm)												
		0.2–1.0	1.1–2.0	2.1–3.0	3.1–4.0	4.1–5.0	5.1–6.0	6.1–9.0	9.1–12.0	12.1–15.0	15.1–20.0	20.1–25.0	25.1–30.0	
n [p] ¹	Waterlogged	342.86	36.95	17.77	6.45	4.32	2.23	3.36	1.50	0.73	0.73	0.41	0.18	
	Well-drained	773.33	99.00	38.33	16.17	6.17	4.17	5.00	3.17	0.50	0.55	0.17	0.11	
n [%] ²	Waterlogged	82.12	8.85	4.26	1.55	1.03	0.53	0.81	0.36	0.17	0.17	0.10	0.04	
	Well-drained	81.69	10.46	4.05	1.71	0.65	0.44	0.53	0.33	0.05	0.06	0.02	0.01	
n without 0.2–1.0 [%] ³	Waterlogged	–	49.51	23.81	8.65	5.79	2.98	4.51	2.01	0.97	0.97	0.55	0.24	
	Well-drained	–	57.12	22.12	9.33	3.56	2.40	2.88	1.83	0.29	0.32	0.10	0.06	
l [cm] ⁴	Waterlogged	31.81	83.25	104.50	106.74	143.85	147.88	146.70	152.92	107.00	165.50	165.50	156.00	
	Well-drained	7.42	31.29	45.41	77.73	76.70	78.06	78.61	67.92	91.28	101.02	119.05	147.28	
l [%] ⁵	Waterlogged	2.10	5.51	6.91	7.06	9.52	9.78	9.70	10.12	7.08	10.95	10.95	10.32	
	Well-drained	0.80	3.39	4.93	8.43	8.32	8.47	8.53	7.37	9.90	10.96	12.92	15.98	
l without 0.2–1.0 [%] ⁶	Waterlogged	–	5.63	7.06	7.21	9.72	9.99	9.91	10.33	7.23	11.18	11.18	10.54	
	Well-drained	–	3.42	4.97	8.50	8.39	8.54	8.60	7.43	9.98	11.05	13.02	16.11	
n × l [cm] ⁷	Waterlogged	10,904.76	3,076.34	1,857.31	688.93	621.17	329.38	493.45	229.38	77.82	120.36	67.70	28.36	
	Well-drained	5,796.94	3,101.98	1,743.14	1,238.12	472.60	337.32	390.00	209.03	45.82	55.35	19.83	16.20	
n × l [%] ⁸	Waterlogged	58.96	16.63	10.04	3.72	3.36	1.78	2.67	1.24	0.42	0.65	0.37	0.15	
	Well-drained	43.18	23.10	12.98	9.22	3.52	2.51	2.90	1.56	0.34	0.41	0.15	0.12	
n × l without 0.2–1.0 [%] ⁹	Waterlogged	–	40.53	24.47	9.08	8.18	4.34	6.50	3.02	1.03	1.59	0.89	0.37	
	Well-drained	–	40.66	22.85	16.23	6.19	4.42	5.11	2.74	0.60	0.73	0.26	0.21	

¹Average number of root branches, ²relative average number of root branches, ³relative average number of root branches without the first root diameter class, ⁴average length of root branches, ⁵relative average length of root branches, ⁶relative average length of root branches without the first root diameter class, ⁷total average length of root branches, ⁸total relative average length of root branches, ⁹total relative average length of root branches without the first root diameter class

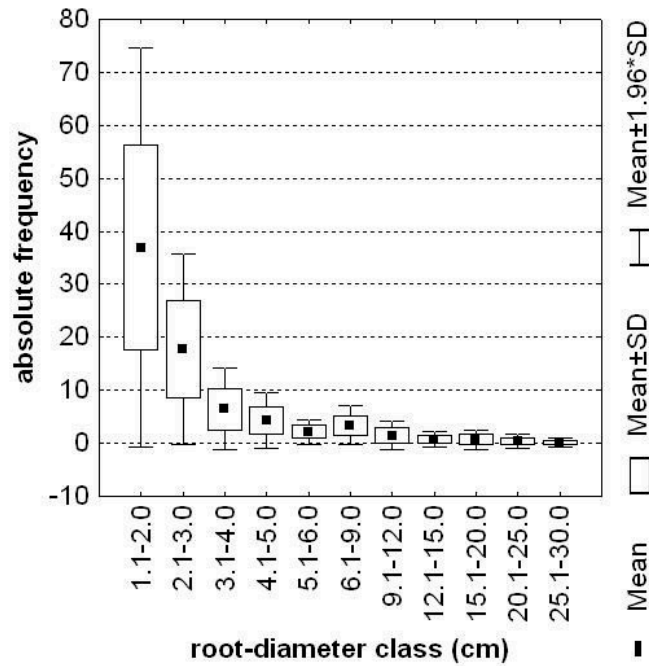


Fig 3. Mean values of frequency of root branches according to the individual root-diameter classes in Norway spruce growing on waterlogged sites

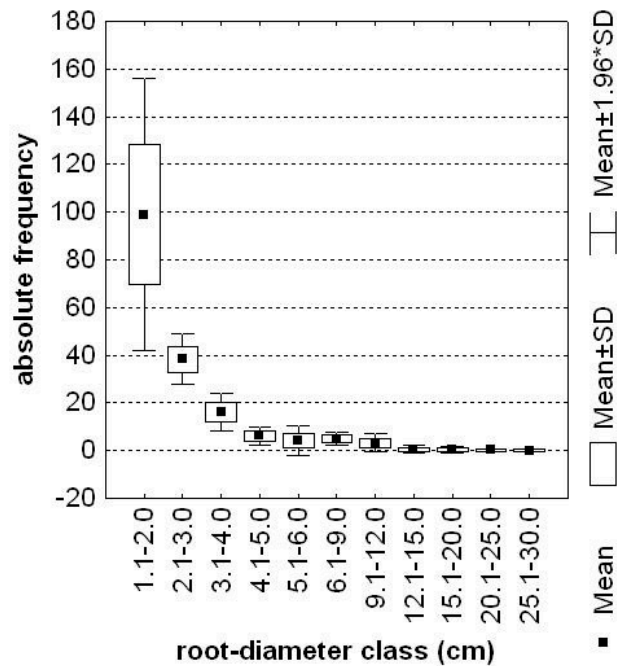


Fig 4. Mean values of frequency of root branches according to the individual root-diameter classes in Norway spruce growing in well-drained sites

Mean value of total length of root branches was two times higher in the first root-diameter class in spruce trees growing on waterlogged sites and these values were noticeably higher in the last four root-diameter classes (12.1–30.0 cm) on waterlogged sites, as well (Figs 5 and 6). Interestingly, we found that the mean

value of total length of root branches was two times higher in the root-diameter class 3.1–4.0 cm in spruce trees growing in well-drained sites. We also detected a rather higher mean value of total relative length of root branches in the first root-diameter class in spruce trees growing on waterlogged sites. However, these values

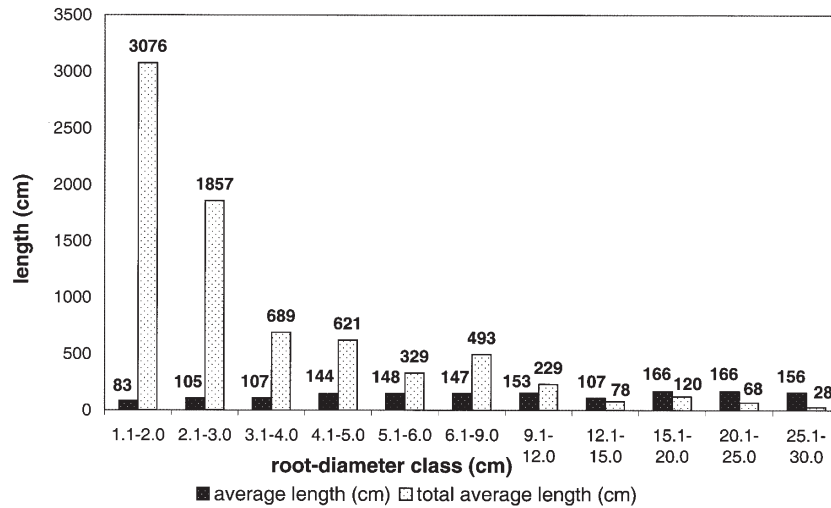


Fig 5. Mean values of length of root branches according to the individual root-diameter classes in Norway spruce growing on waterlogged sites

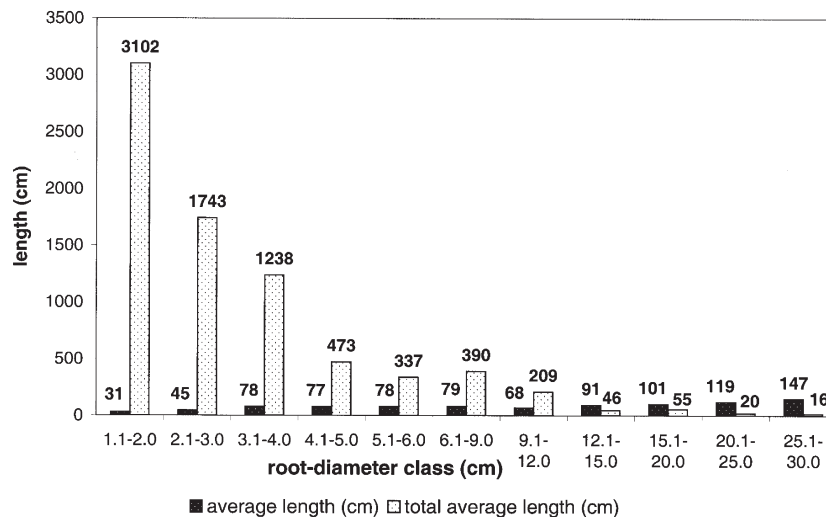


Fig 6. Mean values of length of root branches according to the individual root-diameter classes in Norway spruce growing on well-drained sites

were rather higher in the second (1.1–2.0 cm) and the fourth (3.1–4.0 cm) root-diameter class on well-drained sites. After having excluded the roots belonging to the first diameter class, we found out that the mean values of total relative length of root branches were higher especially in the fourth (3.1–4.0 cm) root diameter class in spruce trees growing in well-drained sites and these values were markedly higher in the last four root-diameter classes (12.1–30.0 cm) on waterlogged sites.

Discussion and conclusions

We found out that the frequencies of roots in the lower (thinner) root-diameter classes were higher in spruce

trees growing on well-drained sites. KODRÍK and HLAVÁČ (1994) analysed the root architecture of Norway spruce on well-drained sites. They found out that the relative frequency of roots with diameter smaller than 2 cm was about 50%, the relative frequency in the diameter class 2.1–7.0 cm was around 30% and the rest was found out belonging to the diameter class 7.1 cm and higher. According to our results, the root frequency up to 2 cm diameter was much higher on both sites. However, after having excluded the roots belonging to the first diameter class, we found out the relative frequency of root branches up to 2 cm diameter was slightly higher (57%) in comparison to the results of KODRÍK and HLAVÁČ (1994). Interestingly, the frequency of root branches in the thicker root-diameter classes was higher

in spruce trees growing on waterlogged sites. On the other hand, KONŌPKA (2005) found larger quantities of roots, especially those with medium and small diameter, on poorly drained sites than on well-drained sites. According to his results, the root systems were extremely long on poorly drained sites, so they had very abundant thinner roots. KODRÍK (2002) analysed the frequency and thickness of root branches with diameter exceeding 1 cm in spruce trees growing on well-drained sites. He found out that the relative amount of roots with diameter not larger than 3 cm was 59.5%, in case of diameter 3.1–9.0 cm it was 28% and with diameter exceeding 10 cm it was only 12.5% of the total root numbers in wind thrown spruce trees. He, however, met different situation with standing spruce trees. In this case, the relative amount of roots with the diameter under 3 cm was 46.6%, with the diameter 3.1–9.0 cm it was 32.5% and with the diameter exceeding 10 cm it was 20.9%. After having excluded the first (only estimated) root-diameter class, we found out higher amounts of root branches in the second and the third root-diameter class (together 79.2% in these two root diameter classes) in spruce trees growing on well-drained sites in comparison to the results obtained by KODRÍK (2002).

In general, we obtained a high frequency for root branches in the first three root-diameter classes and the values of average frequency of root branches slightly declining with increasing their diameters. SCHMID and KAZDA (2001) discovered that the total number of roots per square metre in case of diameter 2–5 mm was 406, in case of diameter 5–20 mm it was 63, and in case of diameter exceeding 20 mm, there were observed two roots in the spruce trees growing in well-drained monocultures. According to our results, the values of total average length of root branches were the highest in the first root diameter class, and these values continually decreased with increasing values of root branch diameter. KODRÍK (2005) observed the highest values of mean root length in the first diameter class (≤ 0.5 cm) and the mean values of root length decreased gradually towards the higher root diameter classes in spruce trees growing on well-drained sites. VYSKOT (1993) found the highest values of fresh weight of Norway spruce underground biomass for root thickness exceeding 10.0 cm, and these values gradually decreased towards the smaller root diameters. KODRÍK (1992) observed the smallest weight of underground biomass in the first (<0.5 cm) and the highest weight of underground biomass in the highest (>10.0 cm) root-size class in Norway spruce growing on sites loaded with air pollution. Based on his results, the highest weight of underground biomass up to the 10.0 cm root diameter was found in the third root-size class (2.1–5.0 cm).

We obtained the lowest values of average length of root branches in the lower (thinner) root-diameter classes, but on the contrary, the average values of total root branch length were the highest namely in these root-

diameter classes. Similarly, KONŌPKA (1997) observed the highest value of total length of root branches in the first root diameter class (1.0–3.0 cm) in spruce trees growing on well-drained sites. After a re-calculation of his data, we have found out that the relative value of total length of root branches with diameter 1.0–3.0 cm was 57.8% from all root branches together. Similarly, re-calculation of our data resulted in finding that the relative value of total length of root branches with diameter 1.1–3.0 cm represented 65.0% of all root branches together (after having excluded the first root-diameter class) on waterlogged sites and it was 63.5% in spruce trees growing on well-drained sites. This difference is not big, therefore it seems that there are not substantial differences in total relative length of root branches in these root diameter classes between waterlogged and well-drained sites.

KONŌPKA (2005) made a detailed comparison of root system architecture between spruces growing in well-drained and poorly drained sites. He observed big differences in total length of roots between spruces growing in poorly drained and well-drained sites. He reports that the mean value of total root length was 58 m on waterlogged sites and 33 m on well-drained sites (trees with $D_{0.2}$ from 6.5 cm to 49.0 cm). He suggests that the average total length of root branches in the root-diameter class 1.0–2.5 cm was 33.3 m (after a re-calculation it was 63.4% of the value obtained for all root-diameter classes together) in spruce trees growing on well-drained sites and 72.4 m (after a re-calculation it was 71.1% of the value for all root-diameter classes together) in spruces growing on waterlogged sites (selected trees with $D_{0.2}$ from 25.1 cm to 35.0 cm). Similarly, we found out that the mean value of total length of root branches was higher on waterlogged sites (by re-calculation we obtained 185 m for the all root-diameter classes together) in comparison to the well-drained sites (the re-calculation resulted at 134 m for all root-diameter classes together). However, after having excluded the first root-diameter class, we found out that the mean value of total length of root branches obtained for all root-diameter classes together was almost the same on waterlogged (75.6 m after re-calculation) and well-drained sites (76.3 m after re-calculation). Similarly, by re-calculation, we found out that the mean value of total length of root branches in the root-diameter classes 1.1–3.0 cm was 48.5 m (by re-calculation we obtained 63.5% for all root-diameter classes together) in spruce trees growing on well-drained sites and it was 49.3 m (by re-calculation obtained 65.0% for all root diameter classes together) on waterlogged sites.

Based on our results it seems that the total mean length of root branches (all root-diameter classes together) with diameter exceeding 1 cm is almost the same in spruce trees, growing both on waterlogged and well-drained sites. RASTIN and MINTENIG (1992) found out that the horizontal roots of Norway spruce at

distance of 40 cm and especially 80 cm from the centre of the rootstocks were thicker on waterlogged soil types than on brown forest soil (well-drained). The spruce trees growing on brown forest soil also developed shorter and thinner horizontal roots than those growing on waterlogged soil types. Similarly, according to our results, spruce trees growing on well-drained sites form shorter root branches in case of thinner root-diameter classes, but the frequency of these root branches is higher in comparison with spruce trees growing on waterlogged sites. Therefore, there is practically no difference between total length of root branches (with diameter exceeding 1 cm) in spruce trees growing in waterlogged and well-drained sites. This contradiction to the results of KONÓPKA (2005) can be caused by different growth conditions in forests in that we carried out our research. KONÓPKA (2005) pursued his research in two localities with different water regime in the High Tatra Mts. Spruce trees analysed by this author, showed very similar aboveground parameters in both localities. The author reports that the mean values of stem diameter $D_{0.2}$ (measured at 20 cm from the ground level) of the analysed spruce trees showed no differences between the localities. The obtained values were 22.8 cm for well-drained and 21.7 cm for waterlogged sites. We studied spruce trees growing under different local growth conditions: waterlogged sites in the High Tatra Mts and well-drained sites in a locality richer in minerals, situated in Low Tatra Mts. Therefore, the aboveground parameters found for the analysed spruce trees showed differences between the two localities – the mean value of stem diameter $D_{0.2}$ of analysed spruce trees was 40.6 cm on waterlogged sites, but it was 62.5 cm on the well-drained sites. Therefore, the results of KONÓPKA (2005) seem to be more relevant in comparison with our results, our results, however, also provide a certain insight in the architecture of root branches of Norway spruce trees growing on sites with different water regimes.

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Štruktúra koreňových vetiev smreka obyčajného vzhľadom na zamokrenie pôdy

Súhrn

V lokalite Hnilá Blatá (Vysoké Tatry) (podmáčané stanovištia) a lokalite Zemská (Nízke Tatry) (nepodmáčané stanovištia) bola meraná štruktúra koreňových vetiev na vyvrátených smrekoch (*Picea abies* [L.] Karst.). Po vyčistení koreňových koláčov sme merali početnosť, hrúbku a dĺžku jednotlivých koreňových vetiev. Jednotlivé koreňové vetvy boli zatriedňované do dvanástich hrúbkových tried podľa ich hrúbky meranej v polovici dĺžky koreňovej vetvy. Priemerné hodnoty absolútnych početností koreňových vetiev v prvých ôsmich koreňovo-hrúbkových triedach (0,2–12,0 cm) boli vyššie pri smrekoch rastúcich na nepodmáčaných stanovištiach, pričom v prvých štyroch koreňovo-hrúbkových triedach boli tieto hodnoty až viac ako dvojnásobne vyššie (Tabuľka 4). V posledných štyroch koreňovo-hrúbkových triedach (12,1–30,0 cm) sme naopak zistili menšie hodnoty priemerných početností koreňových vetiev pri smrekoch rastúcich na nepodmáčaných stanovištiach (Obrázok 3 a 4). Rozdiely v relatívnych početnostiach koreňových vetiev v jednotlivých koreňovo-hrúbkových triedach medzi týmito dvomi skupinami smrekov neboli až také výrazné. Zistili sme značne vyššie hodnoty priemerných dĺžok koreňových vetiev vo všetkých koreňovo-hrúbkových triedach pri smrekoch rastúcich na podmáčaných stanovištiach v porovnaní s nepodmáčanými stanovišťami. Priemerné hodnoty celkovej dĺžky koreňových vetiev boli dvojnásobne vyššie v prvej koreňovo-hrúbkovej triede a taktiež boli výrazne vyššie v posledných štyroch (12,1–30,0 cm) koreňovo-hrúbkových triedach pri smrekoch rastúcich na podmáčaných stanovištiach (Obrázok 5 a 6).

Na základe našich výsledkov sa zdá, že celková priemerná dĺžka koreňových vetiev (spolu všetky koreňovo-hrúbkové triedy) pri koreňoch s hrúbkou nad 1 cm je pri smrekoch rastúcich na podmáčaných a nepodmáčaných stanovištiach takmer rovnaká. Podľa našich výsledkov korene smrekov rastúcich na nepodmáčaných stanovištiach vytvárajú najmä v tenších koreňovo-hrúbkových triedach kratšie koreňové vetvy, ale ich početnosť je oproti podmáčaným stanovišťam vyššia. Tým sú celkové priemerné dĺžky koreňových vetiev (s hrúbkou nad 1 cm) medzi smrekmi rastúcimi na podmáčaných a nepodmáčaných stanovištiach takmer rovnaké.

Short communication

Light conditions in submountain beech stands in dependence on cutting intensity

Rastislav Janík

Institute of Forest Ecology of the Slovak Academy of Sciences, Štúrova 2, 960 53 Zvolen, Slovak Republic,
E-mail: janik@savzv.sk

Abstract

JANÍK, R. 2009. Light conditions in submountain beech stands in dependence on cutting intensity. *Folia oecol.*, 36: 67–71.

In 2001–2002 we ran a research on light intensity on three individual research plots (RP) at the BEES Kremnické vrchy Mts, representing environment of submountain beech stands. Our study followed with measurements realised by Střelec in year 1990 in the same stands and under the same conditions. For all partial plots, our measurements confirmed the light intensity peaks presence during midday hours. The absolute maxima representing 56 klx were recorded on open plot between 12.00–14.00 h in time of full developed foliage. On the other hand, the lowest values – 0.022 klx were obtained for the former plot with clear cut at 06.00 h, in period of full foliage. In period of full leafing, higher values were observed on the open and control plot, on the other hand, in period without foliage, higher values were recorded on the other plots.

Key words

beech stands, illumination, Kremnické vrchy Mts, light

Introduction

The amount of solar radiation reaching the Earth's surface belongs to key factors governing the existence of life across the whole planet. It is crucially important for the man, plants, animals and for all components of all ecosystems. The presence of light is a necessary condition for assimilation of carbon dioxide by plant leaves. It follows that the light is a very important vegetation factor for ecosystem's performance. This fact has been confirmed by a range of authors treating the issue: MITSCHERLICH (1977, 1978), SUNNER and ROHRING (1980),

LÜPKE (1982), HUSS and STEPHANI (1978), SANIGA (1990), STŘELEČ (1992) and others. The man can – due to its activities, significantly influence this determining factor, equally positive and in negative way. Purpose-oriented human activities in forest management have been primarily aimed at increasing production. This endeavour, however, was not always profitable for the forest, and finally, for the human itself. Consequently, the present situation requires as much as possible understanding the performance of individual components of ecosystems. Only management based on good understanding and thorough analysis of this information can improve mutual profits between the ecosystem components, the man himself included. Our aim was quantitative description of light conditions inside beech stands

in the Kremnické vrchy Mts, followed by analysis for assessment optimum intensity of cutting intervention in relation to the light conditions in the studied site.

The research plots BEES are situated in area of the Kremnické vrchy Mts (48°38' N and 19°04' E) belonging to the West Carpathians Mts. The stands on the plots mostly consist of beech trees, 80–110 years old. The local climate belongs to moderately warm, moderately hilly District B5 with an average annual temperature $t_{1951-1980} -6.8$ °C and an average precipitation total of 778 mm, STŘELEČ (1993). More detailed description of plots can be found in works of SCHIEBER (2006), KELLEROVÁ (2006), BARNA (2004). The soil conditions are described in KUKLA (2002) and ŠIRÁŇ (2003). In year 1989 were the plots subjected to shelterwood cutting with the aim to obtain the required stocking. The result was a series of 5 partial plots comprising also control plot, without intervention. In year 1990 ran the first study phase on light conditions on the individual partial plots (PP), STŘELEČ (1992). In year 2002 launched the second phase, following the methodical approach proposed by PETŘÍK (1968) as well as providing with the measuring points established by STŘELEČ (1992) in the first phase. The principle of the research was in establishment of sufficient number of measuring points (10) on each PP. The measuring points were fixed with sticks with a small horizontal tablet tightened to the top – for placing the photo-cell of the appliance. The tablets were 50 cm above the ground. For all measurements we used identical Luxmeters PU 150 (Metra Blansko) working with a precision of 10%. The measurements on all the plots were synchronised and ran at one-hour intervals, in afternoon reduced to half an hour. Both measurement phases ran under anticyclonal weather situations: on August 27, 2001 at time of full foliage, and on March 12, 2002 at time without foliage.

Results

Maximum value of illumination – 52.0 klx in beech stands before foliage was recorded on the open plot at

12.00 h. For comparison JOHNSON (1954) reports a value of 137.0 klx for the upper boundary of the atmosphere.

The average amount of light reaching this plot was 20.3 klx. On the contrary, the lowest value was obtained on control plot left without intervention – 0.246 klx at 6.00 h. The maximum on this plot was shifted to 13.00 h, and it represented a value somewhat lower than 20.0 klx. From these facts it follows that in period before foliage, the ground below beech crowns is reached by some 40.0% of the light reaching the open plot. In average, this amount is 33.0%. STŘELEČ (1992) reports for control plot an amount representing 52.0% of illumination on the open plot.

Table 1 and Fig 1 demonstrate that the amount of light increases with decreasing stocking density. This fact has also been confirmed by SANIGA (1990). PETŘÍK (1971) reports for non-foliated trees in a beech stand a relative value representing 23–45% of the external light supply. TRANQUILLINI (in MITSCHERLICH, 1971) found for a 70-year-old beech stand a relative value of 51.0 % in February, March and April and in November and December. In contrast, he observed only 5.0% values in July, September and October.

Interesting is situation in illumination values on plot H (former clear-cut). In 1990 represented the illumination maximum for this partial plot almost 70.0 klx, 11 years later, it was only 20.1 klx. This 72.0% decrease was caused by the vigorous understorey, at present high more than 6 m. Similar situation is on plot I, in the past subjected to intensive cutting intervention resulting at a density of 0.3 (Table 1, Fig 1). In case of plot S with 0.5 stocking, the average illumination value was 7.9 klx, representing the highest amount compared to the other plots.

The situation on these plots at time of fully foliated beech trees that means on August 27, 2001 was the following: maximum values were again recorded on the open plot, making 56.0 klx from 12.00 noon to 14.00 h. This almost 10% increase was probably caused by declination of the Earth's axis in relation to the Sun.

Full foliage of saplings growing on the former clear cut plot has a very important influence on amount

Table 1. Average values of Illumination i in a beech stand on forest stands with different cutting

Partial plot	Ho	H	I	S	M	K
		before	foliation	(12. 03. 2002)		
Average values (klx)	20.258	6.656	6.997	7.983	7.881	6.720
		full	foliation	(27. 08. 2001)		
Average values (klx)	24.105	0.563	1.664	1.966	1.591	1.244

Ho, open plot; H, former clear cut; I, former stocking 0.3, in time of research 0.4; S, former stocking 0.5, in time of research 0.62; M, former stocking 0.7, in time of research 0.78; K, control plot, stocking 0.9, in time of research 0.87

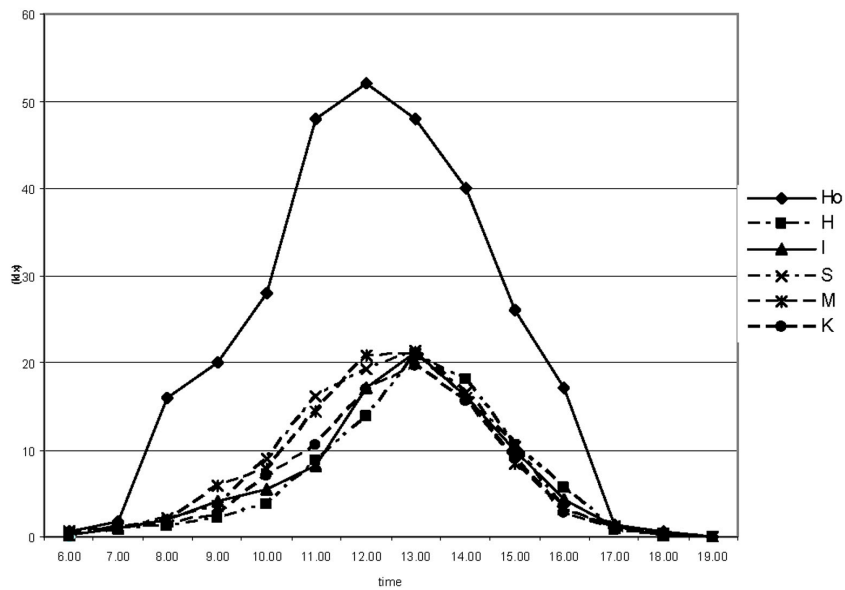


Fig 1. Illumination in a beech stand before foliation (13.03.2002) with different cutting

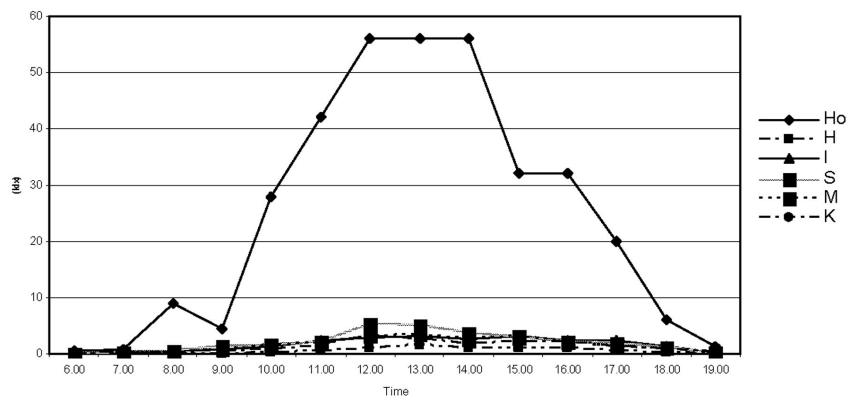


Fig 2. Illumination at the time of full foliation (27.08.2001) with different cutting

of light penetrating this stand. On this plot, the photocells of the measuring appliance were lowest irradiated, with 0.6 klx, representing only 2.3% of light on the open plot. The maximum – 1.4 klx was observed at 13.00 h. The crown canopy on control plot – without intervention, transmitted 5.1% of light on the open plot, 1.2 klx on average. A maximum of 5.9 klx was measured at 14.00 h. The average amount of light penetrating the stand on plot S was the highest – reaching almost 2.0 klx. Comparing our results with the corresponding results obtained in year 1990, we can see that saplings in forest understorey as well as young trees can reduce the light having penetrated through the canopy by even 30.0% at moment of culminating illumination. Similar results also report other authors. SMOLEN (1976) measured a value of 73.8 klx for average illumination intensity in a stand at 16 m above the ground, that me-

ans above tree crowns. The measurement was carried out between 11.00–13.00 h. PETRIK (1986) observed only 5.0% light reaching the ground in a fully foliated 150-year-old beech stand. SANIGA (1990) suggests that relative illumination in spruce-beech forest stands is only 1.7–3.0% when the canopy density is 100–77.5%, which is consistent with our results obtained for control plot without intervention. At canopy density 62.0–40.5% is the relative illumination substantially higher: 15.0–23.3%. TUŽINSKÝ et al. (2003, 2004) declare that the illumination intensity in years 1982–1993 dropped to 9.0% in comparison with the clear-cut, and the relative light supply on the control plot was 2.0–1.5%. The history of illumination intensity values measured on individual partial plots is illustrated in Table 1 and Figs 1, 2.

The measurements of illumination intensity did not confirm linear dependence of light amount penetrating tree crowns on stand stocking. In general, however, it holds that the intensity of natural illumination is directly dependent on the overall intensity of global radiation reaching a horizontal surface.

The highest average illumination values in the studied beech stand were measured, equally in period without leaves and in period of full foliage, on the open plot without forest stand. These values ranged between 20.3 and 24.1 klx, respectively. The absolutely highest value did not exceed 56.0 klx. Among partial plots subjected to shelterwood cutting of various intensity, the highest values of light supply were found on plot S with medium strong intervention and original stocking value of 0.5. At time without leafing (12. 03. 2002) we recorded on this plot a value of 7.9 klx, at time of full foliage (27. 08. 2002) it was on average 1.9 klx. In contrast with the first phase of measuring illumination intensity in year 1990, when the lowest values were obtained on control plot without intervention (STŘELEČ, 1992), in our case were the lowest values recorded on plot H – the former clear cut. At time of complete foliage, the average amount of light penetrating through crowns was only 0.5 klx, in spring it was 6.7 klx. These conditions were determined by the height and canopy density of the succession stand (10-year-old young growth). SANIGA (1990), evaluating height growth of a young beech stand obtained results similar to those of HUSS and STEPHANI (1978). In case of canopy density lower than 90.0% up to 40.0%, beech manifests a considerably plastic ability for adaptation in varying light conditions. In summer period, tree crowns are supplied with light amount by 18.0% higher than in spring. On the other hand, the amount of light transmitted through the tree crowns is higher in spring (10.0–90.0% – compared to summer). The other partial plots have the corresponding illumination values inside the above specified interval.

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Osvetlenie v podhorských bučinách v závislosti od sily ťažbového zásahu

Súhrn

V rokoch 2001–2002 sme v podmienkach podhorských bukových porastov BEES Kremnické vrchy uskutočnili merania intenzity osvetlenia na jednotlivých čiastkových plochách. Merania sa uskutočnili v dvoch obdobiach, a to v čase plného olistenia bukových porastov – 27. 8. 2001 a v dobe bez listov 12. 3. 2002.

Naše merania potvrdili výskyt maximálnych hodnôt intenzity osvetlenia v poludňajších hodinách, na všetkých plochách. Absolútne najvyššie hodnoty osvetlenia boli zaznamenané na voľnej ploche, a to 56,0 klux o 12–14 hod. v čase plného olistenia. Najnižšie hodnoty naopak na ploche bývalej holiny v priemere 0,022 klx o 6.00 hod. ráno. Výrazný vplyv na množstvo dopadajúceho svetla na pôdny povrch tejto plochy mala odrastajúca mladina. Do porastu kontrolnej plochy v čase pred olistením v roku 2002 preniklo 33 % svetla z plochy, kde bol uskutočnený holorub. V roku 1991 to bolo 52 % z hodnôt voľnej plochy. V čase plného olistenia do tých istých porastov preniklo len 2,3 % svetla voľnej plochy.

Vo všeobecnosti vyššie hodnoty osvetlenia boli zaznamenané v čase plného olistenia na voľnej ploche a kontrolnej. V porovnaní so stavom porastov bez olistenia to bolo o 16 %. Na zvyšných plochách sa vyššie hodnoty zaznamenali v čase bez olistenia, v priemere od 18–23 %.

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EIBERLE, K., NIGG, H. 1984. Zur Ermittlung und Beurteilung der Verbissbelastung. *Forstwiss. Cbl.*, 103: 97–110.

Book

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CIBEREJ, J., KOVÁČ, G., BILÁ, A. 1999. Faktory ovplyvňujúce početný stav kamzíka vrchovského v TANAP-e [Factors influencing game populations in chamois (*Rupicapra rupicapra* L.) in the High Tatra National Park]. In KOREŇ, M. (ed.). *Päťdesiat rokov starostlivosti o lesy TANAP-u. Zborník referátov z konferencie*. Poprad: Marmota Press, p. 111–116.

Dissertation

CHROMOVÁ, L. 2002. *Pôdne a vegetačné zmeny lesných spoločenstiev okolia obce Brusno (Veporské vrchy)* [Changes in soils and vegetation of forest communities of the Brusno village (the Veporské Mts.)]. PhD thesis. Bratislava: Comenius University, Faculty of Natural Sciences. 122 p.

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Erratum

The article by Kantor, P., Šach, F., Water balance of young Norway spruce and European beech mountain stands in growing seasons 2005, 2006 (*Folia oecol.*, 35: 6–14), contains a unit-of-measure error.

Page 9, Table 3 caption should read:

I [mm]

Not, I [m].

The publisher apologises for any confusion caused.