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Physiological state of spruce plants (*Picea abies* Karst. L.) in a vessel experiment conditions

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Abstract

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In this paper we are facing the issue of multiple dieback of spruce stands in the region of Horný Spiš. The range of detrimental factors in this area is considerable, and the identification of causal agents of damage to the stands is intricate. We summarise the results of an ecophysiological research pursued in 2004, focussing on evaluation of physiological state of spruce seedlings grown in a vessel experiment consisting of six variants. The primary aim of the experiment was to study the influence of soil properties on health state of the plants. We have evaluated the measured values of parameters of chlorophyll *a* fluorescence, concentrations of assimilatory pigments (chlorophyll *a*, *b*, carotenoids in mg g^{-1} of dry matter), and analysed the influence of selected factors on the studied parameters.

Key words

multiple stress, decline, ecophysiology, seedlings, *Picea abies*

Introduction

The progressive massive dieback of woody plants, primarily spruce, in the regions of Orava, Kysuce, Tatry and Spiš has recently become a well-known reality. Similar damaged stands are in boundary regions of Poland, in the Czech Republic, Germany and Italy. Secondary noxious agents have been turned to primary and commercially important, because they influence physiologically weakened trees. The influence of these factors on Slovak forest increases, in spite of the enormous effort expended to their removal. It is due to the fact that the causes of the worsened health status of the forests have not been identified distinctly yet. Only in general we can assume a whole complex of factors, as eg the global climate change connected with increase in mean air temperature and accessible soil water deficit, long-term impact of airborne pollutants from both local and remote pollution sources, low stability of even-aged, spatially poor structure monocultures of conifers, gradations of biotic noxious agents, primarily wood-destroying fungi and bark beetles.

The direct cause of dieback of forest woody plants is indisputably in their physiological insufficiency and physiological disturbances. From this fact immediately arises a question what is the cause of these physiological disturbances. There is lacking comprehensive understanding of physiology of the dying trees. It is probably a consequence of intricate nature of the issue and also atomisation of special branches reached in the science up to these days (Křístek, 1996).

In frame of the Project APVT "Analyses of causes and proposal of measures against massive spruce dieback in boundary regions of Northern Slovakia" was pursued a multidisciplinary research on spruce stands in regions of Horný Spiš and Kysuce, under the preliminary working title "Unspecific dieback of spruce stands". We studied physiological state of spruce trees (transpiration, assimilatory pigments, chlorophyll fluorescence, mineral nutrition, microclimate characteristics) in different age phases (seedlings, young stand and adult

spruce trees). In this contribution we present the results of analyses of physiological parameters of spruce trees in conditions of a vessel experiment.

Material and methods

The changes in physiology and health state of spruce plants were studied in the vessel experiment established in the Arboretum Borová hora. The aim of the experiment was to prove the hypothesised negative impact of soil environment – long term influenced by spruce litter, on growth and health state of spruce stands. For this purpose, we sampled soil substrate from the active plot (intensively decomposing spruce stand) in the locality Hliníky (Horný Spiš) and also the soil from a beech stand in the same area (without influence of spruce litter) (Table 1) as the standard for comparison. At the same time, we took spruce plants from the active plot in the locality Hliníky in two variants-with symptoms of yellowing needles and relatively green plants without visible symptoms of depigmentation. As the comparison standard we used bare-rooted plants of the same age taken from the tree nursery Smižany (Horný Spiš), evidence number 043448-020 (age 1/2, class 20–25 cm).

The vessel experiment was conducted in the following six variants:

1. Spruce seedlings with symptoms of yellowing needles in soil substrate from the active plot Hliníky (10 exemplars)
2. Spruce seedlings with symptoms of yellowing needles in soil substrate form the beech stand (10 ex)
3. Spruce seedlings relatively green (without visible depigmentation of needles) in soil substrate from the active plot Hliníky (10 ex)
4. Spruce seedlings relatively green (without visible depigmentation of needles) in soil substrate from the beech stand (10 ex)
5. Spruce seedlings from the nursery in soil substrate from the active plot Hliníky (10 ex)
6. Spruce plants from the tree nursery in soil substrate from the beech stand (10 ex).

Analyses of chlorophyll fluorescence

In 2004 we measured parameters of both rapid and slow phase of chlorophyll fluorescence in one-year-old needles (needles from year 2003) on three dates (August 3, August 27, September 21). The needles sampling from these plants was repeated in autumn (needles from year 2003), with the aim to establish concentrations of assimilatory pigments.

Parameters of chlorophyll *a* fluorescence reflect the state and functionality of the photosynthetic apparatus – one of the key-important physiological systems of the tree. The method is based on the high sensitivity of the photosynthetic chain against various stress factors. We focussed our measurements on cardinal parameters of the fluorescence phenomenon. We used transportable measuring equipment – a fluorimeter Plant Efficiency Analyser (PEA, Hansatech Ltd., Kings Lynn, UK). The measurements were made after an adaptation period of 30 minutes at 50% intensity level of saturation light (2,100 μmol m^{-2} s^{-1}), repeated and recorded at 1-sec intervals. Fluorescence is a physical variable without standard measurement units; the fluorescence signal is quantified through relative response in bits by the detector accepted reverse radiation (Kmeť, 1999).

Analysis of assimilatory pigments

Analysis of chlorophylls and carotenoids was made on samples of needles treated with a 80% water solution of acetone and homogenised in a homogeniser. The absorbance values were measured spectrophotometrically (equipment Cintra 6.5, GBS, Australia); the concentrations of photosynthetic pigments were calculated according to adjusted formulae given by Lichtenthaler (1987). The concentration of chlorophylls *a, b, a+b* and carotenoids *x+c* are given per dry mass unit (mg g^{-1}).

Statistical analyses

The results were processed using statistical analysis of variance – Program Sas 6.03 (Sas Institute, 1988). The individual components belonging to the specified factors (treatments) were compared with the residual variance, using F-test. In frame of the variance analysis we explored the influence of three known factors (soil substrate, plant type, measuring date) and of interactions between these factors on the measured values of chlorophyll fluorescence.

The primary aim of the vessel experiment was to study influence of soil properties on physiological state of spruce plants; at the same time, however, it was

Table 1. Soil properties from the free plot, spruce stand (active plot) and beech stand at the locality Hliníky (Spiš region)

	pH/H_2O	pH/KCl	Ca (mg kg^{-1})	Mg (mg kg^{-1})	Na (mg kg^{-1})	K (mg kg^{-1})
Free plot	3.67	2.80	67.05	74.03	24.31	86.39
Spruce stand	3.70	3.00	105.72	72.27	20.84	84.00
Beech stand	3.69	2.96	193.84	86.06	14.66	107.74

necessary to eliminate possible influence of environmental factors that might have had impact on the goal of the experiment. This paper has mainly been focussed on evaluation of analyses of physiological parameters and on assessment of possible causes of differences in vitality of spruce plants between the individual variants of the experiment.

Fig. 1 illustrates the course of selected climate characteristics measured at the hydro-meteorological station Sliač from August 1 to September 30, 2004. Parallel, we also measured physiological parameters. Since spring 2005, there has been installed a micro-climatic station directly in the Arboretum Borová hora, in close proximity to the experimental plot.

Results and discussion

Analyses of assimilatory pigments are in general considered as a good bioindication tool for assessment of health or physiological state of forest woody plants. On the other hand, we need to notice that the quantitative changes in chlorophylls in assimilatory organs are very close connected to the changes in the site environmental factors and also to the changes in frame of the plant ontogenesis. There are many studies focussed on the physiology of coniferous species (analysis of their assimilatory pigments) growing in stress conditions (Polle et al., 1992; Pfanz et al., 1994; Ditmarová et al., 2004, 2006).

Table 2 summarises the mean values of chlorophyll *a, b, a+b*, carotenoids and the ratio of chlorophylls to carotenoids (Chl *a+b*/Car *x+c*) in current needles of spruce plants for the individual variants of the experiment. Based on the assessment and on comparison between the obtained values, it is evident that the concentrations of chlorophylls *a, b* and also carotenoids (comprising carotenes and xanthophylls) in mg g^{-1} of dry matter were higher in all the experiment variants in that we used the soil from the beech stand (out of direct influence of spruce litter). Higher rate between chlorophylls and carotenoids was also found in plants grown in the soil substrate from the beech stand. It was equally true for plants with symptoms of yellowing needles on assimilatory organs, relative green plants (without visible depigmentation of needles) and for plants taken from the tree nursery in Smižany. The highest mean values of concentrations of chlorophylls and carotenoids were found just for the plants taken from the nursery and planted in the soil substrate from the beech stand in the locality Hliníky (Horný Spiš). At the same time, it is necessary to point out the low values of the overall contents of carotenoids and the low values of the ratio between chlorophylls and carotenoids, primarily in variants with the substrate taken from spruce stand – from the viewpoint of photo-protective function of their assimilatory apparatus. Lichtenthaler (1985) suggests that the ratio between chlorophylls and carotenoids (a+b/x+c) in healthy trees (primarily spruces and firs) ranges between 5–8. If the trees are subjected to stress factors, these values can shift to 3–5, while the needles are keeping their green colouring. The yellow-green needles have this value under 3, frequently between 1–2. That means that such trees have increased photo-instability

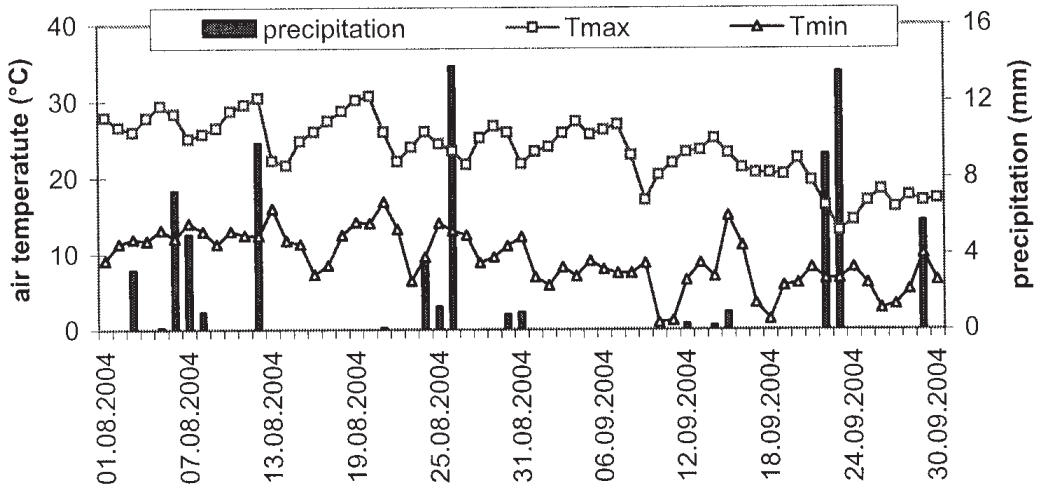

Fig. 1. Course of selected climatic characteristics measured at the hydro-meteorological station Sliač from August 1 to September 30, 2004

of the assimilatory pigments in both green and yellow-green needles. It follows that it is possible to provide with pigment ratios as another biomarker of the damage indicating whether the photosynthetic apparatus is still resisting under influence of stress or it has already been damaged.

It has been recognised that the dynamics of photosynthetic pigments contents in plant assimilatory organs is influenced by a range of environmental factors (natural seasonal changes, differences between sun and shade needles, airborne pollutants, drought, extreme temperatures, mineral nutrition, etc.). This fact explains contradictions not only in concentrations of the individual pigments but also in their mutual ratios (Amundson et al., 1993; Mikkelsen et al., 1996).

The results obtained in study of the initial developmental phase of spruce stands – spruce plants, document the reduced functionality of photosynthetic apparatus in those sample trees whose growth was directly influenced with the substrate from the loaded plot (locality Hliníky).

In Tables 3–6 we give the mean values of the measured parameters of rapid kinetics of chlorophyll *a* fluorescence in the individual variants of experiment. The measurements were made on three dates in year 2004, always on 10 plants for each variant of the experiment on the current needles (the measurements on needles were repeated two times).

We evaluated with attention parameters F_v/F_m (ratio between variable and maximum fluorescence) and *Area*, having the highest description value. The ratio

Table 2. Mean values of assimilatory pigments obtained in individual variants of experiment with spruce seedlings

Variant number	Chl *a*	Chl *b*	Chl *a*+*b*	Car *x*+*c*	Chl *a*+*b*/Car *x*+*c*
Variant 1 (soil from active plot)	1.90	0.64	2.54	0.54	4.70
Variant 2 (soil from beech stand)	2.96	1.02	3.98	0.83	4.80
Variant 3 (soil from active plot)	1.81	0.71	2.52	0.55	4.58
Variant 4 (soil from beech stand)	3.29	1.25	4.54	0.88	5.16
Variant 5 (soil from active plot)	1.72	0.68	2.40	0.57	4.21
Variant 6 (soil from beech stand)	3.88	1.40	5.28	1.04	5.08

Table 3. Mean values of parameters of chlorophyll *a* fluorescence in spruce needles. Measurement date: August 3, 2004

Variant number	Parameters of chlorophyll *a* fluorescence				
	F_0	F_m	F_v	F_v/F_m	*Area*
Variant 1 (soil from active plot)	0.238	0.711	0.474	0.600	0.155
Variant 2 (soil from beech stand)	0.215	0.879	0.664	0.735	0.254
Variant 3 (soil from active plot)	0.227	0.730	0.503	0.605	0.160
Variant 4 (soil from beech stand)	0.228	0.911	0.681	0.747	0.232
Variant 5 (soil from active plot)	0.250	0.901	0.651	0.722	0.235
Variant 6 (soil from beech stand)	0.214	0.912	0.698	0.764	0.218

Table 4. Mean values of parameters of chlorophyll *a* fluorescence in spruce needles. Measurement date: August 27, 2004

Variant number	Parameters of chlorophyll *a* fluorescence				
	F_0	F_m	F_v	F_v/F_m	*Area*
Variant 1 (soil from active plot)	0.210	0.877	0.667	0.746	0.250
Variant 2 (soil from beech stand)	0.217	0.869	0.708	0.729	0.323
Variant 3 (soil from active plot)	0.223	0.973	0.750	0.766	0.300
Variant 4 (soil from beech stand)	0.214	0.993	0.779	0.781	0.338
Variant 5 (soil from active plot)	0.235	1.015	0.780	0.747	0.239
Variant 6 (soil from beech stand)	0.182	0.833	0.652	0.778	0.287

F_v/F_m expresses the maximum quantum yield of the primary photochemical reactions of the photo-system II (PSII). If its value is smaller than 0.725, it indicates beginning of certain physiological disturbances. The parameter *Area* expresses the area above the induction curve between the basic (F_0) and maximum (F_m) fluorescence. It is proportional to the reserve of electrons on the reducing side PSII. The area decreases when the fluency of re-oxidation of the acceptor of electrons in the primary photosynthetic is disturbed.

From evaluation of the values of parameter F_v/F_m from the year 2004, it is evident that this parameter is close copying the trend found for the assimilatory pigments. Only in case of comparison between variant 1 (plants with needle yellowing symptoms planted in soil from the active plot) and variant 2 (plants with symptoms of depigmentation planted in soil from the beech stand) we found that the mean values obtained on August 27 and September 21 were somewhat higher in needles of spruce plants planted in soil from the active plot (loaded with litter and the growth of non-native spruce stands). However, this also may be connected with the actual extent of needle yellowing in the individual spruce plants. In all the other variants of the experiment and measuring dates, higher mean values were found in needles of plants planted in soil taken from the beech stand. The highest mean value of the parameter F_v/F_m (0.795) was obtained in measurements performed in September in variant 4 (fairly green plants planted in soil from beech stand). The lowest mean value of F_v/F_m (0.600), which means very deep below the disturbance threshold, was found in variant 3 on August 3 (plants with needle yellowing symptoms, planted in soil from the active spruce plot).

Practically the same we can say about the course of the parameter *Area*. Only in one case, in September measurements, variants 5 and 6, the lower mean value (0.370) was found in needles of spruce plants growing in soil substrate from beech stand. The highest mean value *Area* (0.436) was also found in variant 4 in September, the lowest in variant 1, measurement performed on August 3, 2004; that means the same as in the preceding parameter.

The main parameter of the rapid phase of kinetics of chlorophyll *a* fluorescence ratio between variable and maximum fluorescence (F_v/F_m) is in general considered as a good marker for the physiological stress in plants, because it reflects the state and functionality of the sensitive photosystem PSII in response to ecological conditions. The values of this ratio in undisturbed plant systems are 0.75–0.85, proportional directly to the use of light and, under normal conditions, to CO_2 fixation. Bolhar-Nordenkampf and Götzl (1992) carried out numerous measurements resulting in obtaining the following threshold values of F_v/F_m in spruce needles: 0.85 – normal, 0.72 – threshold value for occurrence of disturbances, 0.60 – range of severe but reversible disturbances, 0.30 – range of severe damage to the structure, disintegration of membrane systems. In our case, we obtained average F_v/F_m values from 0.600 to 0.795.

The parameter *Area* provides us with supplementing information about capacity of the transport chain of electrons in primary photosynthetic processes, and it is close-correlated with contents of assimilatory pigments. It has been recognised that the values of this parameter are in general higher in those assimilatory organs which have not been subjected to negative influence. Similar results to this vessel experiment we also obtained in an experiment focussed on observation of influence of high temperature and drought on spruce plants (Kmeť, 1998). Also low temperature can induce a decrease in values of *Area*, more remarkable in assimilatory organs with visible damage symptoms. In our experiment with spruce plants in the Arboretum Borová hora we found *Area* values ranging 0.155–0.436. Higher value of this parameter means potentially higher capacity for transport of electrons, and the rate of photosynthesis is in the following dependent on the actual meteorological-climatic situation.

The measured parameters of chlorophyll fluorescence (F_v/F_m, *Area* – parameters with the lowest description value) show significant correlation – mainly with

Table 5. Mean values of parameters of chlorophyll *a* fluorescence in spruce needles. Measurement date: September 21, 2004

Variant number	Parameters of chlorophyll *a* fluorescence				
	F_0	F_m	F_v	F_v/F_m	*Area*
Variant 1 (soil from active plot)	0.219	0.918	0.699	0.742	0.338
Variant 2 (soil from beech stand)	0.211	0.992	0.780	0.717	0.398
Variant 3 (soil from active plot)	0.226	0.861	0.635	0.720	0.243
Variant 4 (soil from beech stand)	0.230	1.125	0.895	0.795	0.436
Variant 5 (soil from active plot)	0.196	0.856	0.660	0.762	0.385
Variant 6 (soil from beech stand)	0.204	0.974	0.770	0.775	0.370

Table 6. Analysis of variance of the measured values of parameters of chlorophyll *a* fluorescence ($p < 0.05$*, $p < 0.01$**, $p < 0.001$**)

Source of variability	Degrees of freedom	Values of F-test					
		F_0	F_m	F_v	F_v/F_m	T_m	*Area*
Soil substrate	1	2.12	2.92	5.97*	8.67**	3.99*	11.97***
Plant type	2	0.71	0.61	0.49	3.00	4.90**	0.30
Soil substrate + plant type	2	1.02	1.34	1.41	1.02	2.32	0.52
Measuring date	2	1.61	2.71	4.94**	6.66**	28.39***	10.85***
Soil substrate + measuring date	2	0.68	2.27	2.18	3.94*	2.64	1.64
Plant type + measuring date	4	0.45	0.64	0.64	0.81	0.42	1.09

the type of soil substrate and with the daily climatic characteristics (measuring date). This finding supports our opinion that the soil properties in this case have an important role in connection with vitality and physiological state of spruce plants, and that more detailed analyses, primarily focussing on physical and chemical properties of these soils, are required in the future.

On the other hand, it is also necessary to pay more attention to the environmental factors (first of all microclimate), because the production activity of forest woody plants and their vitality, derived from this activity, is influenced not only by the state and functionality of their assimilatory apparatus but also with site climate conditions. In this context, the mean values of parameters of the external environment (solar radiation, temperature) are not as important as occurrence of their extreme values. Significant correlation between the parameters of chlorophyll fluorescence and the measuring date reflects the influence of environmental factors on the studied parameters. At present, a transportable meteorological station is situated in close proximity to the vessel experiment, to provide data for a more detailed study of influence of environmental factors on growth and vitality of spruce plants.

Conclusions

The results presented in this paper are, as we have already said in the introduction, a part of a more comprehensive, multidisciplinary research on dieback of spruce stands in the region of Horný Spiš. The research goal was to study the physiological state of spruce trees in all their developmental phases (seedlings, young growth, adult stand), in connection with specified site conditions. The results of physiological parameters obtained at level of the initial developmental phase – plants in the vessel experiment, document lower levels of photosynthetic process in the assimilatory apparatus of seedlings, the growth of which was influenced with properties of soil substrate taken from the loaded (active) locality in Horný Spiš. There is evident some fatigue – exhaustion of the soil under several generations of non-original spruce stands.

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Analýza fyziologického stavu sadeníc smreka (*Picea abies* Karst L.) v podmienkach nádobového pokusu

Súhrn

V príspevku je riešená problematika multifaktoriálneho odumierania smrekových porastov v oblasti Horného Spiša. Štruktúra škodlivých činiteľov v tejto oblasti je veľmi pestrá, čo sťažuje objasňovanie kauzality poškodzovania porastov.

V práci uvádzame výsledky ekofyziologického výskumu uskutočnenom v priebehu roku 2004, v rámci ktorého bol hodnotený fyziologický stav sadeníc smreka pestovaných v nádobovom pokuse v šiestich variantoch, ktorého cieľom bolo predovšetkým sledovať vplyv pôdnych vlastností na ich zdravotný stav. V príspevku sú zhodnotené výsledky merania parametrov fluorescencie chlorofylu *a*, koncentrácie asimilačných pigmentov (chlorofyl *a, b*, karotenoidy v mg g^{-1} sušiny) a analyzovaný vplyv vybraných faktorov na sledované parametre.

Výsledky získané analýzou fyziologických parametrov na úrovni najnižšieho vývojového štádia smreka – sadeníc v rámci nádobového pokusu, svedčia o nižšej úrovni fotosyntetického procesu asimilačného aparátu u tých jedincov, ktorých rast bol priamo ovplyvnený vlastnosťami pôdneho substrátu zo zaťaženej lokality v oblasti Horného Spiša. Je zrejmá istá únava – vyčerpanosť pôdy pod niekoľkými generáciami nepôvodných smrekových porastov.

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Changes in water chemistry after flowing from the spring

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Abstract

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In this work we evaluate changes in chemical composition of water flowing out from its spring (I) and passing through a meadow ecosystem (II–VI). There are the quantitative changes in chemistry of water flowing from sampling sites (I) to (VI): potassium (68.5%), calcium (31%), magnesium (19%), sodium (16%), nitrogen (15%), electric conductivity (24%) and dissolved substances (5.2%) decrease. In opposite, sulphur (25.6%) and pH value (6.6%) increase. We study the influence of this water flow on the given ecosystem and compare the examined water with surface water in streams passing several other sites with similar geological substrate. Values of indicators in the studied samples confirm the nature of surface water. Calcium is the most abundant alkaline nutrient component (7.47 mg l^{-1}), followed by magnesium (3.63 mg l^{-1}) and potassium (1.92 mg l^{-1}). From airborne pollutants, there are present sulphates 31.46 mg l^{-1}, nitrates 10.07 mg l^{-1} and ammonium ions 0.03 mg l^{-1}. The pH value (water reaction) is 6.73, electric conductivity is 131.2 μS cm^{-1}. The amount of dissolved substances is 128.3 mg l^{-1}, from which 50.4% are inorganic and 49.6% are organic. The value of sodium concentration is 6.05 mg l^{-1}. All the indicators, with exception of nitrates ranking the water to the II-nd quality class (clear water), classify it to the first quality class (very clear water). No significant differences were found comparing the examined water with water in other surface streams in the Protected Landscape Area (PLA) Poľana Mts and in the Kremnické vrchy Mts. The changes in water chemistry indicate a favourable influence on the meadow ecosystem – its stability or also the soil cover.

Key words

surface water, changes in water chemistry, meadow ecosystem

Introduction

Chemistry of water flowing out from a spring and passing through a meadow ecosystem is subjected to changes. On the other hand, the water can influence the given ecosystem with dissolved substances (inorganic and organic) and with its chemical and physical properties (pH, electric conductivity). In the sampled water we indicated several acid and alkaline components entering the ecosystem as a result of human activities. Several components of water have an important role as biogenic elements, and their functioning in terms of physiology and biochemistry is key important and necessary for plant nutrition (Bublinec and Mihálik, 1996; Bublinec et al., 1996; Mihálik and Bublinec, 1997). Consequently, the primary importance at water analysis was put on determining nutrient elements and airborne pollutants. Surface waters contain, apart from hydrogen and oxygen, nine principal elements: Ca > C > Cl > Na > Mg > Si > S > K > N – ranked according to their weight concentration (Pačes, 1982). The content of sodium is also evaluated, because higher concentrations of this element can influence the soil and cause its salination, primarily in connection with deficit in calcium and magnesium.

Material and methods

The locality from which we sampled the water is situated southerly from the Protected Landscape Area (PLA) Poľana Mts, and also southerly from the Hriňová village. The material was sampled just at the beginning of growing season (March 1999) from six sampling sites – at the water spring and five other spots following the water flow at 50-meter intervals. The sampling sites

together with the sampled material were labelled in the following way: (I) – spring, (II) – 50 m, (III) – 100 m, (IV) – 150 m, (V) – 200 m and (VI) – 250 m.

The water samples were subjected to physical-chemical and chemical analyses provided accorded to the methods used in the laboratories of the Institute of Forest Ecology of SAS in Zvolen. The pH values and nitrates are determined potentiometrically with an equipment pH/mV-meter and a measuring cell. The measuring cell is a pair of electrodes. The pH values are determined with a glass and a reference calomel electrode; the nitrates with a nitrate ion-selective electrode and a reference calomel electrode. Electric conductivity was determined conductometrically. The measuring equipment consists of a conductometer and a conductometric electrode. Photometric method was used for determination of ammonium ions. Sulphates were determined by titration on the indicator dithizon. Gravimetry (ČSN 83 0530 Standard) was used for obtaining amounts of dissolved substances; from these, the rest after ignition (inorganic portion of dissolved substances) and the loss of ignition (organic portion of dissolved substances) was calculated. Alkaline components were determined using the method of atomic absorption (calcium, magnesium) and atomic emission (sodium, potassium) spectrophotometry (Dubová, 1986, 1987, 1988, 1989, 1990a, b, c, 1992a, b).

The data obtained by physical-chemical and chemical analyses of the water (indicators) were processed statistically. The first information about the individual indicating values in the examined water samples was obtained based on the variation pattern (class, number, histogram) of the arranged data set. Another information was given by numerical characteristics: the characteristics of position (arithmetical mean, median, mode) characterising the average values, characteristics of variability (variance, standard deviation, variation range) expressing the degree of variability with respect to the mean value and the characteristics of skewness and kurtosis characterising the distribution shape, asymmetry (deviation) and concentration (Klein et al., 1999; Microsoft Excel, 2000; Šmelko, 1991).

Results and discussion

In the water sampled at the sampling sites (I)–(VI) we determined contents of nutrient elements (calcium, magnesium, potassium, sulphur and nitrogen) and airborne pollutants (sulphates, nitrates), the results are in Table 1. Other characteristic indicators of surface water quality are – pH value (water reaction), electric conductivity and contents of dissolved substances as well as sodium content (Table 2). Amounts of these indicators found in the studied samples confirm that the nature of the examined water is a surface one.

From alkaline elements was the most abundant calcium (7.47 mg l^{-1}), followed by sodium (6.05 mg l^{-1}), magnesium (3.63 mg l^{-1}) and potassium (1.92 mg l^{-1}). The amounts of sulphur and nitrogen are derived from concentration of sulphates (31.46 mg l^{-1}), nitrates (10.07 mg l^{-1}) and ammonium ions (0.03 mg l^{-1}). Sulphur (sulphate form) reaches higher values (10.5 mg l^{-1}) than nitrogen (2.3 mg l^{-1}), the value of which represents the sum of nitrate and ammonium form.

The mean pH value of water (water reaction) as the measure of its acidity or alkalinity reaches up to 6.73. According to the pH scale used for soil evaluation, this

Table 1. Basic statistical characteristics of nutrient elements and airborne pollutants in the sampled water (UN – unattainable)

Basic statistical characteristics	Ca^{2+}	Mg^{2+}	K^{+}	SO_4^{2-}	NO_3^{-}	NH_4^{+}
	(mg l^{-1})					
Arithmetical mean (AM)	7.47	3.63	1.92	31.46	10.07	0.03
Standard error	0.41	0.15	0.33	1.46	2.03	0.01
Median	7.82	3.76	2.18	32.70	9.84	0.02
Mode	UN	UN	UN	UN	UN	0.02
Standard deviation	1.01	0.36	0.81	3.57	4.98	0.02
Variance	1.02	0.13	0.66	12.72	24.83	0.00
Coefficient of kurtosis	–1.06	–1.91	–2.10	0.85	–1.77	1.43
Coefficient of skewness	–0.63	–0.71	–0.52	–1.23	0.25	1.54
Range	2.66	0.78	1.87	9.41	12.27	0.04
Minimum	6.00	3.18	0.86	25.28	4.68	0.02
Maximum	8.66	3.96	2.73	34.69	16.95	0.06
Number	6	6	6	6	6	6
Coefficient of variation (%)	13.5	9.9	42.2	11.3	49.5	66.7

value is within the neutral range 6.5–7.2. Electric conductivity – the measure of the total content of ions in water reaches a value of 131.2 μS cm^{-1} (13.12 mS m^{-1}). The content of dissolved substances is 128.3 mg l^{-1} and consists of inorganic (50.4%) and organic (49.6%) share. In general, the mean value of dissolved substances contens in surface water is about 120 mg l^{-1} (Pačes, 1982).

Most indicators of the examined water had negative values of kurtosis (K). This negative value (K < 0) means that many values were at the expense of extreme large and extreme small deviations. Negative values of kurtosis were found for ions of calcium, magnesium, potassium, nitrates, electric conductivity, dissolved substances and sodium ions. A positive value of kurtosis (K > 0) indicates lack of values having average deviations from the mean. Such a value was found for pH, ammonium ions and sulphates.

The values of coefficient of skewness (asymmetry) show that most indicators had most frequent negative values (A < 0), and then the result is a right asymmetry (the distribution is leaned to the right side). That means that most values are higher than the arithmetical mean (AM), their deviations from the mean are, however, smaller. This is true for ions of calcium, magnesium, potassium, sulphates, pH values, electric conductivity, dissolved substances and sodium ions. Coefficient of skewness is only positive (A > 0) for nitrates and ammonium ions, in this case, the asymmetry is left one (the distribution is leaned to the left side). That means that most values are smaller than the AM, however, with smaller deviations from the AM, the values on the other side of the distribution are less numerous but they have bigger deviations.

For two nutrients (nitrogen, potassium) we found high variability of the values. The highest value of variation coefficient was found for nitrogen (ammonium 66.7%, nitrate 49.5%). The variability of this element was influenced by low nitrogen concentration (both forms) in the examined water. The low concentration could be the result of higher demands on nitrogen for the ecosystem in spring. The increased variability of potassium values (42%) confirms high mobility of this element in water solutions. Its mobility is conditioned by good solubility of potassium salts in water and easy washout of potassium from plant organisms (Nováček, 1986; Pačes, 1982). Variation coefficients of other indicators were lower, ranging from 3.6% to 13.5%. From all the indicators, the lowest variation coefficient (3.6%) was found for pH (water reaction), which means that the corresponding data set is the most equalised.

We also evaluated quantitative changes in values of the individual indicators of water quality after flowing from the spring (sampling site I). With increasing distance from the spring, the examined water showed decreasing electric conductivity, content of dissolved substances, concentration of nitrates and alkaline elements (calcium, magnesium, potassium, sodium). On the other hand, there were moderately increasing pH values. There were also increased concentration of

Table 2. Basic statistical characteristics of pH values and electric conductivity values, contents of dissolved substances and sodium in the sampled water (UN – unattainable)

Basic statistical characteristics	pH	Electric conductivity (μS cm^{-1})	Dissolved substances	Na^+
			(mg l^{-1})	
Arithmetical mean (AM)	6.73	131.2	128.3	6.05
Standard error	0.10	5.2	6.0	0.22
Median	6.79	135.5	129.0	6.25
Mode	uN	137.6	uN	6.51
Standard deviation	0.24	12.7	14.7	0.53
Variance	0.06	160.9	216.7	0.29
Coefficient of kurtosis (K)	3.81	–0.6	–2.6	–2.12
Coefficient of skewness (A)	–1.78	–0.7	–0.1	–0.59
Range	0.68	34.4	34.0	1.16
Minimum	6.28	111.8	110.0	5.35
Maximum	6.96	146.2	144.0	6.51
Number	6	6	6	6
Coefficient of variation (%)	3.6	9.7	11.5	8.8

sulphates and ammonium ions. The values obtained in the examined water stream were finally compared with the data obtained for surface water streams in the PLA Poľana Mts (Bobrovo, Hučava, Šafranička and Veľká voda) and in the Kremnické vrchy Mts (Kováčovský potok). The mean indicator values are summarised in Tables 3 and 4. Dissolved substances for these two streams were not determined.

Calcium

From the alkaline elements, calcium has the highest concentration in the examined water. The mean concentration is 7.47 mg l^{-1}. Variation coefficient of calcium concentration is 13.5% (Table 1). The values of concentration decrease from maximum (8.66 mg l^{-1}) in the spring (I) up to minimum (6.0 mg l^{-1}) in site (VI). This decrease makes 31%, or 2.66 mg l^{-1} (Fig. 1), which is also the value of variation range. The trend is linear, and it can be expressed by equation $y = a + bx$, with $a = 9.1747$, $b = -0.4866$. Correlation coefficient (r) is 0.9003. The decrease in concentration from (I) to (IV) is 0.61 mg l^{-1}, from (IV) to (VI) it is 2.05 mg l^{-1}. Mean concentration (7.47 mg l^{-1}) in the examined water (Table 3) is most similar to the value obtained for the water stream Bobrovo in the PLA Poľana Mts (7.68 mg l^{-1}). Comparing the examined water with surface water in a mountain stream (Kováčovský potok) in the Kremnické

Table 3. Comparison of nutrient elements contents (arithmetical means) between the examined surface water-flow and water of some other streams

Locality	Ca^{2+}	Mg^{2+}	K^{+}	SO_4^{2-}	NO_3^{-}	NH_4^{+}
			mg l^{-1}			
Examined flow of water	7.47	3.63	1.92	31.46	10.07	0.03
LPA Poľana Mts Bobrovo, stream	7.68	3.59	0.87	31.67	1.32	0.17
LPA Poľana Mts Hučava, stream	8.65	3.80	0.85	23.54	6.19	0.07
LPA Poľana Mts Šafranička, stream	5.58	3.35	0.64	27.36	3.09	0.12
LPA Poľana Mts Veľká voda, stream	5.50	3.11	1.08	25.05	2.61	0.09
Kremnické vrchy Mts Kováčovský potok, stream	14.43	6.48	1.76	36.30	4.48	0.22

Table 4. Comparison of the values of pH, electric conductivity and concentration of sodium (arithmetical means) between the examined surface water-flow and water of some other streams

Locality	pH	Electric conductivity (µS cm^{-1})	Na^{+} (mg l^{-1})
Examined flow of water	6.73	131.2	6.05
LPA Poľana Mts Bobrovo, stream	7.74	135.6	6.14
LPA Poľana Mts Hučava, stream	7.53	113.1	3.74
LPA Poľana Mts Šafranička, stream	7.41	103.3	3.63
LPA Poľana Mts Veľká voda, stream	7.68	112.7	4.43
Kremnické vrchy Mts Kováčovský potok, stream	7.28	165.7	4.08

vrchy Mts (14.4 mg l^{-1}), our values were almost two times lower (Bublinec and Dubová, 1993a).

Magnesium

The mean concentration of this element (3.63 mg l^{-1}) in the examined samples was about a half of that of calcium. The value of variation coefficient is 9.9% (Table 1). The concentration of magnesium decreased from 3.96 in site (I) to 3.18 mg l^{-1} in site (VI). This 19% decrease can also be fitted with a linear equation (a = 4.1460; b = –0.1474). The value of correlation coefficient is 0.7747 (Fig. 1). The mean concentration of magnesium in the examined water (3.63 mg l^{-1}) is the most similar to the value (3.59 mg l^{-1}) obtained for the stream Bobrovo (Table 3). As in case of calcium, the mean concentration of magnesium in the examined water samples is almost two times lower than in the stream Kováčovský potok with a value of 6.48 mg l^{-1}.

Potassium

From alkaline elements, potassium had the lowest content in the examined water (Table 1). The mean concentration of potassium is 1.92 mg l^{-1} and the value of variation coefficient is 42.2% (Table 1). Its concentration decreased from site (I) to (VI), from a value of 2.73 to 0.86 mg l^{-1} (Fig. 1). This decrease is the steepest (68.5%) from the discussed alkaline elements, and it is also linear (a = 3.3753, b = –0.4163). The value of correlation coefficient is 0.9565. The mean concentration of potassium in the examined water (1.92 mg l^{-1}) is most similar to the value obtained for the stream Kováčovský potok (1.76 mg l^{-1}) and 2- to 3-times higher than in surface water streams in area of the PLA Poľana Mts (Table 3).

Sodium

The concentration of sodium in the examined water samples follows immediately after calcium. The mean sodium concentration is 6.05 mg l^{-1}. The variation coefficient of sodium concentration has the second lowest value (8.8%) – subsequent to pH (3.6%), from all the studied indicators (Table 2). It also decreases from site (I) to (VI), with the values of 6.51 to 5.46 mg l^{-1}. Compared to the other alkaline elements (Fig. 1), the decrease of sodium concentration is the lowest (16%). The change is linear (a = 6.8633, b = –0.2314). The value of correlation coefficient is 0.8097. The mean sodium concentration (Table 4) in the examined water (6.05 mg l^{-1}) is the closest to the value found for the stream Bobrovo (6.14 mg l^{-1}). It is higher than the value for Kováčovský potok (4.08 mg l^{-1}) and other streams in the PLA Poľana Mts (3.63 to 4.43 mg l^{-1}).

Sulphates (Sulphur)

The mean value of concentration of sulphates in the examined water is 31.46 mg l^{-1}. The variation coefficient is 11.3% (Table 1). The concentration of sulphates increases from site (I) to (II), from a value of 25.28 to 34.69 mg l^{-1}. This change (9.41 mg l^{-1}) represents the whole variation range. The initial increase was followed by a

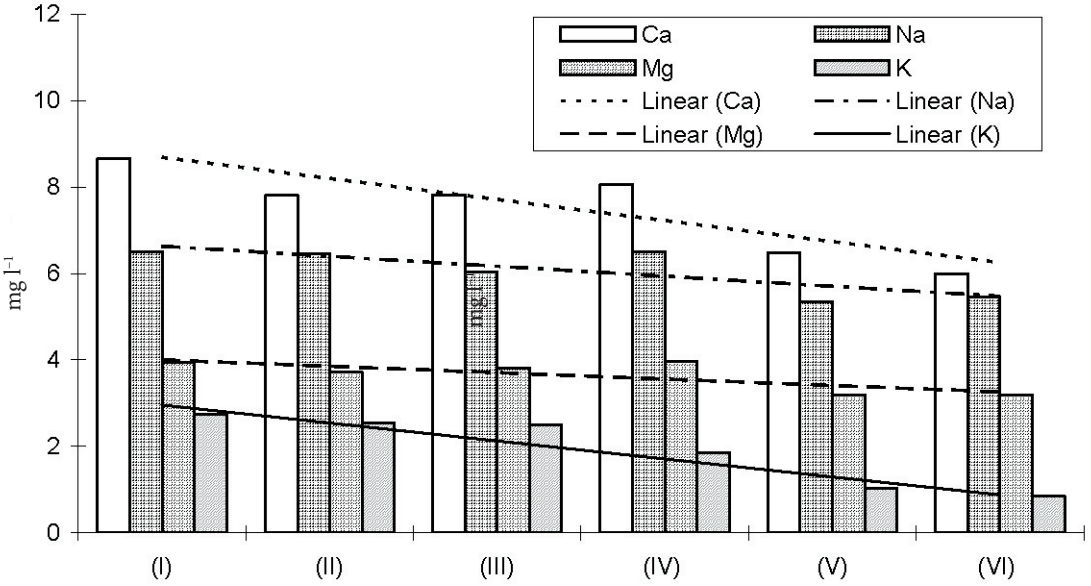

Fig. 1 Changes in contents of alkaline elements, following the water flow from sampling site (I) to (VI)

decrease to 29.39 mg l^{-1} at (IV) and another moderate increase to 34.00 mg l^{-1} in site (VI). These changes (Fig. 2) can be well fitted with a 3-rd degree-polynomial for which the correlation index (r) is 0.9251. However, the sulphate concentration is still evident increasing when the trend is fitted with a linear function (a = 9.4600, b = 0.2971). The value of correlation coefficient is 0.4671. The sulphates concentration values in Fig. 2 are expressed in form of sulphate sulphur (S), for comparison with nitrogen obtained from both its forms. The mean value of concentration of sulphates (Table 3) in the examined water (31.46 mg l^{-1}) is the most similar to the value determined for the stream Bobrovo (31.67 mg l^{-1}). In terms of sulphates content (<80 mg l^{-1}), the examined water can be ranked to the first quality class (very clean water), according to the classification used for assessment of surface water quality (STN 75 2221 Standard).

Nitrates and ammonium ions (Nitrogen)

The concentration of nitrates is very variable. From site (I) to (VI) it was lowered by 2.15 mg l^{-1}. The mean concentration is 10.07 mg l^{-1}. Concentration of ammonium ions is also very variable and low. The minimum value (0.02 mg l^{-1}) is about the threshold of discernibility. The mean concentration is 0.03 mg l^{-1}. The two indicators have high values of variation coefficient (Table 1): 49.5% (nitrates) and 66.7% (ammonium ions). The variation range for nitrates is 4.68–16.95 mg l^{-1}, with the maximum value in sampling site (III). The variation range for ammonium ions is 0.02–0.06 mg l^{-1}, with the maximum value in (IV). The nitrogen content (sum on the two forms) decreases from (I) to (VI) (Fig. 2). The mean concentration of nitrates in the examined waters (10.07 mg l^{-1}) is two or more times higher than the values determined for streams in the PLA Poľana Mts and for the stream Kováčovský potok (Table 3). However, the values of nitrates concentration are not as high as to have an adverse influence on the examined ecosystem. As for the nitrates content (<15 mg l^{-1}), the examined water can be classified as belonging to the second quality class (clean water) according to the surface water assessment (STN 75 2221).

Water reaction (pH)

The mean pH value in the examined water is 6.73. Variation coefficient has the lowest value (3.6%) from all the studied indicators (Table 2). The pH value of water (6.28) in the sampling site (I) is in the moderately acid range (5.5–6.5). Then the value pH moderately increases (Fig. 3) through the site (II) to (III) up to the neutral range (6.5–7.2). The value in site (III) is 6.96, ie by 0.68 lower than in site (I). Then it follows a slight decrease to 6.72 in site (VI). The pH value, despite decrease, maintains in the neutral range. The pH increase over the whole pathway from (I) to (VI) was 0.44. At the linear trend (a = 6.5353, b = 0.0566) the coefficient of correlation is 0.4470. The change in water reaction (pH) can be better fitted with a polynomial of the 3-rd degree. The value of correlation index is 0.9985. The mean pH value (6.73) classifies the water to the neutral range, although pH values of all the compared streams

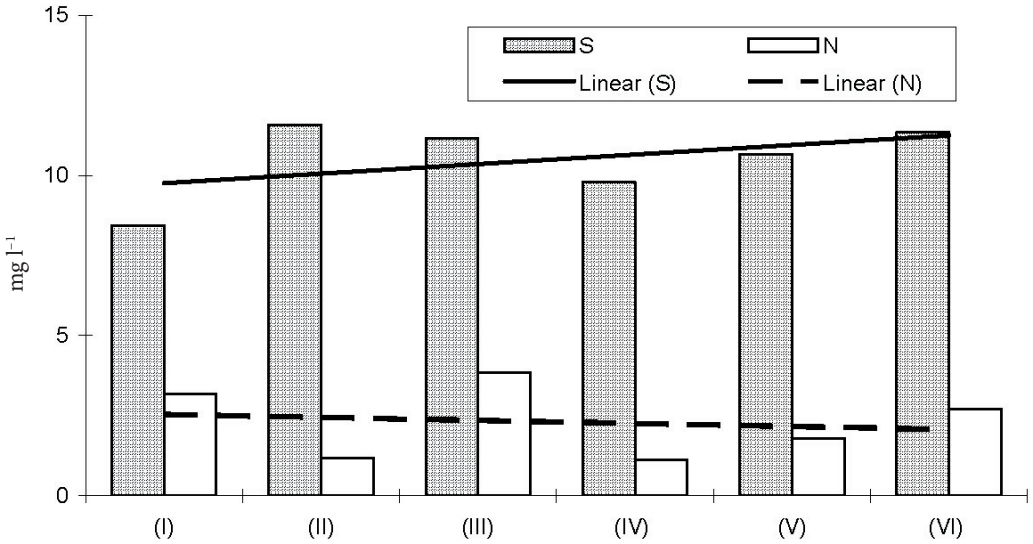

Fig. 2. Changes in contents of sulphur and nitrogen, following the water flow from sampling site (I) to (VI)

are situated in moderate alkaline range (7.2–8.5). The pH value of our examined water is lower almost by 0.55–1.01 pH unit – compared to the other referred streams (Table 4). The pH of our water is the most similar to the pH value (7.28) for the stream Kremnický potok (Dubová, 2001).

Electric conductivity

The mean value of electric conductivity is 131.2 μS cm^{-1}. The coefficient of variation is 9.7% (Table 2). The electric conductivity (EC) moderately decreases from site (I) to (VI) (Fig. 4). This decrease (24%) can be considered as linear (a = 153.94, b = –6.5114, r = 0.9605) and it represents 34.4 μS cm^{-1}. From the maximum value 146.2 μS cm^{-1} in site (I), decreases electric conductivity to a minimum of 111.8 μS cm^{-1} in site (VI). The decrease over the first segment from (I) to (III) is more moderate (12.9 μS cm^{-1}) than over the second one from (III) to (VI) (21.5 μS cm^{-1}). The mean value of electric conductivity of the examined water flow (131.2 μS cm^{-1}) is within the range of the values of all the examined watercourses (Table 4). The most similar value was found for the stream Bobrovo (135.6 μS cm^{-1}).

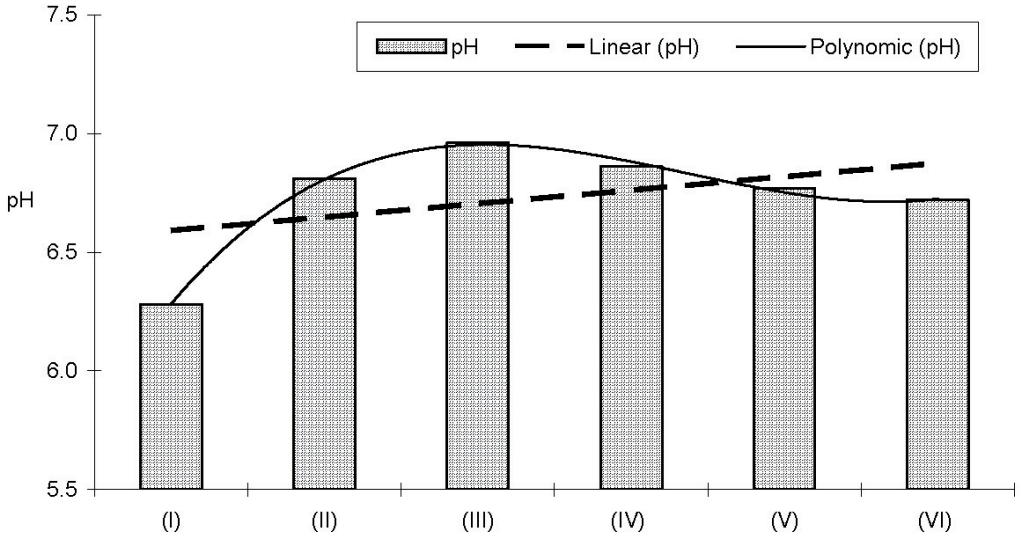

Fig. 3. Changes in pH-values, following the water flow from sampling site (I) to (VI)

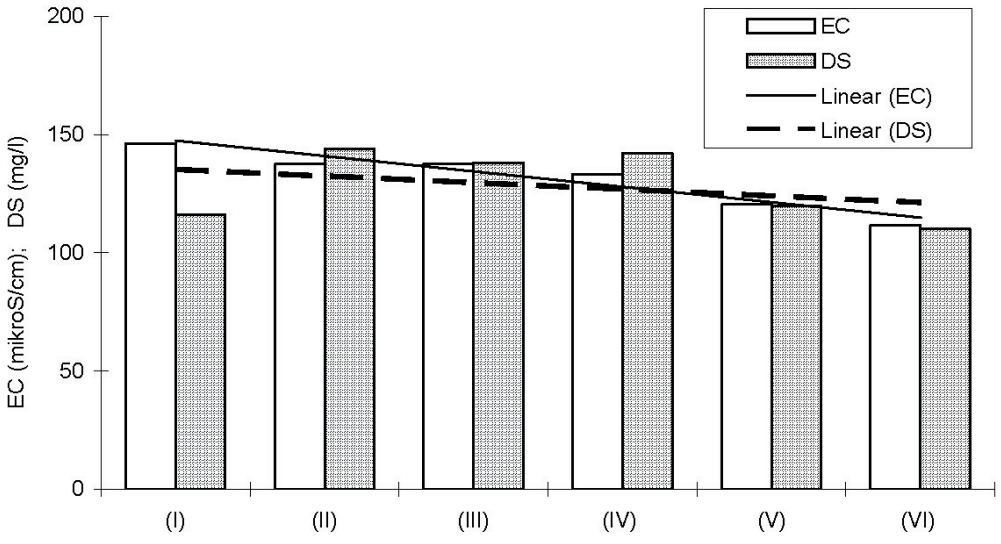

Fig. 4. Changes in electric conductivity (EC) and contents of dissolved substances (DS), following the water flow from sampling site (I) to (VI)

Dissolved substances

The mean value of the dissolved substances (DS) content is 128.3 mg l^{-1}, the coefficient of variation is 11.5% (Table 2). The content of dissolved substances only showed a little decrease from site (I) to (VI); from a value of 116 to 110 mg l^{-1}. In spite of the fact that the value of this parameter was found higher in sites (II)–(IV) reaching above 140 mg l^{-1}, after 250-meters of water flow, at site (VI), the dissolved substances reached almost their initial value (I). After fitting with a linear function (a = 138.13, b = –2.80), we have obtained the correlation coefficient of 0.3558 (Fig. 4). More appropriate fitting is possible with a 3-rd degree polynomial. In this case, the correlation index is 0.9549.

Dissolved substances represent the total of inorganic and organic substances dissolved in water. After the first 50 m along the water flow, from (I) to (II), the content of inorganic substances was lowered (31%), and the content of organic substances was increased by more than two times. We suggest that this conspicuous change in (II) was the result of impact of the meadow ecosystem contacting the water after its flow from the spring. From site (II) up to (VI), the content of inorganic substances increases, the content of organic substances decreases. The total change in inorganic substances from (I) to (VI) is a very small (2 mg l^{-1}) increase. For fitting with the linear trend (a = 56.667, b = 2.2857), the correlation coefficient is 0.4658. On the other hand, the change of inorganic substances content from (I) to (VI) was somewhat lowered (8 mg l^{-1}). At the linear trend (a = 81.467, b = –5.0857) the correlation coefficient is 0.4145.

Conclusions

The aim of this work was to evaluate the changes in chemistry of a water flow crossing a meadow ecosystem, and to assess its influence on the ecosystem. The amounts and trends in nutrient elements (calcium, magnesium, potassium, sulphur and nitrogen), the most important airborne pollutants (sulphates, nitrates, ammonium ions) as well as sodium content suggest about their favourable influence of the meadow ecosystem. There are the quantitative changes in chemistry of water flowing from sampling sites (I) to (VI). Potassium (68.5%), calcium (31%), magnesium (19%), sodium (16%), nitrogen (15%), electric conductivity (24%) and dissolved substances (5.2%) decrease. In opposite, sulphur (25.6%) and pH value (6.6%) increase. Quantitative values of these indicators in the examined samples confirm the nature of surface water. Calcium (7.47 mg l^{-1}) is the most abundant alkaline nutrient, followed by magnesium and potassium (3.63 mg l^{-1} and 1.92 mg l^{-1}, respectively). Concentrations of the most important airborne pollutants are: 31.46 mg l^{-1} sulphates (10.5 mg l^{-1} sulphate sulphur), 10.07 mg l^{-1} nitrates (nitrate nitrogen 2.28 mg l^{-1}) and 0.03 mg l^{-1} ammonium ions (ammonium nitrogen 0.02 mg l^{-1}). The pH value (6.73) is, according to the scale used for soils, in the neutral range. Electric conductivity is 131.2 μS cm^{-1}. The amount of dissolved substances is 128.3 mg l^{-1}, from which 50.4% (64.7 mg l^{-1}) are inorganic and 49.6% (63.7 mg l^{-1}) are organic. Sodium concentration is 6.05 mg l^{-1}. All these values rank the examined water in the first quality class (very clean water), apart from nitrates, ranking it to the second quality class (clean water).

Comparing the examined water with water of several surface streams in the PLA Poľana Mts (Bobrovo, Hučava, Šafranička, Veľká voda) and in the Kremnické vrchy Mts (Kováčovský potok), there are no significant differences. From the obtained results we can see that our values of calcium, magnesium, potassium, sulphates, ammonium ions, electric conductivity and sodium are comparable to the values in the above listed streams. Only the concentration of nitrates is 1.6- to 7.6-times higher. As we have already stated, it is not such high as to have an adverse influence on the examined ecosystem, its stability or, eventually, soil cover. The mean pH value in the examined water (neutral range 6.5–7.2) is lower than were the pH values found for all the compared streams (moderately alkaline, pH 7.2–8.5). The difference between them is 0.6–1.0 pH. The values and changes found in the chemistry of the water flow suggest about its favourable influence on the relevant meadow ecosystem.

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Zmeny v chemizme vody po odtoku z prameňa

Súhrn

V práci hodnotíme zmeny v chemizme vody, ktorá vyteká z prameňa (I) a steká povrchom lúčneho ekosystému (II) až (VI), ako tok vody ovplyvňuje daný ekosystém a vodu porovnávame s povrchovými tokmi na stanovištiach s porovnateľným geologickým podložím. Chemizmus vody sa kvantitatívne mení, pričom klesá draslík (68,5 %), vápnik (31 %), horčík (19 %), sodík (16 %) ako aj dusík (15 %), elektrická vodivosť (24 %) a rozpustené látky (5,2 %). Naopak, zvyšuje sa obsah síry (25,6 %) a hodnota pH (6,6 %). Kvantitatívne hodnoty ukazovateľov v skúmanej vode potvrdzujú charakter povrchovej vody. Alkalické zložky dosahujú 7,47 (Ca^{2+}), 3,63 (Mg^{2+}), 1,92 (K^{+}) a 6,05 (Na^{+}) mg l^{-1}, imisné zložky 31,46 (SO_4^{2-}), 10,07 (NO_3^{-}) a 0,03 (NH_4^{+}) mg l^{-1}. Hodnota pH je 6,73 a elektrická vodivosť 131,2 S cm^{-1}. Rozpustených látok je 128,3 mg l^{-1}, z čoho 50,4 % je podiel anorganických a 49,6 % organických látok. Všetky ukazovatele zaraďujú skúmanú vodu do I. triedy čistoty (veľmi čistá voda), okrem dusičnanov, ktoré sú v II. triede čistoty (čistá voda). Skúmaná voda sa od porovnávaných povrchových tokov v Chránenej krajinnej oblasti Poľana a v Kremnických vrchoch výrazne neodlišuje. Zmeny v chemizme vody hovoria o priaznivom vplyve pretekajúcej vody na lúčny ekosystém, jeho stabilitu, prípadne pôdny pokryv.

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Contents of bioelements and energy equivalent in assimilatory organs of European chestnut (*Castanea sativa* Mill.)

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Abstract

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The work evaluates the content of selected bioelements (Ca, Mg, K, P, Na, Fe, Mn, Zn, Cu) and energy amount in the assimilatory organs of various stand types of European chestnut (*Castanea sativa* Mill.). In assimilatory organs of the European chestnut were determined optimum contents of Ca, Mg, P and Zn. The content of Na, Fe and Cu was found slightly increased and Mn was high. Content of K was lower. Analysis of variance identified statistically very significant differences among all the analysed bioelements across several years and in various stand types. Energy values in leaves of European chestnut varied from 18.193 to 19.837 kJ g^{-1}. There were found high significant differences in energy contents among the stand types.

Key words

macroelements, microelements, energy equivalent, biomass, *Castanea sativa* Mill.

Introduction

Mineral nutrition is one of the main factors influencing growth and development of woody plants, and biomass creation as well. The interest in works oriented on assessment of bioelements content in assimilatory organs of woody plants, arisen in the fiftieth years of the last century, has not been interrupted up to the present. In our conditions was the topic documented with valuable data by Huzulák (1972) and Bublinec (1975, 1994). Supuka et al. (1991) studied bioelements content in woody plants in urban greenery. Study of biomass of woody plants belongs to the basic issues in assessment of their production and functional efficiency. Oszlányi (1988) monitored trends in weight of aboveground biomass development for *Fagus sylvatica* L. in the Small Carpathians Mts. The data about quantification and structure of phytomass in alien woody plants in Slovakia can be found in Tokár (1998, 1999, 2002) and Benčať (1989). Vreštiak (1988, 1991) evaluated leaf biomass in urban greenery in several model Slovak towns.

To reach more precise evaluation of organic matter quality in production-ecological studies, it is necessary to express the biomass size in units of energy (J), instead of dry weight, because equal amounts of different biological materials don't need have equal energy values (Duvigneaud, 1988). Knowledge of the energy values of organic materials is important when we examine the flow of energy through individual trophic levels of ecosystems, because it enables us more to provide objective comparison of production in forest ecosystems with other ecosystems, calculation of solar energy utilization, etc. Lieth (1968), Runge (1973) began with calculations of caloric values of biological materials and assessment of their ecological effectiveness in the seventies of the last century. Porcorossi (1989) elaborated a list of caloric values of biomass in stands of European chestnut in Italy. Núñez et al. (1997), Núñez-regueira et al. (2004) reported caloric values of woody plants (*Sorbus aucuparia* L., *Acer pseudoplatanus* L., *Taxus baccata* L., *Fagus sylvatica* L., *Quercus robur* L., *Castanea sativa* Mill.) that are typical for the temperate zone, forming broadleaved deciduous forests, in the region of Galicia in Spain. Biomass energy values of plants in Slovakia are reported by Oszlányi (1988), Vokoová (1987), Benčať (1994), Kováčová (1997), Kováčová et al. (1996a, b, 1999), Schieber and Kováčová (2003), and Konôpková and Tokár (1997, 2000).

The subject of this work is evaluation of bioelements content and energy values in assimilatory organs of European chestnut (*Castanea sativa* Mill.).

Material and methods

We determined contents of selected macrobiogenic elements (Ca, Mg, K, P), microbiogenic elements (Zn, Fe, Mn, Cu) and Na, from group of beneficial elements. The study material was sampled in stands of European chestnut, on permanent experimental plots – PEP II, PEP IV, PEP VIII and PEP X in Lefantovce, at two-month intervals, during the vegetation periods 1995–1997. The stand composition on the PEP is as follows:

- PEP II – monoculture of *Castanea sativa* Mill. (100%)
- PEP IV – mixed stand of *Castanea sativa* Mill. (80%) and *Quercus petraea* (Mattusch.) Liebl. (20%)
- PEP VIII – mixed stand of *Castanea sativa* Mill. (60%) and *Tilia cordata* Mill. (40%)
- PEP X – mixed stand of *Castanea sativa* Mill. (60%) and *Pinus sylvestris* L. (40%).

PEP Lefantovce belong to the oak forest vegetation tier, management set HS 25 (nutritive beech oak-woods), management set of forest types HSLT 111 (nutritive hornbeam oak-woods), group of forest types SLT Carpineto-Quercetum (CQ), LT 1308 (production vetch hornbeam oak-wood). The site is situated at 230 m above sea level, with mean annual precipitation of 560 mm, and mean annual temperature of 9.7 °C. The soil type is brown soil, the stand age in 1995 was 32 years.

Average leave samples were taken from 3 sample trees (from each PEP), from the central third of shoots (annual shoot) on crown surface, in the lower part of the crown. The samples were dried, homogenised and processed by wet ashing. In the obtained mineralised material, we determined amounts of Ca, Mg, K, Na, Fe, Zn, Mn, Cu by the method of atomic absorption spectrophotometry; P concentration was measured spectrophotometrically. We calculated the average concentrations of individual elements in mg g^{-1} of dry matter from three parallel experimentally obtained values, then the average values of bioelement contents for individual years, and for the whole studied period (Konôpková, 2003).

The samples of plant material, in which we assessed the content of biogenic elements, were also used for assessment of energy values. Energy values (= combustion heat) given in kJ g^{-1} dry matter, ash inclusive, were measured in a water calorimeter, following the method suggested by Jakrlová (1987).

We subjected the obtained results to statistical evaluation by the multi-way analysis of variance and the Tukey's test.

Results and discussion

Content of bioelements in assimilatory organs

The analysis of plant assimilatory organs and assessment of their nutrition state allow us to provide an early diagnostics of damage to stands, before the damage symptoms can be identified visually.

We assessed the nutrition state of European chestnut during the years of observation on the basis of average annual values of the assessed nutrients. We confronted these values with the values reported in literature (Bergmann, 1988; Procházka et al., 1998; Fecenko and Ložek, 2000). We evaluated the level of mineral nutrition on the individual experimental plots on the basis of average values of bioelements contents for the whole three-year period (Tables 1–2).

The content of Ca in assimilatory organs of European chestnut varied from 17.63 to 21.36 mg g^{-1}. Magnesium varied from 3.29 to 4.00 mg g^{-1}. In the course of the experiment was kept the content of K within the range of 9.40 to 11.85 mg g^{-1}. Phosphorus reached the values from 1.97 to 2.59 mg g^{-1}, and Na from 0.071 to 0.076 mg g^{-1}. Fe was present in an amount of 0.128–0.161 mg g^{-1}. The values of Zn varied from 0.044 to 0.050 mg g^{-1}, and Mn from 1.826 to 2.066 mg g^{-1} dry matter. The content of Cu varied from 0.023 to 0.027 mg g^{-1} dry matter. The optimum contents of Ca, Mg, P and Zn found in assimilatory organs of European chestnut were compared with the data published in literature. The content of Na, Fe and Cu was slightly increased, and content of Mn was high. Most of the assessed values of K were lower or low, near the lower limit of optimum.

Table 1. Contents of macroelements in assimilatory organs of *Castanea sativa* Mill. on individual experimental plots

Experimental plot	Ca	Mg	K	P
	(mg g^{-1})± SE			
PEP II.	18.50±0.439 a	4.00±0.246 a	10.60±0.535 ab	2.59±0.163 b
PEP IV.	18.01±0.411 a	3.78±0.202 ab	9.40±0.488 a	2.39±0.138 b
PEP VIII.	21.39±0.459 b	3.56±0.134 ab	11.85±0.691 b	2.48±0.133 b
PEP X.	17.63±0.596 a	3.29±0.185 b	10.63±0.516 ab	1.97±0.141 a

Table 2. Contents of microelements and Na in assimilatory organs of *Castanea sativa* Mill. on individual experimental plots

Experimental plot	Ca	Mg	K	P
	(mg g^{-1})± SE			
PEP II.	18.50±0.439 a	4.00±0.246 a	10.60±0.535 ab	2.59±0.163 b
PEP IV.	18.01±0.411 a	3.78±0.202 ab	9.40±0.488 a	2.39±0.138b
PEP VIII.	21.39±0.459 b	3.56±0.134 ab	11.85±0.691 b	2.48±0.133 b
PEP X.	17.63±0.596 a	3.29±0.185 b	10.63±0.516 ab	1.97±0.141 a

Mean values followed by the same letters (a)–(d) are not significantly different at the 0.01 level of significance (Tukey's multiple range rest).
PEP – permanent experimental plots (for the symbols see Material and methods)

Table 3. Mutual ratio K/Mg

Experimental plot^{-1}	Woody plant	Year of sampling	K/Mg
PEP II.	*Castanea sativa* Mill.	1995	1.53
		1996	2.75
		1997	4.80
		$\bar{x}$	3.03
PEP IV.	*Castanea sativa* Mill.	1995	1.98
		1996	2.77
		1997	3.01
		$\bar{x}$	2.59
PEP IV.	*Quercus petraea* (Mattusch.) Liebl.	1995	2.68
		1996	3.32
		1997	4.62
		$\bar{x}$	3.54
PEP VIII.	*Castanea sativa* Mill.	1995	2.56
		1996	3.65
		1997	4.08
		$\bar{x}$	3.43
PEP VIII.	*Tillia cordata* Mill.	1995	1.89
		1996	3.49
		1997	5.57
		$\bar{x}$	3.65
PEP X.	*Castanea sativa* Mill.	1995	2.41
		1996	3.20
		1997	4.73
		$\bar{x}$	3.44
PEP X.	*Pinus sylvestris* L.	1995	1.83
		1996	2.45
		1997	3.03
		$\bar{x}$	2.44

x – average value for three years period, PEP – permanent experimental plots (for the symbols see Material and methods).

Bergmann (1988) reported that also values of K/Mg < 3 suggest an insufficient storage of K; in 1995, such values were found on all studied PEP, and on PEP II. and PEP IV. (Table 3) also in 1996.

Gallardo et al. (1998) studied contents of bioelements in 25-year old stands of European chestnut in the mountain range Siera de Gata (central part of western Spain). The authors report following amounts of macronutrients in leaves: Ca – 5.0; Mg – 3.0; K – 4.3; P – 1.9; in mg g^{-1} dry matter and micronutrients Fe – 74; Zn – 27; Mn – 919; Cu – 14 and Na – 408; in mg kg^{-1} dry matter. Compared with these results, we have found higher concentrations of bioelements, with exception of Na and Mn in all stand types of European chestnut.

Analysis of variance (ANOVA) showed statistically high significant differences among values of all the assessed elements in the individual years (Tables 4–5).

The results of Tukey's test also confirmed statistically high significant differences among the tested values of Ca, Mg, K, P, and Mn (Tables 1–2) on individual experimental plots. Differences in average values of macro and microelements between individual years and between experimental plots are to a considerable extent caused by meteorological factors as well as by different values of exchangeable soil reaction (pH/KCl). For evaluation of climatic conditions during the studied years, we used the data assembled by the Agrometeorological station of the University of Agriculture (Konôpková, 2003). The average annual temperature was 10.1 °C in 1995; 9.0 °C in 1996 and 9.6 °C in 1997. From the measured values it follows that, concerning the precipitation, the year 1995 was normal (580.4 mm), 1996 was extraordinary wet (680.7 mm), and 1997 was normal (495 mm) again. Exchangeable soil reaction (pH/KCl) reached the following values: PEP II. – 3.96; PEP IV. – 3.81; PEP VIII. – 3.80 and PEP X. – 3.86; indicating strong acid soil reaction.

Works of Santa Regina and Salazar (2005) and Santa Regina et al. (2005) also mention dependence between mineral nutrition and biomass production. The authors found significant differences in amount of hu-

mus cover in dependence on the stand age, and they suggested that the changes in nutrient utilization coefficient might depend on the type of stand. Portela (2000) and Portela and Louzada (2005) studied the relation between nutrient content in health state of *Castanea sativa* Mill., and they observed that calcium reduced the ink disease of chestnut trees (*Phytophthora cambivora* (Petri) Buism., *Ph. Cinnamoni* Rands.). During the study of malignant influence of canker (*Cryphonectria parasitica* (Murr.) Barr.), there were detected significant differences in nutrient concentrations between the healthy stands and the stands affected by the disease.

The average values of energy equivalent of the assimilatory organs of *Castanea sativa* Mill. on the experimental plots in the studied period (1995–1997) ranged from 18.193 kJ g^{-1} to 19.838 kJ g^{-1} (Fig. 1). We compared the obtained results with the values given by Jakrlová (1989).

Interesting is also comparison with dry matter energy values in other wood species reported by Oszlányi (1988): *Pinus sylvestris* L. 20.27 kJ g^{-1}, *Picea excelsa* Link. 19.94 kJ g^{-1}, and *Fagus sylvatica* L. 19.42 kJ g^{-1}. Vooková (1987) found in leaves of *Ligustrum vulgare* L. an energy content of 20.37 kJ g^{-1}. Kováčová (1997), Kováčová et al. (1995, 1996, 1999) studied production and energy equivalent of aboveground phytomass at various development stages in a population of *Carex pilosa* Scop. The authors found the maximum average energy value of biomass in the juvenile population of *Carex pilosa* in June (18.107 J g^{-1}) and minimum one in August (17.884 J g^{-1}).

On the obtained results, we can see that there were not considerable differences between the studied years, unlike among the different types of European chestnut stands. This has also been confirmed by the results of variance analysis. The differences between the repetitions of individual analyses were not statistically significant (Table 6).

The results of Tukey's test showed statistically high significant differences in energy values of assimilatory organs in European chestnut on PEP II. and PEP IV., PEP II. and PEP X., PEP IV. and PEP VIII., PEP IV. and PEP X., PEP VIII. and PEP X.

The obtained results show on an example of different stand types of European chestnut that in case they are not fertilised, the level of mineral nutrition is influenced by stand type (quality of the litterfall) and thinning methods (quantity of litterfall). The appropriateness of a given European chestnut stand type can be assessed based on the content of nutrients and energy values reflecting its phytomass production. The obtained results show that the most suitable type of stand is the mixed stand of European chestnut and small-leaved linden (PEP VIII.).

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Table 4. ANOVA of contents of macroelements in assimilatory organs of *Castanea sativa* Mill.

Source of variation	d.f.	Ca			Mg			K			P		
		Mean square	F-ratio	P level	Mean square	F-ratio	P level	Mean square	F-ratio	P level	Mean square	F-ratio	P level
A: Year	2	26.462	7.772 **	0.001	36.529	112.492 **	0.000	27.928	5.088 **	0.008	13.760	100.215 **	0.000
B: Plot	3	77.291	22.700 **	0.000	2.475	7.623 **	0.000	27.190	4.954 **	0.003	1.969	14.340 **	0.000
C: Repetition	2	0.896	0.263	0.769	0.191	0.590	0.557	1.338	0.244	0.784	0.006	0.042	0.959
Residual	98	3.405			0.325			5.489			0.137		

**significant at P = 0.01

Table 5. ANOVA of contents of microelements and Na in assimilatory organs of *Castanea sativa* Mill.

Source of variation		Na			Fe			Zn			Mn			Cu		
	d.f.	Mean square	F-ratio	P level	Mean square	F-ratio	P level	Mean square	F-ratio	P level	Mean square	F-ratio	P level	Mean square	F-ratio	P level
A: Year	2	0.020	56.968 **	0.000	0.027	11.220 **	0.000	0.007	78.894 **	0.000	1.190	19.043 **	0.000	$8.235.10^{-4}$	14.320 **	0.000
B: Plot	3	$1.768.10^{-4}$	0.505 **	0.680	0.003	1.163 **	0.328	$2.071.10^{-4}$	2.384 **	0.074	0.300	4.810 **	0.004	$8.873.10^{-5}$	1.543	0.208
C: Repetition	2	$1.300.10^{-5}$	0.037	0.964	$1.200.10^{-5}$	0.005	0.995	$7.400.10^{-6}$	0.085	0.919	0.014	0.2150	0.807	$1.837.10^{-5}$	0.319	0.727
Residual	98	$3.503.10^{-4}$		0.002				$8.684.10^{-5}$			0.062			$5.750.10^{-5}$		

**significant at P = 0.01

Table 6. ANOVA – energy equivalent

Source of variation	d.f.	Mean square	F-ratio	P-level
A: Year	2	0.461	1.628	0.2016
B: Plot	3	15.437	54.490**	0.0000
C: Repetition	2	0.193	0.681	0.5086
Residual	98	0.283		

**significant at P = 0.01

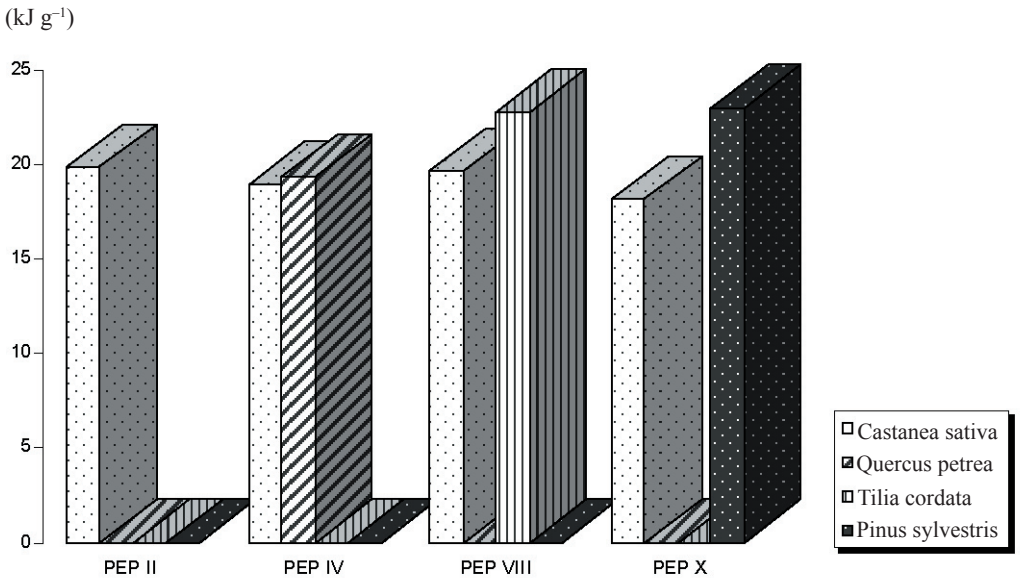

Fig. 1. Average values of energy equivalent on experimental plots

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Obsah bioelementov a energetický ekvivalent v asimilačných orgánoch gaštana jedlého (*Castanea sativa* Mill.)

Súhrn

Minerálna výživa je jedným z hlavných faktorov ovplyvňujúcich rast a vývoj rastlín a v konečnom dôsledku tvorbu rastlinnej hmoty. Primeraný rast drevín a zdravá listová zeleň svedčia o harmonickej výžive. Naopak, disproporcie vo výžive sa prejavujú špecifickými príznakmi, ktoré možno do určitej miery identifikovať podľa vizuálnych symptómov. Analýzami asimilačných orgánov a zistením stavu výživy je však možné signalizovať poškodenie porastov skôr, ako sa tieto symptómy vizuálne prejavia. Preto jedným z cieľov práce bolo zhodnotenie obsahu bioelementov v asimilačných orgánoch porastov gaštana jedlého (*Castanea sativa* Mill.), počas obdobia vegetácie rokov 1995 až 1997.V asimilačných orgánoch gaštana jedlého bol v porovnaní s literárnymi údajmi optimálny obsah Ca, Mg, P a Zn. Obsah Na, Fe a Cu bol mierne zvýšený a obsah Mn vysoký. Väčšina stanovených hodnôt K bola nižšia, alebo blízka spodnej hranici optima. Analýza variancie poukázala na štatisticky vysoko preukazné rozdiely medzi hodnotami všetkých stanovovaných prvkov v asimilačných orgánoch gaštana jedlého, v jednotlivých rokoch a výsledky Tukeyovho testu potvrdili, že obsahy Ca, Mg, K, P a Mn stanovené na jednotlivých experimentálnych plochách sú tiež štatisticky vysoko preukazné. Na vyjadrenie produkcie biomasy sme použili energetický ekvivalent ako kvantitatívne vyšší porovnávací ukazovateľ. Energetické hodnoty asimilačných orgánov porastov *Castanea sativa* Mill. mali hodnoty od 18,193 do 19,838 kJ g^{-1} sušiny.

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

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Abstract

KUKLOVÁ, M., KUKLA, J. 2006. Phytoparameters and content of risk elements in *Dryopteris dilatata* (Hoffm.) A. Gray populations. *Folia oecol.*, 33: 102–107.

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

Key words

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

Introduction

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

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

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

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

segments undamaged and damaged spruces geobiocoenoses on values of phytoparameters of this fern species populations and their connections to content of some risk elements in aboveground biomass.

Material and methods

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

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

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

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

Results and discussion

Character of the phytocoenoses and geobiocoenoses

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

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

Growth parameters of the *Dryopteris dilatata* species

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

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

The total energy content in plants is primarily dependent on amount of energy contained in the separate organic components as carbohydrates (especially saccharides), proteins and lipids (Usui et al., 1994). In case of *Dryopteris dilatata* species were not found significant fluctuations in mean weight and energy content per 1 g of dry matter and the higher values were found in samples taken from damaged spruce stands. The higher

contents of ash in material sampled from control plots were probably connected with unfavourable light conditions. The contents of ash found on damaged plots A and C are, according to Larcher (1988), characteristic for soils very poor in accessible nutrients.

Content of risk elements in the *Dryopteris dilatata* species

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

Table 1. Base characteristics of the studied geobiocoenoses

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

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

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

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

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

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

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

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

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

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

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

Conclusions

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

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

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

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

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

Súhrn

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

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Plant communities on oil-contaminated ruderal sites in the Lopejská basin, district Brezno

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Abstract

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The paper deals with three plant communities with mono-dominance of the species *Carex hirta, Melilotus albus* and *Calamagrostis epigejos,* occurring within a territory affected by activity of an oil-processing plant, situated in the geomorphological unit Lopejská kotlina basin, in district Brezno. We describe their species composition, ecological conditions and taxonomic characteristics in relation to soil contents of non-polar extractable substances (NE) in localities loaded by hazardous waste material – acid oil residue. All the examined plant communities are developed under influence of oil substances in soil. In most cases, concentrations of non-polar extractable substances considerably exceed the maximum allowable limit – 500 mg kg^{-1}. In sites with dominance of *Carex hirt*a species, the concentrations of oil substances range from 5,517.6 to 8,090.1 mg kg^{-1}. The plant community with dominance of *Melilotus albus* species is less influenced by waste materials in case of locality Predajná I. Much higher concentrations were found in locality No. 3 inside the oil processing plant area (2,125.5–3,822.5 mg kg^{-1}). The similar results were obtained for the community with dominance of species *Calamagrostis epigejos*. The highest content of oil substances in soil made 6,992.6 mg kg^{-1}. The NE concentrations in soil are so high, that the species *Carex hirta*, *Melilotus albus* and *Calamagrostis epigejos* can be considered as very resistant to pollution by oil substances.

Keywords

oil waste, soil contamination, ruderal phytocoenoses

Introduction

Operation of the oil refinery Petrochema in Dubová village is connected with production of hazardous waste products and contamination of the territory with oil substances. Consequently, there has arisen a natural interest in evaluation of the spreading of the oil substances in soil as well as qualitative and quantitative evaluation of the composition of the existing phytocoenoses.

The discussed oil-processing plant generates hazardous wastes products – acid oil residue, in process of three-step refining of mineral oils with sulphuric acid. In the past, the waste was disposed inside the plant's area (1954–1964) and on two waste dumps outside (1964–1983).

The problem of hazardous waste disposal is high important and asked to be kept on agenda due to dangerous properties of these materials: ecotoxicity, inflammability, corrosiveness, self-igniting, and primarily their lack of ability to meet the constitutional requirements of the modern legislation for the existing damps of hazardous waste (Act No. 223/2001).

The basic requirement on the current waste dumping is to guarantee a perfect landfill sealing with a suitable construction of the sealing system. This is just the requirement not met with old dumps causing contamination of natural environment (Piatrik, 2000).

The soil substrate influenced with oil substances or with waste containing oil substances provides specific sites for vegetation development. Neither direct impact on, nor direct uptake by plant root systems has been recognised unambiguously. It is, however, undisputable that the oil substances absorbed by the surface of the soil particles reduce partially or totally the distribution

of water and nutrients through the soil capillary system to the plant roots and the other organs. As the result, there are affected all physiological processes and the overall vitality of the individual plants. Consequently, deviations from the normal vitality observed in plants of individual populations growing in the locality can serve as the first diagnostic signal of a contamination.

The changes in species diversity of the populations as well as occurrence of synathropic species and retreat of meadow species give us the high valuable information on the spatial distribution of oil carbohydrates over the studied territory. All the changes are associated with several site conditions (geology, soil conditions, hydrology, and naturally, amount of oil substances in soil and their properties).

In this paper we deal with plant communities occuring in localities polluted with waste products containing oil substances, their diversity, cover and species abundance in stands under influence of the oil processing plant in Dubová village. We also present amounts of non-polar extractives in soils.

Material and methods

We performed a several-year botanic and soil-science-oriented research in the area of the oil processing plant Petrochema Dubová, situated in the village of Nemecká, part Dubová, in district Brezno. The two deposits of waste oil substances in the area of village Predajná (4 km NE of the plant) – Predajná I. and Predajná II. consist of excavated depressions filled with liquid to pasty waste material.

The dump Predajná I. (research locality No. 1) is situated 800 m E of Predajná village, on the SE foothills of the hill Hôrka, at 520 m asl. It was established in 1962–1964 with an area of 10,921 m^2 and a capacity of 100,000 m^3. The using of dump was finished in 1974 (Fig. 1).

The dump Predajná II. (research locality No. 2) is situated 200 m W of the dump Predajná I., 520 m asl. It was established in 1973–1974 with an area of 12,000 m^2 and a capacity of 60,000 m^3. This dump was in function up to 1983 (Fig. 2).

Fig. 1. Waste dump Predajná I.

Fig. 2. Waste dump Predajná II.

Fig. 3. Waste dumps in the oil processing plant Petrochema Dubová
×occurrence of community with dominance of *Carex hirta* species, •occurrence of community with dominance of *Melilotus albus* species, °occurrence of community with dominance of *Calamagrostis epigejos* species

The four dumps inside the plant area (research locality No. 3) were constructed in 1954–55 and they served for disposal of acid residue. To the present, two of them, have already been settled out (landfills B and C), the other two (landfills A and D) are still functioning and they are used as temporary disposals for acid residue before the liquidation in the incineration facilities (Fig. 3).

Since 1993, acid residue, the waste by-product in oil processing has not been put on waste dumps. The entire amount of the produced waste with high sulphur content is burnt together with alkaline oil sludge from the waste water treatment plant (Halajová, 1995).

According to Mazúr and Lukniš (1980), the research localities belong to the Fatransko-tatranská region, unit Horehronské podolie and district Lopejská kotlina basin. The parent rock below the waste dumps situated near Predajná village consists of light-grey Triassic Choč Mts dolomites and Reiflin calcites. The plant is situated on Quaternary floodplain clays and gravel clays of contemporary valley floodplains and floodplain cones. The upper layer is, however, consisting of anthropogene sediments similar to clays and gravels with varying content of clayey and sandy constituents, 0.4–2.5 m in thickness (Petríková, 2003). The territory of the Lopejská kotlina basin belongs to the wet valley sub-district with cold winter of the moderately warm climatic district with an average air temperature in July being 14.5–16 °C and an average annual precipitation of 610–900 mm. The temperature in the vegetation period (April–September) is characterized with an isotherm of 16 °C, representing the mean value for 1901–1950 (Collective, 1991). The study area belongs to the phytogeographical district Slovenské stredohorie Mts (Futák, 1966). The autochthonous vegetation cover consists of oak-hornbeam forests belonging to the alliance Carpinion betuli (Michalko et al., 1986).

The floristic and phytocenological research was carried out in vegetation periods 1998–2000. The study was

focused on synanthropic and grassy-herbal stands. The analysis of stands in field as well as processing of the sampled material was provided on the base of the Zürich-Montpellier school (Braun-Blanquet, 1964). Plots for phytocenological relevés were selected on banks of filled land depressions and in close neighbourhood on dump slopes. The area of each plot was 25 m^2. In case of smaller plots we present their area in the relevant phytocenological tables. The quantitative shares of the species were estimated using the combined seven-point scale for abundance and dominance. The permanence of the species in the phytocoenoses is evaluated by means of scale I.–V. The obtained phytocenological relevés were subjected to phytocenological analysis and synthesis. In this step we used an auxiliary method – numerical classification with the program Twinspan (Hennekens, 1996).

Because it was not possible to assign all the identified synathropic plant communities to the codified ones, we always report the dominant species of the community. The classification in higher coeno-taxa will only be possible based on an further appropriate ecological and phytocenological study of phytocoenoses in similar site conditions. The species occurring in the examined herbaceous stands are listed in tables assorted according to their relevance to higher syntaxonomical units, following Jarolímek et al. (1997), or according to their permanent presence in the communities (community with *Carex hirta*).

The names of vascular plants follow Marhold and Hindák (1998), site ecology description is according to Jurko (1990).

The non-polar extractives (NE) contaminating the soil was determined by infrared spectrophotometry, over the frequency range of 3,150–2,750 cm^{-1}. The method is based on extraction of substances (both polar and non-polar) with an organic solvent – 1,1,2 trifluortrichloretan and the subsequent separation of the polar substances by adsorption on silica gel. The testing samples of soils were prepared according to the standardised procedure stated in the "Methodical instructions for sampling and analysis of ground waters and soils polluted with oily and chlorinated carbohydrates" edited by the Ministry of Environment of SR and the Research Institute of Water Management in Bratislava (Collective, 1995). The soil dry matter was determined with an extra portion of the sampled material after drying to a constant weight at a temperature of 105 °C. The soil samples were taken from a depth of 0–20 cm, in autumn 1999.

Results and discussion

The species diversity of plant communities with dominance of ***Carex hirta*** species (Table 1) is very low. There occur only 14 species, five on average per a relevé. The average plant cover is 50%, which means that the stands have relatively low density and height. The dominant species *Carex hirta* has the highest abundance and cover. The two relevés are mono-dominant phytocoenoses with *Carex hirta* species. Permanence of degree IV. and III. has been recognized for *Tanacetum vulgare*, *Lotus corniculatus* and *Oenothera biennis* agg.

In stands of this community are dominant hemicryptophytes, with only a little admixture of terophytes and geophytes. The community is characterised with the species associated with dry to wet soils. So, there are absent species distinctly xerophilous and hydrophilous. Relevant are species with wider ecological amplitude as for water demands. From the viewpoint of soil ecology, the phytocoenosis is characterised with the species that are easy adapted to conditions on mild acid, neutral and mild by alkaline soils. From the species preferring more acid soils, there only occurs *Agrostis capillaris*, from the ones preferring more alkaline soils, *Medicago lupulina*. As for nitrogen content, there are dominant species preferring medium nitrogen amount in soil. In total, we can say that the community consists of species with wide ecological amplitude, easy adaptable to extreme life conditions. The development optimum is reached in June–July.

The species characteristic for higher taxonomical units according to Jarolímek et al. (1997) are not present in our localities, consequently we only identify the community as a stand with one dominant species. Jarolímek et al. (1997) characterised the community as a monodominant, quite dense, low and poor in species, occurring most frequently in sun-exposed and heated sites. Occurrence of most species is random. Identically called association in Austria was reported by Mucina et al. (1993).

Kontrišová and Kontriš (1999) document an occurrence of this community in area of oil resources in the Záhorská nížina lowland. Pyšek (1981) classifies *Carex hirta* as a resistant species tolerating the soil contamination with oil substances.

We present six phytocoenological relevés for the community with *Carex hirta* in the area of plant Petrochema Dubová. Five of them were taken from the plant, the sixth one, with an area of 25 m^2 from the dump Predajná II. at 0.2 m from the border. The occurrence of *Carex hirta* species we also observed directly on the acid residue outside the each of precipitation water. The NE concentration in soil on such sites reached 6,404.6 mg kg^{-1}. As we can see in Table 1, the measured NE values ranged from 5,517.6 to 8,090.1 mg kg^{-1}. The allowable threshold of NE concentration in soil set by the Standard STN 75 7111 is 500 mg kg^{-1} (Jusko, 1997). After exceeding this limit, it is required to begin with a survey and to seek identification of the source of contamination. It is evident that in all cases

the exceeding was enormous. The lowest NE value of 5,5176 mg kg^{-1} was found at the 0.2 m distance from the southern border of dump A in the plant area. This dump serves for temporary disposal of precipitation water from the waste dumps in Predajná. In this site with an area of 5 m^2 and herb cover of 30% we recorded an almost mono-dominant *Carex hirta* community. Apart from the dominant species, only the *Lotus corniculatus* species with abundance of + was found. The highest measured NE value in soil was 8,090.1 mg kg^{-1}. The plant community growing at a 1 m distance from the western border of dump C (at present extinct) on an area of 5 m^2 consisted of seven species with total cover of 50%. The community with *Carex hirta* species occurring east of the dump A (0.5 m from the border), growing on an area of 14 m^2 in soil containing 6,298 mg kg^{-1} oil substances has a cover of even 100%. The cover 100% was also found for community of species *Lotus corniculatus, Equisetum arvense, Tanacetum vulgare, Trifolium pratense, Leontodom autumnalis and Oenothera biennis* agg. Directly at the bottom of dump C, we recorded a mono-dominant plant community with *Carex hirta* species on an area of 5 m^2 with a cover of 15%. The content of oil substances in soil was 7,027.7 mg kg^{-1}. The last relevé with *Carex hirta* was taken at 5 m from the western border of dump C, on an area of 24 m^2 with herb cover of 60% and NE content in soil making 5,855.4 mg kg^{-1}.

The community with dominance of ***Melilotus albus*** species (Table 2) was in our research localities documented by means of seven phytocenological relevés. The stands are gappy, medium dense to dense, opened, with a cover of 70 to 100%. The community consists of 56 species, 16 on average in a relevé. The

Table 1. Plant community with dominance of *Carex hirta* species

Relevé number	1	2	3	4	5	6	
Relevé working number	13	7	11	12	43	55	
Locality*	3	2	3	3	3	3	
Year	1999	1999	1999	1999	1999	1999	Permanence of species
Month	6	6	6	6	7	7	
Day	8	7	8	8	2	13	
Area (m^2)	24	25	5	5	5	14	
Cover E_1 (%)	60	50	50	15	30	100	
Number of species	7	5	7	1	2	7	
NE concentration (mg kg^{-1})	5,855.4	6,404.6	8,090.1	7,027.7	5,517.6	6,298.0	
Slope (°)	0	0	0	0	10	0	
Aspect	–	–	–	–	N	–	
Carex hirta	3	3	3	2	3	5	V.
Tanacetum vulgare	+	r	r	.	.	+	IV.
Oenothera biennis agg.	r	r	.	.	.	r	III.
Lotus corniculatus	.	.	r	.	+	2	III.
Taraxacum officinale agg.	r	.	r	.	.	.	II.
Melilotus officinalis	.	r	r	.	.	.	II.
Trifolium pratense	r	.	.	.	.	+	II.
Calamagrostis epigejos	2	.	.	.	.	.	I.
Agrostis capillaris	1	.	.	.	.	.	I.
Rubus hirtus	.	+	.	.	.	.	I.
Pastinaca sativa	.	.	r	.	.	.	I.
Medicago lupulina	.	.	r	.	.	.	I.
Leontodon autumnalis	.	.	.	.	.	+	I.
Equisetum arvense	.	.	.	.	.	1	I.

*Locality: 2 – dump Predajná II., 3 – plant area

dominant genus is *Melilotus*, which reaches the highest abundance, cover and permanence. There are two species of the genus in the studied area – *Melilotus albus* and *M. officinalis*. These species reach a height up to 1.5 m. Considerably permanent are also the species *Tanacetum vulgare* and *Lotus corniculatus*. The herbal storey has a two-layered structure. The lower layer consists of species *Trifolium repens, T. pratense, Lotus corniculatus, Taraxacum officinal*e agg., *Medicago lupulina, Leontodon autumnalis, L. hispidus* and *Achillea millefolium*. The upper layer comprises biennial hemicryptophytes with dominance of both *Melilotus* species. From grasses are quite abundant *Agrostis capillaris, Arrhenatherum elatius*, *Poa pratensis* agg. and *Festuca rubra*. The development optimum of the community is reached in June–July.

The community occurring in all the three localities very close to the dumps consists mostly of hemicryptophytes, less terophytes and geophytes. Dominant are species with wide ecological amplitude in terms of water demands, absent are both distinctly xerophilous ones (from the second are only present *Tithymalus cyparissias, Scabiosa ochrolueca*) and hydrophilous. The species occurring in this community prefer mildly acid to mildly alkaline soils. From basiphilous species, there are present *Erysimum odoratum, Festuca rupicola, Medicago lupulina, Potentilla heptaphylla and Scabiosa ochroleuca.* As for the soil nitrogen, there are present species associated with soils with medium nitrogen content. From nitrophobic occur – *Festuca rupicola, Pilosella bauhinii, Potentilla heptaphylla, Pseudolysimachion spicatum, Scabiosa ochroleuca* and *Trifolium montanum.*

Comparing this community with the communities described by Jarolímek et al. (1997), we can identify a considerable species affinity and classify their stands to the class Artemisietea vulgaris Lohmeyer et al. in R. Tx. ex von Rochow 1951, order Onopordetalia acanthii Br.-Bl. et R. Tx. ex Klika et Hadač 1944 and alliance Dauco-Melilotion Görs 1966. The relevés from our research localities are poorer in species and have higher proportion of meadow species, primarily from the classes Molinio-Arrhenatheretea and Festuco-Brometea.

Edificator species of this community is *Melilotus albus*, which is according Hartman (1980) a species resistant against oil substances and prone to excessive growth. Manifestations of gigantism were also recorded in our research localities – an excessive height (1–1.5 m) was mainly reached inside the plant area. The *Melilotus officinalis* species was less abundant in our localities than species *Melilotus albus* and did not reach excessive heights.

The soil contents of non-polar extractives in sites with occurrence of the plant community dominated by *Melilotus albus* species are listed in Table 2. For the dump Predajná I. we present 4 phytocenological relevés, three of them occurring at the same transect at different distances from the northern border of the dump. At the distance of 5 m from the dump border we recorded an NE concentration in soil of 903.3 mg kg^{-1}. The stand on plot with an area of 25 m^2 had a cover of 70% and comprised in total 21 taxa. Dense cover was found in case of *Festuca rupicola* and *Lotus corniculatus* species. The other two sites were situated at distances 20 and 25 m from the dump border on northward oriented slopes with inclination of 30º and 25º with oil substances content in soil being 186.4 and 219.9 mg kg^{-1}. These values do not exceed the allowed limit (500 mg kg^{-1}). The herbal stands on plots, each 4 m^2 in area, have the same cover of 90% and the species number 18 and 23, respectively. In stands on both plots we observed higher cover of some grasses such as *Poa pratensis* agg., *Festuca rubra* and *Arrhenatherum elatius*, which indicates more favourable soil conditions of the site. The community with *Melilotus albus* in the locality Predajná I., we even described in close proximity of the dump southern border. The measured concentration of 2,002.3 mg kg^{-1} was considerably above the stated allowed limit. We only recorded 15 taxa of higher plants on the plot 25 m^2 in area in spite of a 100% total cover. Apart from the dominant species *Meliotus albus*, considerable cover was found also in case of the species *Festuca rubra* and *Agrostis stolonifera*.

All the three concentration values of NE found inside the plant area were considerably higher than the set limit. This was probably also reflected in the fact that the number of identified plant species was lower compared to the locality Predajná I. We found the value of NE concentration in soil of 3,352.3 mg kg^{-1}, herbal cover of 70% and species number 14, on the plot with an area of 28 m^2, situated in close proximity of the western border of dump A. The values determined on the southern border of the same dump on the slope with an inclination of 30º at distance of 4 m from the dump border was following: content of NE soil 3,822.5 mg kg^{-1}, the plant community cover 100% and 13 species on an area of 5 m^2. The last spot of the discussed plant community occurs at the SW border of dump C, has an area of 8 m^2, herbal cover of 90% and 11 plant species. The value of oil substances content in soil at distance of 1 m from the dump border was 2,125.5 mg kg^{-1}.

The plant community with dominance of ***Calamagrostis epigejos*** species (Table 3) comprises 63 species, on average 15 per one relevé. The dominant and stand forming species is *Calamagrostis epigejos*, determining the community physiognomy and forming dense stands with dominance of 4 and height of 1–1.5 m. The stand cover ranges from 80 to 100%. The permanence found for species *Calamagrostis epigejos* and *Tanacetum vulgare* was V., for *Achillea millefolium* and *Hypericum perforatum* IV. and for species *Cirsium arvense, Carex hirta, Oenothera biennis* agg., *Agrostis capillaris* and *Lotus corniculatus* III.

Distinctly dominant species in the community are hemicryptophytes, less abundant are terophytes and other life forms. As for soil moisture content, species with wide ecological amplitude are most characteristic for the community. From xerophilous species are present *Anthyllis vulneraria, Securigera varia, Tithymalus cyparissias, Festuca rupicola, Polygala major, Potentilla heptaphylla, Sanguisorba minor, Stachys recta*, from hydrophytes *Lythrum salicaria* and *Thalictrum flavum*. A mildly acidophilous species is only *Agrostis capillaris.* More abundant are species preferring neutral to alkaline site conditions: *Aquilegia vulgaris, Festuca rupicola, Medicago lupulina, Polygala major, Potentilla heptaphylla, Sanguisorba minor, Stachys recta* and *Thalictrum flavum*. The other species do not show preferences in connection with this factor. As for nitrogen content, there occur species preferring soils with medium nitrogen content. Nitrophobic species are: *Securigera varia, Festuca rupicola, Polygala major, Potentilla heptaphylla* and *Pseudolysimachion spicatum*, nitrophilous species are represented by *Eupatorium cannabinum* and *Urtica dioica*.

Table 2. Plant community with dominance of *Melilotus albus* species

Relevé number	1	2	3	4	5	6	7	
Relevé working number	78	15	16	57	145	146	24	
Locality*	1	3	3	3	1	1	1	
Year	1999	1999	1999	1999	2000	2000	1999	Permanence of species
Month	7	6	6	7	6	6	6	
Day	21	8	8	13	6	6	9	
Area (m^2)	25	28	5	8	4	4	25	
Cover E_1 (%)	100	70	100	90	90	90	70	
Number of species	15	14	13	11	18	23	20	
NE concentration (mg kg^{-1})	2,002.3	3,352.3	3,822.5	2,125.5	186.4	219.9	903.3	
Slope (º)	0	30	30	0	30	25	0	
Aspect	–	N	N	–	N	N	–	
Dauco-Melilotion								
Melilotus albus	4	3	4	5	4	4	4	V.
Tanacetum vulgare	1	r	+	+	+	+	+	V.
Melilotus officinalis	+	.	.	+	.	.	+	III.
Picris hieracioides	+	.	.	.	.	.	.	I.
Artemisietea vulgaris								
Artemisia vulgaris	+	r	.	.	+	.	+	III.
Elytrigia repens	.	+	1	.		+	.	III.
Cirsium arvense	.	.	.	+	+	+	.	III.
Arrhenatherion elatioris								
Carum carvi	.	+	+	.	.	.	.	II.
Arrhenatherum elatius	.	.	.	.	2	2	.	II.
Galium mollugo	.	.	.	.	+	r	.	II.
Pastinaca sativa	.	.	.	.	.	r	.	I.
Cynosurion								
Agrostis capillaris	.	2	3	.	.	.	1	III.
Leontodon autumnalis	.	.	.	1	.	.	.	I.
Scabiosa ochroleuca	.	.	.	.	.	.	r	I.
Arrhenatheretalia								
Lotus corniculatus	.	+	+	+	r	r	2	V.
Trifolium repens	+	1	+	.	.	.	.	III.

Table 2. Continued

Taraxacum officinale agg.	.	.	+	.	.	+	+	III.
Daucus carota	+	.	.	.	.	.	.	I.
Dactylis glomerata	.	.	.	.	.	.	+	I.
Molinio-Arrhenatheretea								
Poa pratensis agg.	+	+	2	.	.	1	.	III.
Leontodon hispidus	.	.	.	.	+	+	1	III.
Festuca rubra	3	.	.	.	1	.	.	II.
Lathyrus pratensis	.	.	.	.	+	r	.	II.
Plantago lanceolata	.	r	.	.	.	.	.	I.
Bromion erecti								
Trifolium medium agg.	.	3	.	.	1	1	.	III.
Lathyrus sylvestris					r	+		II.
Trifolium montanum	.	.	.	.			+	I.
Pilosella bauhinii	.	.	.	.			+	I.
Festuco-Brometea and Brometalia								
Medicago lupulina	.	2	+	.	.	.	1	III.
Plantago media	r	.	.	.	.	.	+	II.
Anthyllis vulneraria	.	+	.	.	.	.	.	I.
Senecio jacobaea	.	.	.	r	.	.	.	I.
Silene nutans	.	.	.	.	r	.	.	I.
Hypericum perforatum	.	.	.	.	r	.	.	I.
Securigera varia	.	.	.	.	.	r	.	I.
Tithymalus cyparissias	.	.	.	.	.	+	.	I.
Festuca rupicola	.	.	.	.	.	.	2	I.
Potentilla heptaphylla	.	.	.	.	.	.	r	I.
Pseudolysimachion spicatum	.	.	.	.	.	.	+	I.
Other								
Petasites sp.	3	.	.	.	.	.	.	I.
Rubus caesius	+	.	.	.	.	.	.	I.
Glechoma hederacea	r	.	.	.	.	.	.	I.
Agrostis stolonifera	2	.	.	+		.	.	II.
Tripleurospermum perforatum	.	1	1	.	.	.	.	II.
Carex hirta	.	.	1	1	.	.	.	II.
Hieracium umbellatum	.	.	.	r	.	.	.	I.
Tussilago farfara	.	.	.	.	+	+	.	II.
Astragalus glycyphyllos	.	.	.	.	+	1	.	II.
Equisetum arvense	.	.	.	.	+	1	.	II.
Linaria vulgaris	.	.	.	.	.	r	.	I.
Rumex conglomeratus	.	.	.	.	.	r	.	I.
Erysimum odoratum	.	.	.	.	.	r	r	II.
Calamagrostis epigejos	.	.	.	.	.	.	r	I.

*Locality: 1 – dump Predajná I., 3 – plant area

The community with dominance of *Calamagrostis epigejos* species represents in the studied area evident transition between two classes – Artemisietea vulgaris and Molionio-Arrhenatheretea. There are just abundant species belonging to the second class, order Arrhenatheretalia. Before the construction of the waste dumps, the studied localities had been covered with oat grass – *Arrhenatherum elatius* (L.). The human activities, construction and operation of waste dumps caused disturbance of vegetation, its synatropisation and ruderalisation.

More abundant are species belonging to the class Festuco-Brometea and order Brometalia. These are the species preferring dry, sun-exposed, heated and frequently calcareous sites – alike our research localities (Predajná I. and Predajná II.): *Aquilegia vulgaris, Hypericum perforatum, Lembotropis nigricans, Polygala major, Potentilla heptaphylla, Sanguisorba minor, Stachys recta* and *Trifolium medium* agg.

A phytocoenosis with dominance of *Calamagrostis epigejos* species growing in the Žiarska kotlina basin was characterised by Kontrišová (1980), similar case from Austria was reported by Mucina et al. (1993). Kontrišová and Kontriš (1999) also described a mesotrophic plant community with dominance of *Calamagrostis epigejos* species, occurring in area of oil resources in the Záhorská nížina lowland. The last community prefers moister sites and forms poor-in-species stands in combination with *Deschampsia caespitose* species.

Hartman (1980) and Pyšek (1981) rank *Calamagrostis epigejos* to resistant species with high tolerance against soil pollution with oil substances.

The stands with *Calamagrostis epigejos* community are documented with seven relevés from research localities No. 1 and 3. For the three plots inside the plant area are typical high NE concentrations in soil. Only 8 taxa were found on the plot with an area of 6 m^2 situated at distance of 0.2 m from the eastern border of dump A, where we found NE value of 6,992.6 mg kg^{-1} in soil. Rather higher dominance (2) was found for *Carex hirta* species. Almost the same number of taxa (7) was found on the plot with an area of 12 m^2, herb cover of 80% and NE concentration of 5,732.3 mg kg^{-1} situated at distance of 3 m from the western border of dump C. Higher cover was recorded for the species *Agrostis capillaris* and *Deschampsia caespitosa*, which we consider as resistant against impact of oil substances. On both plots very rarely occur also meadow species from the classes Molinio-Arrhenatheretea and Festuco-Brometea. At distance of seven m from the north-eastern border of dump C, on the plot with an area of 25 m^2 and herb cover of 100%, we identified 17 taxa of higher plants, several meadow species included, and considerable NE content in soil (6,563.1 mg kg^{-1}). On the waste dump Predajná I., we recorded stands with *Calamagrostis epigejos* community almost adjacent to the northern, eastern and western dump borders. The NE concentrations in soil on this site are much lower compared with values found in the plant area. The allowable limit was only exceeded in one case at distance of 0.2 m from the northern dump border on the plot with an area of 25 m^2, where the content of NE in soil was 2,611.2 mg kg^{-1}, cover reached 80% and even 25 plant taxa were present. At the same distance from the eastern dump border, the measured NE value was 292.6 mg kg^{-1}; consequently, the allowable limit was not exceeded. But on the plot with an area of 25 m^2 and cover of 100% we identified only 8 taxa of higher plants. Site factors and physical regularities controlling the transport of oil substances throught the environment evidently influence the situation. The permeability of the bedrock promotes or reduces the distribution distance of NE from the dump. This fact has finally been confirmed with analyses of soil samples taken from the transect at greater distances from the dump. The soil on two plots at the western dump border did not show increased contamination with oil substances. At distances of 0.2 and 2 m from the dump border was the herb cover of 100% and the contents values of NE were 329 and 169.5 mg kg^{-1}, respectively. On the first plot with an area of 4 m^2, we identified 11 herb species, on the second, with an area of 25 m^2 there were growing 27 species, mostly grasses belonging to the classes Molinio-Arrhenatheretea and Festuco-Brometea. On both plots the higher dominance had *Festuca rubra* species.

Conclusions

All the described phytocoenoses are under influence of oil substances present in soil. In most cases, the concentrations of non-polar extractable substances are considerably exceeding the allowable limit – 500 mg kg^{-1}. The stands of the herb community with dominance of *Carex hirta* species have been developed in a very close proximity to the dumps and disposals of oil acid residue. The first are even occurring directly on the waste material, out of the influence of precipitation water. These stands represent initial phases of a starting secondary succession on man-made translocated soils polluted by oil substances. The herb stands are very poor in species and sparse. The phytocoenoses with dominance of *Melilotus albus* species are medium dense to dense, and they reach a height of 1.5 m. We also recorded these plant communities at greater distances from the waste deposits with more abundant occurrence of some grass species. The stands of the community with dominance of *Calamagrostis epigejos* species occur fairly close to the dumps and disposals. The stands are dense and rather high. Namely in case of Predajná I., the stands with *Melilotus albus* and *Calamagrostis epigejos* are typical with higher presence of meadow species, which

Table 3. Plant community with dominance of *Calamagrostis epigejos* species

Relevé number	1	2	3	4	5	6	7	Permanence of species
Relevé working number	54	14	18	60	64	62	80	
Locality*	3	3	1	3	1	1	1	
Year	1999	1999	1999	1999	1999	2000	1999	
Month	7	6	6	7	7	6	7	
Day	13	8	8	13	15	7	21	
Area (m^2)	6	12	25	25	25	4	25	
Cover E_1 (%)	100	80	80	100	100	100	100	
Number of species	8	7	25	17	8	11	27	
NE concentration (mg kg^{-1})	6,992.6	5,732.3	2,611.8	6,563.1	292.6	329	169.5	
Slope (°)								
Aspect								
Calamagrostis epigejos	5	4	4	4	5	5	5	V.
Onopordetalia acanthii								
Linaria vulgaris	.	.	r	.	.	.	+	II.
Artemisietea vulgaris								
Cirsium arvense	.	1	+	.	.	+	.	III.
Artemisia vulgaris	.	.	r	.	.	.	+	II.
Dauco-Melilotion								
Tanacetum vulgare	.	+	1	1	+	+	+	V.
Oenothera biennis agg.	r	+	2	.	.	.	.	III.
Melilotus albus	r	.	.	.	.	.	.	I.
Picris hieracioides	.	.	.	.	r	.	.	I.
Agropyro- Rumicion crispi								
Carex hirta	2	.	1	.	.	.	+	III.
Potentilla anserina	.	.	r	.	.	.	+	II.
Agrostis stolonifera	.	.	.	+	.	.	1	II.
Lysimachia nummularia	.	.	.	.	.	.	1	I.
Odontites vulgaris	.	.	.	.	.	.	+	I.
Arrhenatherion elatioris								
Campanula patula	.	.	.	+	.	.	r	II.
Knautia arvensis	.	.	.	+	.	.	.	I.
Pastinaca sativa	.	.	.	.	.	.	+	I.
Cynosurion								
Agrostis capillaris	.	2	.	1	.	.	1	III.
Polygala major	.	.	r	.	.	.	.	I.
Jacea phrygia	.	.	.	r	.	.	.	I.
Arrhenatheretalia								
Achillea millefolium	.	.	1	2	1	2	1	IV.
Lotus corniculatus	+	.	.	+	.	r	+	III.
Trifolium repens	+	.	.	+	.	.	.	II.
Taraxacum officinale agg.	.	r	.	.	.	.	.	I.
Daucus carota	.	.	.	+	.	.	.	I.
Leucanthemum vulgare	.	.	.	1	.	.	.	I.
Trifolium pratense	.	.	.	.	.	.	+	I.

Table 3. Continued

Molinio-Arrhenatheretea								
Poa pratensis agg.	+	.	r	.	.	.	.	II.
Leontodon hispidus	.	.	+	.	.	+	.	II.
Festuca rubra	.	.	.	.	.	3	2	II.
Deschampsia caespitosa	.	2	.	.	.	.	.	I.
Phleum pratense	.	.	.	+	.	.	.	I.
Euphrasia rostkoviana	.	.	.	.	.	.	r	I.
Lathyrus pratensis	.	.	.	.	.	.	+	I.
Bromion erecti								
Carlina vulgaris	.	.	r	.	.	.	.	I.
Trifolium medium agg.	.	.	.	+	.	.	.	I.
Pseudolysimachion spicatum	.	.	.	.	+	.	.	I.
Festuco-Brometea a Brometalia								
Hypericum perforatum	.	.	+	1	1	+	+	IV.
Medicago lupulina	r	.	.	.	.	.	+	II.
Tithymalus cyparissias	.	.	r	.	.	.	.	I.
Sanguisorba minor	.	.	+	.	.	.	.	I.
Festuca rupicola	.	.	+	.	.	.	.	I.
Silene nutans	.	.	r	.	.	.	.	I.
Potentilla heptaphylla	.	.	r	.	.	.	.	I.
Pilosella officinarum	.	.	.	1	.	.	.	I.
Arenaria serpyllifolia	.	.	.	.	.	.	+	I.
Securigera varia	.	.	.	.	.	.	+	I.
Anthyllis vulneraria	.	.	.	.	.	.	r	I.
Stachys recta	.	.	.	.	.	.	r	I.
Other								
Aquilegia vulgaris	.	.	+	.	.	.	.	I.
Equisetum arvense	.	.	+	.	.	.	.	I.
Fallopia dumetorum	.	.	r	.	.	.	.	I.
Tussilago farfara	.	.	r	.	.	.	.	I.
Rubus caesius	.	.	r	.	.	.	.	I.
Urtica dioica	.	.	r	.	.	.	.	I.
Eupatorium cannabinum	.	.	.	+	.	.	.	I.
Vicia sepium	.	.	.	.	+	.	.	I.
Armoracia rusticana	.	.	.	.	+	.	.	I.
Lembotropis nigricans	.	.	.	.	.	1	.	I.
Alchemilla xanthochlora	.	.	.	.	.	+	.	I.
Cruciata glabra	.	.	.	.	.	+	.	I.
Fragaria vesca	.	.	.	.	.	.	2	I.
Lythrum salicaria	.	.	.	.	.	.	+	I.
Thalictrum flavum	.	.	.	.	.	.	+	I.

*Locality: 1 – dump Predajná I., 3 – plant area

is probably connected with the former occurrence of phytocoenoses of the alliances Arrhenatherion elatioris, Cynosurion and Bromion erecti in these localities before the construction and operating of waste dumps. Because the contents of NE in soil are very high, we can conclude that the present dominant species *Carex hirta*, *Melilotus albus* and also *Calamagrostis epigejos* are resistant against contamination with oil substances.

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Rastlinné spoločenstvá na ruderálnych stanovištiach ovplyvnených ropnými látkami v Lopejskej kotline v okrese Brezno

Súhrn

V oblasti podniku Petrochema Dubová (Lopejská kotlina, okres Brezno), v okolí skládok gudrónov, sme skúmali tri fytocenózy (spoločenstvo s *Carex hirta*, s *Melilotus albus* a s *Calamagrostis epigejos*), ich výskyt a druhovú, ekologickú a taxonomickú charakteristiku v závislosti od obsahu nepolárnych extrahovateľných látok v pôde. Všetky charakterizované fytocenózy sú ovplyvnené obsahmi ropných látok v pôde. Vo väčšine prípadov koncentrácie nepolárnych extrahovateľnách látok vysoko prekračujú najvyššiu prípustnú koncentráciu – 500 mg kg^{-1}. Porasty spoločenstva s dominanciou *Carex hirta* sa vyvíjajú vo veľmi tesnej blízkosti skládok gudrónov a predstavujú prvé fázy začínajúcej sekundárnej sukcesie na navezených antropogénnych pôdach. Ide o porasty druhovo veľmi chudobné a riedke. Spoločenstvá s dominanciou druhu *Melilotus albus* sú stredne husté až husté a vysoké až 1,5 m. Zaznamenali sme ich aj vo väčšej vzdialenosti od skládok, a to s vyšším zastúpením niektorých druhov tráv. Porasty spoločenstva s dominanciou druhu *Calamagrostis epigejos* sa vyskytujú v pomerne tesnej blízkosti skládok. Ide o porasty dosť husté a pomerne vysoké. Pre spoločenstvá s dominanciou druhov *Melilotus albus* a *Calamagrostis epigejos* je charakteristický vyšší podiel lúčnych druhov, čo pravdepodobne súvisí s výskytom spoločenstiev zväzov Arrhenatherion elatioris, Cynosurion a Bromion erecti na týchto lokalitách pred výstavbou a prevádzkou skládok. Vzhľadom na zistené vysoké koncentrácie NEL v pôde považujeme druhy *Carex hirta, Melilotus albus* i *Calamagrostis epigejos* za druhy odolné voči ropnému znečisteniu.

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Home range sizes and roosting places in capercaillie (*Tetrao urogallus* L.) cocks living solitary in the West Carpathians

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Abstract

Saniga, M. 2006. Home range sizes and roosting places in capercaillie (*Tetrao urogallus* L.) cocks living solitary in the West Carpathians. *Folia oecol.*, 33: 121–128.

From 1988–2005, home range sizes and roosting places in capercaillie cocks leaving solitary were studied in the mountains of central Slovakia (Veľká Fatra Mts., Malá Fatra Mts., Kremnické vrchy Mts., Starohorské vrchy Mts., and Nízke Tatry Mts., West Carpathians, 18°50'–19°10'E; 48°47'–49°19'N). Home range sizes in males living solitary were largest in summer (82 ha) and smallest during the display period (only 34 ha). Capercaillie males roosted during day prevailingly on the ground all year long (maximally in spring – 96%). Most roosting sites were located at the base of the tree trunks underneath the low branches (77%), then near wind-falls or stumps (9%) and rock boulders (5%). Capercaillie males roosted during night almost exclusively on trees. Only when conditions for snow-roosting were good (sufficient amount of powder snow) and temperature dropped below –15 °C, capercaillies also roosted in snow burrows (13% during winter and 3% in autumn).

Key words

capercaillie *Tetrao urogallus*, home range, roosting, Carpathians

Introduction

Capercaillie *Tetrao urogallus* L., 1758 is large ground-nesting grouse species with precocial chicks inhabiting in small isolated populations also a central-European mixed spruce-beech-fir and mountain spruce forest in the West Carpathians (Klaus et al., 1986; Saniga,1996a, b, c). These forests have been undergoing radical changes from a natural regime to a managed system in the course of the twenty century. Modern forestry is one of the most important landscape factors in forest ecosystems today. Especially during the last fifty years, the forestry practice of clear-felling has fragmented the forests into a mosaic of clear-cuts, plantations and remaining islands of old forest.

In recent years, more attention has been directed towards the effects of forest habitat changes on faunal diversity and performance of wildlife populations (e.g., Helle, 1985; Väisanen et al., 1986; Lindén,1981; Storaas et al., 1999). The loss and insularization of forest habitat are accompanied by a loss of forest species diversity. In terms of landscape ecology this large-scale change in forest mosaic is expected to have profound effects on spacing pattern and range use of wildlife species, especially those having home ranges and cruising radii within the critical area interval (Rolstad and Wegge, 1989). Capercaillie belongs to this area-sensitive category, inhabiting old forest most of the year, and having seasonal ranges between 10 and 100 hectares in size (Wegge and Larsen, 1987). Modern forestry modifies capercaillie habitats by fragmenting continuous forest, and by altering the internal structure and tree species composition of forest stands.

In recent few decades, capercaillie populations throughout most of western Europe have declined markedly (e.g., Nováková and Šťastný, 1982; Klaus et al., 1986; Klaus and Bergmann, 1994; Saniga, 1999). A decline in capercaillie populations has also been observed during the last 20–30 years in Fennoscandia and Russia (e.g., Rajala and Lindén,1984; Rolstad and Wegge, 1989).

Most Slovakian data concerning the population dynamics of the capercaillie come from hunting statistics (Bancík, 1969; Ferianc, 1977; Richter, 1983). Only few serious ecological and ethological population studies have been made on this endangered grouse species in the West Carpathians (Saniga,1996a, b, 1999).

This paper documents important structural features of the habitat, home range sizes and roosting places in capercaillie cocks leaving solitary in the mountains of the West Carpathians.

Study area

The field work took place in the mountains of central Slovakia (Veľká Fatra Mts, Malá Fatra Mts, Kremnické vrchy Mts, Starohorské vrchy Mts, and Nízke Tatry Mts, West Carpathians, 18°50'–19°10'E; 48°47'–49°19'N) from 1988–2005.

The topography rises from 600 m asl to 1,530 m asl. The climate is moderately continental with a mean temperature of the warmest month (July) of 14.5 °C and minus 5.5 °C for the coldest (January). Annual mean precipation is 1,000–1,400 mm, and the ground is usually covered with snow from mid-November to late March or April (depending on the see-level and exposure).

In the area under study, mixed forest biocoenoses consisting of the spruce-beech-fir vegetation belt dominate (90%) (*Picea abies* Karsten, 1881, *Abies alba* Miller, 1768, *Fagus sylvatica* L., 1753, *Acer pseudoplatanus* L., 1753). Coniferous forests of the spruce vegetation belt constitute around 10% of the study area (*Picea abies* dominated, sprinkled with *Acer pseudoplatanus*, *Fagus sylvatica*, and *Sorbus aucuparia* L., 1753).

The area is a mosaic of small patches of different groups of forest types (classifications according to Randuška et al., 1986). Fageto-Aceretum, Abieto-Fagetum and Fageto-Abietum cover about 80% of the forested area under study, and Sorbeto-Piceetum with Acereto-Piceetum about 10%.

As for the age-space structure of forest stands, in the spruce-beech-fir vegetation belt, islands of old forests (over 80 years) very different in size (from 5 ha to maximally 50–75 ha) are broken up into a mosaic of clearcuts and plantations of various ages and sizes. In the spruce vegetation belt, unmanaged natural forests around 150–180 years old predominate (80%).

Ground vegetation changes locally depending on the forest type. In the mixed forests (spruce-beech-fir vegetation tier), ferns (*Athyrium filix-femina* Roth, 1799, *Dryopteris* sp.) are often common. In the biocoenoses of the spruce vegetation tier, dominant ground vegetation is Bilberry (*Vaccinium myrtillus* L., 1758), some species of graminoids (*Deschampsia flexuosa* Drejer, 1852, *Calamagrostis* sp.) and also ferns (*Dryopteris dilatata* Christens, 1905).

Potential capercaillie egg and chick predators are corvid birds, particularly Jay *Garrulus glandarius* (L., 1758) and raven *Corvus corax* L., 1758, sparrowhawk *Accipiter nisus* (L., 1758), goshawk *Accipiter gentilis* (L., 1758), golden eagle *Aquila chrysaetos* (L., 1758), ural owl *Strix uralensis* Pallas, 1771, and tawny owl *Strix aluco* L., 1758. Among mammals there are red fox *Vulpes vulpes* L., 1758, pine marten *Martes martes* (L., 1758), beech marten *Martes foina* (Erxleben, 1777), small mustelids (*Mustela erminea* L., 1758, *Mustela nivalis* L., 1766), wild boar *Sus scrofa* L., 1758, brown bear *Ursus arctos* L., 1758, and lynx *Lynx lynx* (L., 1758).

According to the latest census work, the spring density of capercaillie is 0.3–0.7 males per km^2, roughly corresponding to 1/3 of female density (Saniga, 1999).

Material and methods

Home ranges of six capercaillie solitary living cocks were studied in 1988–2005 during spring (March–May), summer (June–September), autumn (October–November), and winter (December–February). Three males were studied six years and three seven years. I defined a solitary living cock as a male which lived and displayed alone and neighbouring cock lived minimally in 5 km distance. Home ranges were determined especially by searching for birds. Indirect evidence of capercaillie cocks occurrence and activity was also collected (tracks in the snow and sand, caecal droppings, shed feathers, scraps of left-over food, such as broken twigs, spilled needles and absence of buds on seedlings). These data helped to guide me to leks, roosting and feeding places (trees), and eventually, they made clear the seasonal distribution of capercaillie cocks in the forest biocoenoses of the study area.

Because ground activities take place near to feeding and roosting trees, home ranges can be mapped by locating feeding and roosting trees (activity trees). An activity tree was a tree with a minimum of five droppings beneath it. A feeding tree was an activity tree beneath which I also found spilled needles with beak marks. I consider the number of activity trees to be a good measure of how much an area was used by capercaillie, because in cases for which data were available the number of activity trees was positively corelated with the number of birds present and the time of stay. Intestinal faeces excreted regularly every 12–13 min. (Klaus et al., 1986), and caecal droppings excreted once or twice a day (Moss and Hanssen, 1980), accumulate beneath capercaillie feeding trees (identified by droppings and spilled needles) and roosting trees (droppings only) especially during winter. To ensure that the bird has stayed at the spot for some time, only heaps with three or

more droppings were included. In early spring (March-early May), conspicuous yellowish-brown faecal remnants in the melting snow show trees used during the preceding 5–6 months (Gjerde, 1991a).

Home ranges of six capercaillie cocks living solitary were investigated. In all, 1,020 roosting places (484 in spring, 140 in summer, 190 in autumn, and 206 in winter) and 584 daytime locations (229 in spring, 75 in summer, 178 in autumn, and 102 in winter) were registered. Daytime locations were used to estimate sizes of home ranges and other measures of spacing. I estimated the sizes of home ranges according to a modified version of Harvey and Barbour's (1965) „modified minimum area method". The distance between the two widest-spaced daytime positions was measured and divided in half. A line was then drawn clockwise among all successive outermost points that were spaced shorter than this half maximum distance. Positions farther away than the maximum distance were defined as excursions and were not included in the estimate of home range size.

Because home range size is a function of sample size and increased to an asymptote with increasing number of locations, the sizes of home ranges could be estimated reliably only for males that were located a minimum of 25 times. Values reported are means ± SE.

Results and discussion

Home range size in capercaillie males living solitary

Home range sizes in males living solitary were largest in summer (82 ha) and smallest during the display period (only 34 ha). Birds living in highly fragmented areas (4) have larger home ranges than those living in continuous nature forests in (Table 1). All males lived close to their home leks (showed strong affinity for their lek areas) during spring, winter and autumn seasons (Fig.1). Males belonging to highly fragmented lek areas stayed farther away from the lek in winter, spring and autumn than males with leks situated in less fragmented areas. Gjerde and Wegge (1989) found at Varaldskogen in south-east Norway that in highly fragmented areas, home ranges of capercaillie males were always large. In less fragmented areas, both large and small home ranges existed, indicating that factors other than habitat fragmentation also affected home range size. Among these factors, different quality of old forest habitats and local social situations may be of particular importance. According to Wegge and Larsen (1987), capercaillie males younger than 3 years have larger home range sizes than older than 3 years during the breeding season. These authors found home range sizes for 1 and 2 year old males 126 ha, for 3 year old cocks 61 ha, and for 4 year olds and older 21 ha during the breeding season, which corresponds with the results of this study. Young males have the largest home ranges during winter, as during spring (Wegge and Larsen, 1987) and summer (Rolstad et al., 1988). This probably reflects a general tendency of habitat exploration among young individuals. In south-east Norway, winter home range sizes of subadults was 98.4 ha and adult males 63.5 ha (Gjerde and Wegge, 1989), which are very similar values of my study. Rolstad and Wegge (1987) found that among adult capercaillies (>2 years), 77% made distinct movements from spring territories to summer home ranges at Varaldskogen in south-east Norway. A distinct movement was defined as a directional movement of 1 km or more within a 5 day period. Of these capercaillies, 21 had no overlap between spring and summer ranges, which was not observed among capercaillies living solitary investigated in the West Carpathians (Fig. 1). Rolstad (1989) and Gjerde and Wegge (1989) found that whereas spring and late winter home ranges usually overlapped, summer and autumn ranges were located further away from the lek with little or no overlap. The data from the Russian leks confirmed that capercaillie males undertook distinct seasonal movements from pine-dominated winter/spring ranges to rich spruce-dominated summer ranges (Hjeljord et al., 2000).

Thus, like tundra and steppe inhabiting grouse genera, forest-dwelling grouse may undertake well-defined long-distance migrations in certain parts of their distribution range, but may be partially migratory with short-distance movements or almost sedentary in other

Table 1. Size of home ranges in hectares (N – number of home ranges, HR – range, M – mean, SE – standard error in capercaillie cocks living solitary in the West Carpathians, Slovakia (1988–2005)

	Nighttime locations				Daytime locations			
Season	N	HR	M	SE	N	HR	M	SE
Spring	6	3–22	13	±2	0	12–58	34	±6
Summer	3	14–34	26	±5	4	37–112	82	±15
Autumn	4	11–30	18	±3	6	30–92	67	±12
Winter	4	13–29	20	±3	4	28–102	62	±11

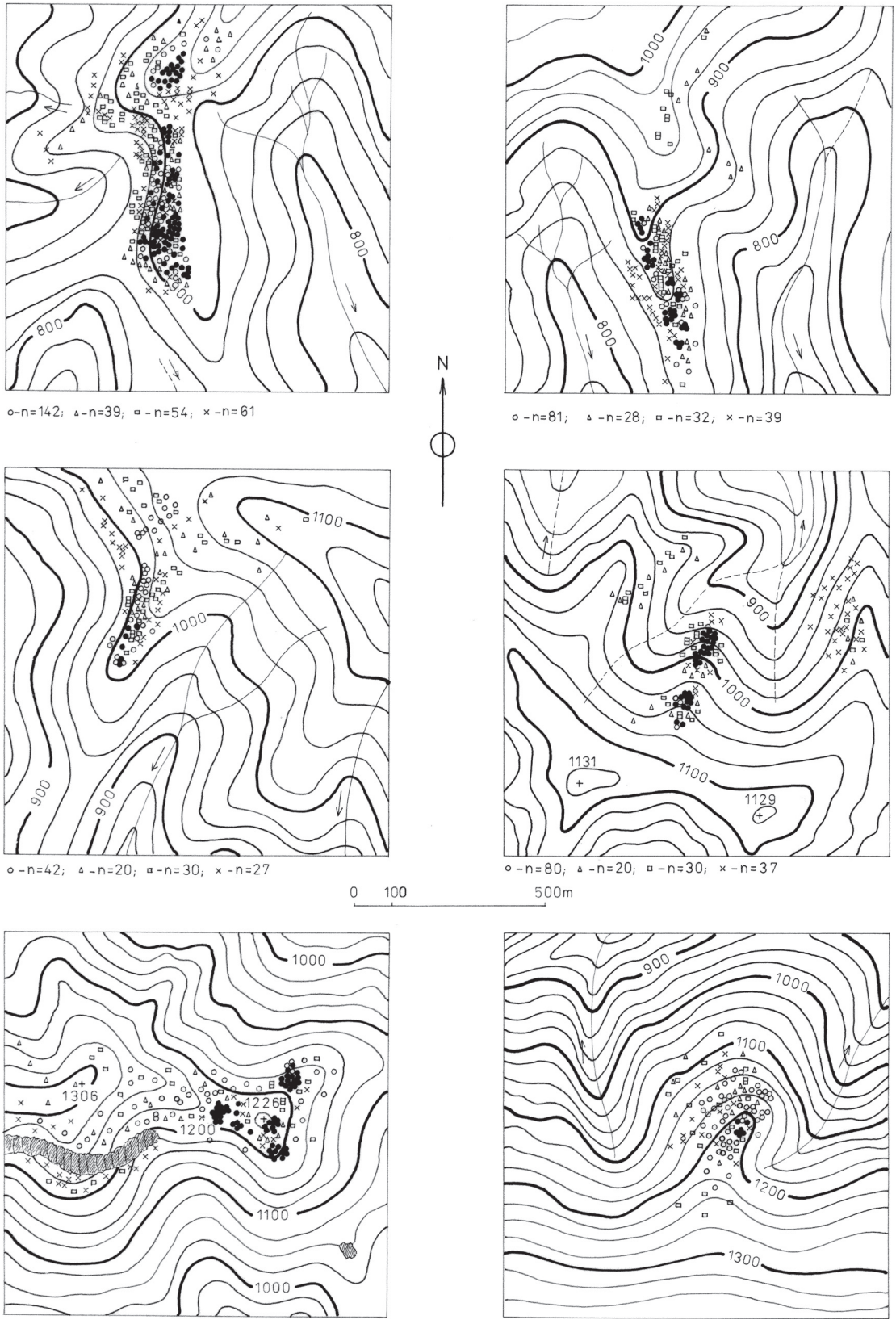

Fig. 1. Daytime and nighttime locations of roosting places in six capercaillie cocks living solitary in the West Carpathians, Slovakia, 1988–2005, n = 1020
○ – spring season, Δ – summer season, □ – autumn season, x – winter season

parts (the West Carpathians). The data from the Russian leks confirmed that capercaillie males undertook distinct seasonal movements from pine-dominated winter/spring ranges to rich spruce-dominated summer ranges (Hjeljord et al., 2000).

Areas where capercaillie cocks spent nights ("nighttime home ranges") were significantly smaller (roughly 1/3) than daytime home ranges (Table 1, Fig. 1). Site fidelity to nighttime roosting places was strong and all birds used the same territory in successive years (six and seven years, respectively). On the contrary to the investigations of Wegge and Larsen (1987), the lek area was also part of the daytime territory of all the males living solitary also during the lekking period. All investigated males visited during their lives only one lek during the display season.

Daytime roosting sites in capercaillie males living solitary

Capercaillie males roosted during day prevailingly on the ground all year long (maximally in spring – 96%, Table 2). Daytime roosting on trees was the highest during summer season (12%), because in this part of the year are best hiding places among deciduous tree species. Among the sites on the ground, most roosting sites were located at the base of the tree trunks underneath the low branches (77%), then near wind-falls or stumps (9%) and rock boulders (5%). When conditions for snow-roosting were good, capercaillies roosted in snow drifts (11% during winter season).

Birds preferred Norway spruces for daytime roosting all year long, especially during winter season (87%, Table 3). Daytime roosting places at the base of the coniferous trees were favoured to deciduous (94% and 6%, respectively). Coniferous trees were used as shelter almost dominantly especially during winter season (96%). Proportion of daytime roosting places near the trunk of deciduous tree species rised in spring and summer season (7% and 12%, respectively). Other coniferous tree species (Fir-tree, Pine) may substitute for spruce as cover when the birds roost on the ground, and a shrub layer may even be unimportant when conditions for snow-daytime roosting (drifts) are good (Gjerde, 1991a). According to this author, the importance of spruce roosts for saving energy is more uncertain, because spruce roosts are not used at night (low temperatures) and are used more frequently in late winter than in mid-winter.

In relation to height of the trees, capercaillies roosted prevailingly near the trees higher than 10 m (69%). During summer and autumn seasons, birds were found to roost in higher degree also in thickets (19%, and 22%, respectively, Table 4). Vegetation types with well developed understorey were preferred whereas forests which were thinned by reducing the amount of understorey spruce (single-layered stands) were avoided which is in accordance with Finne et al. (2000) conclusions. According to these authors, it is possible that capercaillie males prefer forest with a well-developed understorey when roosting. I never found capercaillie males roosting at plantations, which confirms Larsen and Wegge (1985) conclusions that plantations are unsatisfactory habitats for food and shelter against predators. Several studies, including this study, have documented the importance of spruce and forest understorey for capercaillie. Seiskari (1962) stated that the dependence on spruce seemed to be the essential feature in the habitat requirements of capercaillie during snow-free season. In a large uncut reserve in the northern Russian taiga, Beshkarev et al. (1995) reported an extensive use of clumps of spruce within the open pine-dominated forest during daytime in spring. The importance of understory cover for capercaillie males in winter has been documented empirically and demonstrated experimentally by removing spruce trees in intensively used areas (Gjerde, 1991a, b). According to Finne et al. (2000), to create forest suitable for both roosting and foraging a varying forest structure and density is advantageous, and thinnings in middle-aged plantations should be executed in a way that increase the heterogeneity of the stand in relation to type of tree species and stem density. High

Table 2. Positioning of daytime roosting sites in capercaillie cocks living solitary in the west Carpathians, Slovakia, n = 353 (1988–2005)

Place	Tree trunk		Rock boulder		Windfall		On tree		Snow drift		Sum
Season	N	%	N	%	N	%	N	%	N	%	N
Spring	135	83	7	4	12	7	6	4	2	2	162
Summer	43	74	2	4	6	10	7	12	0	0	58
Autumn	45	74	3	5	7	11	4	7	2	3	61
Winter	47	65	5	7	8	11	4	6	8	11	72
Sum	270	77	17	5	33	9	21	6	12	3	353

vertical cover close to the ground can also be obtained by rejuvenating the forest on the basis of selection-cutting and natural regeneration instead of clear-cutting and planting.

Because dense cover reduces the probability that the birds are detected by a predator, but at the same time increases the risk of being killed once detected, capercaillie males have to compromise between shelter and outlook. Finnes's et al. (2000) data indicate that males prefer good cover at the expense of good overview of the surroundings when selecting roosting sites, and that tree density is usually too dense in younger plantations, probably because outlook is reduced and flying obstructed. The forest structures preferred by capercaillie in winter may be optimal when hidding from predators, or those preferences may simply reflect the forest types that support the best food (Gjerde, 1991a, b).

Nighttime roosting sites in capercaillie males living solitary

Capercaillie males roosted during night almost exclusively on trees (Table 5). Only when conditions for snow-roosting were good (sufficient amount of powder snow) and temperature dropped below –15 °C, capercaillies also roosted in snow burrows (13% during winter and 3% in autumn). Both in southern Finland (Seiskari and Koskimes, 1955) and in southeastern Norway (Gjerde, 1991a) roosting of capercaillies in snow burrows was uncommon compared with roosting at the base of the spruce trees.

During display season, males preferred for nighttime roosting deciduous trees (59%), whereas in other parts of the year birds roosted more often on coniferous trees (54% in summer, 66% in winter and 74% in autumn, respectively). Seasonal differences in selection of tree species for nighttime roosting were coditioned by (1) climatic conditions (better in canopies of coniferous species); (2) protection against potential aerial and ground predators (better cover in conifers especially during the winter season); (3) display activity of the cocks (better visibility of displaying males in deciduous trees).

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Table 3. Positioning of daytime roosting sites in capercaillie cocks living solitary in relation to tree species in the West Carpathians, Slovakia, n = 270, (1988–2005)

Tree species	Spruce		Fir-tree		Pine		Larch		Beech		Sycamore		Sum
Season	N	%	N	%	N	%	N	%	N	%	N	%	N
Spring	104	77	15	11	4	3	3	2	6	5	3	2	135
Summer	25	58	4	9	5	12	4	9	2	5	3	7	43
Autumn	37	82	4	9	2	4	1	2	0	0	1	3	45
Winter	41	87	2	5	1	2	1	2	1	2	1	2	47
Sum	207	77	25	9	12	5	9	3	9	3	8	3	270

Table 4. Positioning of daytime roosting sites in capercaillie cocks living solitary in relation to tree height in the West Carpathians, Slovakia, n = 270, (1988–2005)

Season	Spring		Summer		Autumn		Winter		Sum	
Height class	N	%	N	%	N	%	N	%	N	%
1–5 m	15	11	8	19	10	22	7	15	40	15
5–10 m	19	14	8	19	8	18	7	15	42	16
>10 m	101	75	27	62	27	60	33	70	188	69
Sum	135	100	43	100	45	100	47	100	270	100

Table 5. Positioning of nighttime roosting sites in capercaillie cocks living solitary in the West Carpathians, Slovakia, n = 667, (1988–2005)

Tree species	Spruce		Fir-tree		Pine		Larch		Beech		Sycamore		Rowan		Snow burrow		Snag		Sum
Season	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N
Spring	72	23	19	6	40	12	24	7	123	38	29	9	3	1	0	0	12	4	322
Summer	15	18	7	9	12	15	10	12	23	28	11	13	3	4	0	0	1	1	82
Autumn	53	41	14	11	21	16	8	6	20	16	7	5	0	0	4	3	2	2	129
Winter	51	38	20	15	17	13	12	9	12	9	4	3	0	0	18	13	0	0	134
Sum	191	29	60	9	90	13	54	8	178	27	51	8	6	1	22	3	15	2	667

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Veľkosť teritória a odpočinkové miesta kohútov tetrova hlucháňa (*Tetrao urogallus* L.) žijúcich solitárne v Západných Karpatoch

Súhrn

Práca prináša poznatky o veľkosti teritórií a odpočinkových miestach solitárne žijúcich kohútov tetrova hlucháňa získané v rokoch 1988–2005 na lokalitách v pohoriach stredného Slovenska (Veľká Fatra, Malá Fatra, Kremnické vrchy, Starohorské vrchy a Nízke Tatry, Západné Karpaty, 18°50'–19°10'E; 48°47'–49°19'N). Najväčšie teritóriá obhajovali kohúty tetrova hlucháňa v letnom období (jún–september, 82 ha) a najmenšie na jar počas obdobia tokania (marec–máj, 34 ha). Kohúty žijúce vo viac-menej súvislých lesných komplexoch obývali menšie teritória ako na lokalitách vyznačujúcich sa vysokým stupňom fragmentácie dospelých porastov. Kohúty odpočívali počas dňa prevažne na zemi počas celého obdobia roka (najviac na jar – 96 % nálezov). V korunách stromov odpočívali kohúty vo zvýšenej miere (12 % nálezov) najmä v letnom období (jún–september), kedy olistené listnáče (buk lesný a javor horský) poskytovali vtákom vhodný úkryt. Prevažná väčšina odpočinkových miest bola lokalizovaná pri báze kmeňov pod vetvami hlboko zavetvených stromov (77 %), potom v blízkosti koreňových koláčov vývratov a povalených kmeňov stromov (9 %) a veľkých skál (5 %). Kohúty tetrova hlucháňa trávili nočný odpočinok takmer výlučne v korunách stromov. V prípade vhodných snehových pomerov (sypký sneh) a nevhodných poveternostných podmienok (silný mráz pod mínus 15 °C a vietor) hlucháne trávili odpočinok aj v snehu (13 % nálezov počas zimných mesiacov, 3 % v jeseni). Počas tokania kohúty preferovali pre nočný odpočinok listnaté stromy (59 %), zatiaľ čo v ostatnom období roka prevažovalo nocovanie na ihličnatých stromoch (54 % v lete, 66 % v zime, resp. 74 % v jeseni). Sezónne diferencie vo výbere nocovacích stromov boli podmienené: (1) mikroklimatickými podmienkami (lepšie v korunách ihličnatých drevín); (2) ochranou pred potenciálnymi vzdušnými a pozemnými predátormi (lepšie krytie v ihličnatých drevinách najmä počas zimných mesiacov, keď sú listnaté dreviny bez listov); (3) aktivitou súvisiacou s prejavmi tokania kohútov (lepšia viditeľnosť tokajúcich kohútov na neolistených listnatých drevinách než na ihličnatých).

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Occurrence of fungus *Cryphonectria parasitica* (Murr.) Barr on oak trees in the Carpathian-basin

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Abstract

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"Chestnut blight" caused by the fungus *Cryphonectria parasitica* (Murr.) Barr is the most important disease of *Castanea* spp. in Europe. In the 20-th century, this serious disease caused serious damage to chestnut populations throughout the world, including the Carpathian-basin. Towards the end of the last century, typical blight symptoms were observed on oak trees in several other European countries as well, and the fungus was also detected on some young *Quercus petrea* trees in Hungary. We studied the manifestation of *C. parasitica* on oaks, in several regions across the Carpathian-basin. Our examinations confirmed that the blight fungus has infected several oak trees in Romania and in Hungary, and potentially it could be a serious disease agent for the oak species.

Key words

Cryphonectria parasitica, Castanea sativa, Quercus petrea

Introduction

Cryphonectria parasitica (Murr.) Barr (syn: *Endothia parasitica* [Murr.] And.) is a very important pathogen of the *Castanea* species. At the beginning of the twentieth century, this fungus killed almost all American chestnut (*Castanea dentata*) populations in the USA (Anagnostakis, 1987). At the middle of the century, it was also for the first time recorded in Europe, in an European chestnut (*Castanea sativa*) forest near Genova – Italy, 1938 (Biraghi, 1946), and later it caused the "Chestnut blight" disease spreading across the continent.

In Europe, *C. parasitica* spread epidemically and heavily infected the chestnut stands. Then symptoms of the fungus were detected in the Carpathian basin, including Hungary (Körtvély, 1970), Austria (Donaubauer, 1964), Slovakia (Juhásová, 1976), Romania (Florea and Popa, 1989) and Ukraine (Radócz, 2001).

Towards the end of the last century, typical symptoms of "Chestnut blight" were observed on some oak trees in the USA and in some South European countries (Torsello et al., 1994). In Hungary, *C. parasitica* was detected on *Castanea sativa* only since 1998. But later there were found some young *Quercus petrea* trees showing typical blight symptoms in mixed chestnut-oak forests at Zengővárkony and Kőszeg (Radócz and Holb, 2002). Although these symptoms were not such serious on *Quercus petrea* as on *Castanea sativa*, it seems that *Cryphonectria parasitica* became a new serious threat for young oak trees in the Carpathian basin, mainly in heavily infected chestnut forests. The first observation of fungus *C. parasitica* on oak trees was reported by Juhásová and Leontovyč (1996), Juhásová et al., 2002.

We made field investigations in South Hungary and in North-West Romania with the aim to find blight symptoms on oaks. During the field works, bark samples were collected for laboratory examinations and identifications. The main goals of our studies were the following:

- Investigation of damages caused by *C. parasitica* on oak trees
- Analysis of the collected samples and testing the isolates in laboratory.

Material and methods

Field examination was done in two different regions of the Carpathian-Basin (North-West Romania, at the town of Baie Mare, and South Hungary in the Mecsek-Mountain by the Bakonya village – Fig. 1) in chestnut-oak mixed forests. During the field works, we either investigated all oak trees in the examined populations, or we selected a sampling plot with definite number of oak trees and examined only these trees. Bark samples for laboratory identifications and further examinations were collected from the infected or suspect trees with a sterile sharp scalpel.

PDA (potato-dextrose-agar) media were used in the laboratory examinations. Surface sterilized bark samples were cultivated on the PDA media and the isolates were incubated for 7 days in an acclimatising chamber. Then, there were done tests of vegetative compatibility, in which the isolates were paired to study their compatibility. Finally, the pure cultures of isolates were paired with the EU-tester strains with the aim to classify their Vegetative Compatibility Groups (VCG-s). Those isolates that formed a visible barrage zone at the edge of their growing mycelia were classified into different VCG-s.

Results and discussion

Examinations in South-Hungary

In 2004, we made field examinations in four chestnut-oak mixed populations on the south oriented slopes of the Mecsek-Mountain (1. Bakonya I., 2. Bakonya II., 3. Boda, 4. Hetvehely), with the chestnut trees infected by the chestnut blight fungus. We checked 150 randomly selected oak trees in all growing areas, and examined them for blight symptoms.

Table 1. The number of the oak trees infected by *C. parasitica* and the infection rates in the South-Hungarian examined sites

Test site	Number of examined trees	Number of infected trees (by *C. parasitica*)	Infection rate (%)	EU-strain (EU 1-31)
BAK I.	150	40	26.66	Not identified
BAK II.	150	0	0	–
BO	150	0	0	–
HET	150	0	0	–

BAK – Bakonya, BO – Boda, HET – Hetvehely

Symptoms of the pathogen were found on sessile oak trees in only one of the examined areas (Bakonya I.). Oak trees in the other studied populations were healthy (Bakonya II., Boda, Hetvehely) as it is shown in Table 1.

A test site with 150 oak trees was established in the forest with infected oak trees by the Bakonya village (04. 07. 2004). Since then, all trees in the test site were checked yearly, so we accomplished 3 examinations: in 2004, 2005 and 2006. We could observe progressive increase in number of infected oak trees in the examined test site. The results of the yearly surveys are presented in Table 2. It was also detected that the symptoms of the fungus were aggravated with the time (Table 3).

Table 2. The number and the rate of the oak trees infected by *C. parasitica* in Bakonya I. test site

Time of field-examination (at Bakonya I.)	Number of examined trees	Number of infected trees (by *C. parasitica*)	Infection rate (%)
2004. 12. 07.	150	40	26.66
2005. 11. 10.	150	51	34.0
2006. 09. 28.	150	52	34.6

Table 3. Symptoms of *C. parasitica* fungus on the trees according to the infection rate classification system

Infected tree number	Infection	Infected tree number	Infection
BAK I.	2ab	67.	3b
6.	4a	73.	4ab
7.	5	80.	4a
8.	5	81.	4b
12.	2ab	86.	4ab
17.	2ab	87.	3ab
19.	2b	88.	4ab
20.	3b	89.	3ab
21.	2b	91.	5
23.	3ab	93.	3ab
24.	4ab	96.	2b
30.	2ab	97.	3ab
31.	2b	99.	5
33.	3ab	100.	3b
34.	2ab	109.	4ab
35.	3ab	110.	3ab
38.	4ab	116.	3b

Table 3. Continued

Infected tree number	Infection	Infected tree number	Infection
41.	5	118.	4ab
49.	3ab	119.	4ab
50.	2ab	126.	3ab
53.	5	132.	4ab
55.	5	137.	5
56.	4ab	145.	4ab
62.	3ab	148.	2a
63.	3ab	149.	3ab
66.	2b	150.	4ab

2 – a – suspect symptom in the crown of the tree
2 – b – suspect symptom on the trunk of the tree
3 – a – 1 cancer symptom in the crown
3 – b – 1 cancer symptom on the trunk
4 – a – more cancers in the crown
4 – b – more cancers on the trunk
5 – killed tree by *C. parasitica*

Examinations in North-West Romania

Field examinations were done in 2004 and 2005, near the town of Baie Mare in five different chestnut populations with admixture of several oak trees (1. site – Baie Mare-Tautii de S., 2. – Baie Mare-Kőbánya, 3. – Baie Mare-Borpatak, 4. – Baie Mare-Veresvíz, 5. – Tautii Magheraus). During the field studies it was observed that chestnut trees were infected by *Cryphonectria parasitica* in all the examined sites. Apart from this, there were found several infected young oak trees in three chestnut growing areas. In two other sites, no infected oak trees were detected until 2005, as it can be seen in Table 4.

Table 4. Results of field examinations in chestnut-oak mixed populations near Baie Bare town, North-West Romania

Test site	Number of examined trees	Number of infected trees	Infection rate (%)	EU-strain (EU 1-31)
BM-TS	20	2	10	EU-12
BM-K	50	0	0	–
BM-B	20	0	0	–
BM-V	50	6	12	EU-12
TM	50	18	36	EU-12

BM-TS – Baie Mare Tautii de S., BM-K – Baie Mare- Kőbánya, BM-B – Baie Mare-Borpatak, BM-V – Baie Mare-Veresvíz, TM – Tautii Magheraus.

The laboratory examinations confirmed that *Cryphonectria parasitica* has infected several oak trees in Romania and in Hungary. However, the infected oak trees only occurred in populations mixed with chestnut. The fungus has not hitherto caused such serious injuries to oaks as to the chestnut trees, but in future it may turn to a serious endangering agent for the oak species in the Carpathian-basin.

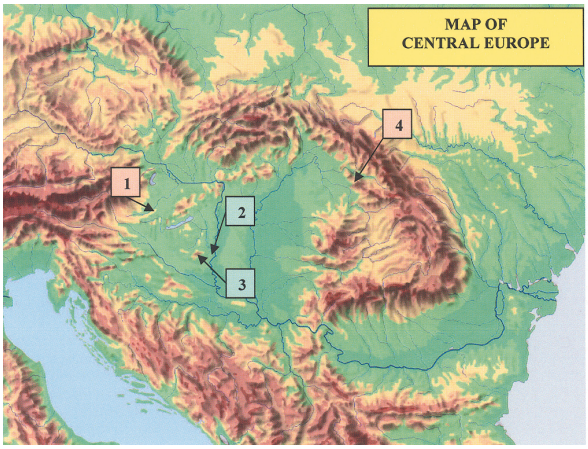

Fig. 1. Map of Central-Europe with the examined sites
1 – Kőszeg, 2 – Zengővárkony, 3 – South-Hungarian study sites, 4 – Romanian study sites

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Výskyt huby *Cryphonectria parasitica* (Murr.) Barr na duboch v Karpatskej kotline

Súhrn

Huba *Cryphonectria parasitica* je najvýznamnejší pôvodca ochorenia druhov rodu *Castanea* spp. v Európe. Je pôvodcom rakoviny kôry gaštana jedlého a spôsobuje vážne škody vo všetkých pestovateľských oblastiach gaštana jedlého vo svete. V polovici 20. storočia sa choroba objavila aj v strednej Európe a huba sa za niekoľko desaťročí stala hlavným patogénom gaštana jedlého (*Castanea sativa* Mill.) v takmer všetkých pestovateľských oblastiach. Huba sa do Karpatskej kotliny dostala v poslednej tretine minulého storočia. Najprv bola zaznamenaná v Maďarsku, neskôr aj na Slovensku, aj v týchto krajinách spôsobila obrovské škody.

Na konci minulého storočia sa pozorovali typické rakovinové rany aj na duboch v mediteránnych krajinách, neskôr na Slovensku aj v Maďarsku. Doteraz bola huba zistená predovšetkým na mladých duboch v zmiešaných alebo susediacich s porastmi gaštana jedlého. V práci sú uvedené výsledky rozšírenia huby *C. parasitica* na duboch v jednotlivých porastoch v Karpatskej kotline a zhodnotenie škôd, ktoré spôsobuje.

Terénny výskum sme robili v južnom Maďarsku, resp. Servernom Erdélyi v okolí Nagybánya v zmiešaných porastoch gaštana jedlého s dubmi. Zistili sme, že huba v menšej alebo väčšej miere napadla aj duby v oboch oblastiach, a to dub zimný (*Quercus petrea*) a bola zistená aj na mladom dube *Quercus petrea* v Maďarsku. Študovali sme hubu *C. parasitica* na duboch vo viacerých regiónoch v Karpatskej kotline. Náš výskum potvrdil, že huba infikovala niekoľko dubov v Rumunsku a v Maďarsku a potenciálne predstavuje závažnú chorobu druhov rodu *Quercus*.

V pohorí Mecsek sledujeme štyri porasty na juhozápadných svahoch, z ktorých sme hubu *C. parasitica* na duboch identifikovali len v jednom poraste. Výskumnú plochu sledujeme od 7. októbra 2004 pravidelne každý rok a zistili sme, že počet infikovaných stromov rastie z roka na rok.

V okolí Baie Mare sme sledovali 5 lokalít, z nich na troch sme našli napadnuté mladé duby zimné (Tabuľka 4). Výsledky laboratórnych prác potvrdzujú, že ten istý kmeň huby (EU-12), ktorý intenzívne ničí gaštany, infikoval aj duby.

Výsledky našej práce poukazujú na to, že huba *C. parasitica* sa stala vážnym potenciálnym patogénom dubov. Ochorenie nespôsobovalo doteraz také škody na duboch ako na gaštane jedlom, ale potenciálne treba počítať s tým, že v budúcnosti sa môžu škody stupňovať aj na duboch.

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Short communication

Introduction of species of the *Juglans* genus in the West of Ukraine

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Abstract

Termena, B., Batsura, H., Kotsyuban, I. 2006. Introduction of species of the *Juglans* genus in the West of Ukraine. *Folia oecol.*, 33: 133–136.

This article is dealing with occurrence of species of the genus *Juglans* L. in 36 woodland subjects in the Western Ukraine: old parks, arboretums, forests and artificial plantations. We evaluate the tree age, growth (height, $d_{1,3}$ diameter), abundance (tree number), fecundity and germination capacity. The most frequently cultivated species is *Juglans nigra* L. (21 subjects), the most rare are *Juglans cordiformis* Maxim. and *Juglans manshurica* Maxim. (in 3 subjects each). The cultivated *Juglans* trees are the most abundant in the Precarpathian region Opollya (24 subjects).

Key words

Introduction of woody plants, *Juglans*, West of Ukraine, fecundity, germination rate

Introduction

The *Juglans* genus is a walnut which belongs to tribus Juglandeae of subfamilia Juglandoideae of familia Juglandaceae of ordo Juglandales in subclassis Hamamelidales of classis Magnoliopsida of divisio Magnoliophyta (Manning, 1948; Tahtadjan, 1987).

There are very different opinions as for the species number belonging to the *Juglans* (walnut) genus, ranging between 21 (Manning, 1948) and 44 (Dode, 1909). Walnut trees prefer moderate, subtropical and tropical regions of the northern hemisphere and they can also be found in the Andes and Brazil in the southern hemisphere. Almost always they grow in mountain localities in broadleaved and mixed forest stands (Sokolov, 1951).

By structure of the fruits (Dode, 1909), the *Juglans* species can be specified in sections: *Dioscaryon, Cardiocaryon, Rhysocaryon* and *Trachycaryon*, by structure of the flowers (Manning, 1948) we differentiate among: *Juglans, Cardiocaryon, Rhysocaryon* and *Trachycaryon*. By structure of the pollen grains (Kuprianova, 1965) we distinguish among four subtypes: *Regia, Cinerea*, *Mollis* and *Australis*.

Material and methods

The research objects were species of *Juglans* L. genus growing in old parks, arboretums, forests and artificial plantations; the localities have been labelled according to preliminary zoning of the Ukrainian Carpathians and Western Podollya (Termena et al., 2004). The approximate age of walnut trees was assessed visually and on the background of the documentation on the parks. The taxation indexes were determined by methods commonly recognised for taxation. The tree number was expressed categorically, using the following scale: less than six (the exact number), several (S) – 6–20 trees, many (M) – 21–50 trees, very many (VM) – more than 50 trees. The fecundity was assessed visually, using the 6-point scale by Korchagin (1960): 0 – no fruits, 1 – very low production, 2 – low production, 3 – satisfactory production, 4 – good production, 5 – very good production; figures in brackets express duration of the study in years. The germination capacity of seeds was specified according to GOST 13056.8-68 (Anonymus, 1968).

Results

There exists a century-old experience with introduction of a number of *Juglans* species in territory of Western Ukraine from their domestic regions in Iran-Turan (*J. regia* L.), East Asia (*J. ailantifolia* Carr., *J. cordiformis* Maxim., *J. manshurica* Maxim.), North America (*J. nigra* L., *J. cinerea* L.), and Rocky Mountains (*J. rupestris* Engelm.) (Tahtadjan, 1974).

Pocorny (1864) summarising the experience with introduction of alien woody plants noted that *J. regia* had already been growing wild across the territory of Bukovina. By the end of the 19th century, different walnut species, *J. nigra* (Anonymus, 1899) and *J. cinerea* (Willkom, 1975) in particular, appeared spontaneously in several localities.

Table 1. Genus *Juglans* species in Western regions of Ukraine

Place of growth	Age, years	Maximum size		Tree number*	Fecundity* (years of observation)	Germination capacity, %
		Height, m	Diameter, cm			
Section *Cardiocaryon* Dode et Mann., subtype *Cinerea* Kuprian. – *J. ailantifolia* Carr.						
8	50	14	46	2	2.5 (10)	89.6–92.9
11	40	12	28	4	2.7 (12)	92.8–98.4
12	20	8	24	S	2.3 (3)	–
24	60	14	36	1	2.7 (3)	–
J. cordiformis Maxim.						
11	40	15	28	4	2.7 (16)	80.5–91.2
15	30	12	24	S	2.5 (1)	73.3
19	20	8	12	2	2.5 (3)	–
J. manshurica Maxim.						
11	40	20	40	2	2.6 (8)	93.6–100.0
32	20	8	16	M	2.5 (3)	–
34	20	6	16	VM	2.5 (3)	–
Section *Dioscaryon* Dode, *Juglans* Mann., subtype *Regia* Kuprian. – *J. regia* L.						
4	80	16	48	1	2.7 (10)	92.3–100.0
7	80	15	80	S	2.8 (3)	–
10	60	14	40	S	2.3 (1)	87.7
11	50	17	42	3	2.7 (16)	87.0–95.2
27	25	8	28	S	2.3 (3)	–
30	80	20	100	M	2.6 (12)	89.4–100.0
33	30	10	32	VM	2.6 (3)	
35	20	7	24	VM	2.5 (3)	85.4– 98.1
36	60	12	46	S	2.5 (8)	–
Section *Rhysocaryon* Dode et Mann., subtype *Mollis* Kuprian. – *J. nigra* L.						
4	30	10	20	2	2.5 (5)	–
1	120	22	40	1	2.5 (5)	94.8–100.0
5	100	24	80	S	2.8 (8)	100.0
9	120	24	60	1	2.3 (8)	–
2	140	18	100	1	2.7 (8)	100.0
3	100	20	80	1	2.5 (8)	100.0
6	40	12	40	3	2.5 (8)	–
10	30	10	22	M	2.0 (8)	–
14	80	28	96	1	2.5 (5)	–

Table 1. Continued

Place of growth	Age, years	Maximum size		Tree number*	Fecundity* (years of observation)	Germination capacity, %
		Height, m	Diameter, cm			
13	120	30	84	1	3.0 (1)	89.4
17	100	24	48	1	2.5 (3)	
36	120	20	104	1	2.5 (8)	93.7–100.0
11	100	35	84	2	2.6 (16)	92.3–97.6
16	80	20	42	1	2.3 (10)	76.3–90.0
20	80	18	48	S	2.5 (5)	100.0
22	80	18	56	1	2.5 (3)	–
28	80	16	56	2	2.5 (1)	93.4
29	80	20	46	S	2.7 (5)	100.0
31	100	29	84	1	2.6 (5)	–
Section *Trachycarion* Dode et Mann., subtype *Cinerea* Kuprian. – *J. cinerea* L.						
11	90	18	46	2	2.8 (8)	–
13	120	20	60	1	2.3 (5)	–
17	80	16	42	2	2.5 (1)	93.7
18	100	17	64	S	2.5 (8)	–
19	20	8	12	3	2.0 (3)	–
21	20	5	12	S	2.0 (8)	–
23	90	16	80	1	2.9 (1)	89.1
24	140	26	84	1	2.6 (3)	80.6–100.0
25	70	15	70	1	2.6 (3)	–
26	120	18	80	1	2.7 (10)	95.2–100.0

*See Material and methods.

Transcarpathian lowland introduction district. Parks: 1 – hospitals in the town of Beregovo, 2 – Horkyi Park in the town of Vynogradiv, 3 – Kinderhouse # 3 in the town of Vinogradiv.

Transcarpathian foothills introduction district. Arboretums: 4 – Botanical Gardens of the Uzhorod State University. Parks: 5 – the township of Bushtyno, 6 – Druzhba Park in the town of Hust, 7 – the village of Ruskoe pole.

Carpathian mountain introduction district. Parks: 8 – park zone in the town of Kosiv, 9 – the town of Rahiv, 10 – the township of Velykyi Bereznyi.

Opollya-Precarpathian introduction district. Arboretums: 11 – Botanical Gardens of the Chernivtsi National University, 12 – Hermakivka forestry office, 13 – Lviv Forestry University, 14 – Botanical Gardens of the Lviv National University, 15 – Storozhynets Forestry College. Parks: 16 – hospital of the town of Berehomet, 17 – the town of Bolehiv, 18 – the village of Cherlenivka, 19 – Chernivtsi National University, 20 – Hlyboka district hospital, 21 – school in the village Hrushivtsy, 22 – the old-aged house in the village of Petrychanka, 23 – the Vashkivtsi branch of Chernivtsi regional research agricultural station, 24 – Vyshnianskyi agricultural college, 25 – Vyzhnytsya district hospital, 26 – Sad-Hora children's tubercolosis sanatorium, 27 – the children's tuberculosis sanatorium in the village of Stara Zhadova, 28 – the technical school in the village of Stavchany, 29 – boarding school in the town of Storozhynets. Plantations: 30 – the city of Chernivtsi, 31 – the village of Yablunivka. Woodlands: 33 – the village of Izheshtsk, 36 – the village of Klishkivtsi, 37 – the village of Slavtsi, 33 – the village of Valia Kuzmin.

Western-Podollian introduction district. Parks: 16 – the village of Skala Podilska.

The top qualities of walnut trees such as the high growth rate, high longevity, wide ecological amplitude and strong adaptive capacity ensured them a wide expanding distribution range. The experience with introduction of Juglans trees into the western part of Ukraine is of a great theoretical and practical importance in context of expanding cultural areas of precious wood species.

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Introdukcia druhov rodu *Juglans* v západnej Ukrajine

Súhrn

Zhodnocuje sa zastúpenie druhov rodu *Juglans* v 36 dendrologických objektoch západnej Ukrajiny. Vyhodnocuje sa vek, rast (výška, hrúbka $d_{1,3}$), početnosť, plodnosť a kvalita semena (klíčivosť). Najviac pestovaným druhom je *Juglans nigra* L. (21 objektov), najmenej *Juglans cordiformis* Maxim. a *Juglans manshurica* Maxim. (po 3 objekty). Najrozšírenejšou oblasťou pestovania druhov rodu Juglans v západnej Ukrajine je zakarpatský región Opollya (24 objektov).

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Book review

Ash species in Europe: biological characteristics and practical guidelines for sustainable use. Oxford: Oxford Forestry Institute, University of Oxford, 2005. 128 p. ISBN 0-85074-163-7.

The book was published by the Oxford Forestry Institute and the Department of Plant Sciences, University of Oxford, Great Britain (UK) in 2005. The concern is about an important international scientific issue focussed by a collective of authors working on the FRAXIGEN project. This book has 128 pages, contains 25 full colour photographs, 13 maps, 9 figures including schemes, 10 graphs and 2 tables.

The publication is composed following the research project FRAXIGEN implemented in the frame of the Fifth Framework Programme of the European Union: "Biodiversity and Ecosystems". The project was prepared in participation of ten European research institutions, comprising 33 contributors from 6 countries (Great Britain, Sweden, Spain, Greece, Romania and Slovakia). The book has a high scientific level, imaginative and well-balanced layout and provides a particular piece of new knowledge on genetics and phenology of ash trees studied in Europe.

The book addresses all research stakeholders, from specialists in plant science and plant genetics to students interested in this theme and specialists in related topics and in forest research area. The publication consists of an introductory chapter about the project, 7 main chapters, referred literature and a glossary.

The book gives a summary of research results obtained in solving the FRAXIGEN project, oriented on study of three ash species: the common ash (*Fraxinus excelsior* L.) the narrow leaved ash (*Fraxinus angustifolia* Vahl) and the manna ash (*Fraxinus ornus* L.), from January 2002 to June 2005. It also provides conclusions and recommendations for forest practice, tree nurseries and seed orchards.

The discussed project and publication were focussed on studies of the genetic diversity and generative phenology of the three ash species, influenced by diversity and variability in their reproductive biology. The secondary subject was the study of natural ash populations adapted to their environment, human impact on their positive selection and proposals for specialists how to conserve ash genetic sources.

Each chapter is introduced with a panorama photo illustrating the topic. The photos are of high quality, and they represent a considerable contribution to the book's graphical outlook.

Chapter 1: Native ash species of Europe – offers fundamental information about the three ash species in Europe, about their global natural distribution range – documented by three maps. The emphasis is also put on the present practical utilization. The presented information is very useful, but some additional would be profitable to provide a deeper first insight into the topic.

Chapter 2: Sustainable seed source selection – the policy framework. The chapter presents materials on forest genetic sources, especially the seed sources selection. It is divided into five subchapters: Ash for conservation and ecological restoration; European forest policies supporting planting for conservation; How local is local?; Examples of seed sourcing policies in Europe; The importance of diversity in adapting to environmental change. The chapter summarises the state of art in international legislation dealing with seed sources protection.

Chapter 3: Understanding ash genetic resources, research under FRAXIGEN – the mentioned chapter is dealing with research methods of the implemented project, and also with partial tasks and processes. Three ash species were subjected to analyses. This chapter has two subchapters. The first, entitled Concepts in forest genetic resources research has the paragraphs: Adaptive and neutral variation; Population identification; Sampling strategies; Seed zone designation. The second: The scientific approach of FRAXIGEN is divided into paragraphs: Estimating genetic diversity; Using DNA profiling to track pollen movement; What kind of tree makes the best father?; Research in local adaptation.

Then follow three chapters analysing the obtained results for individual ash species, each containing the same subchapters for the corresponding species: Distribution and systematics; Ecology and silviculture; Traditional and modern uses; Research under FRAXIGEN; Genetic variation; Reproductive biology and gene flow; Local adaptation.

Chapter 4 is devoted to the common ash (*Fraxinus excelsior* L.) and analyses the characteristics of this woody plant over its distribution range in Europe. This chapter consists of 33 pages, including figures, maps and graphs. The subchapter: Distribution and systematics describes in brief the occurrence of the common

ash in Europe and SE Asia. The subchapter: Ecology and silviculture consists of the paragraphs: Climate and altitude, Soil; Suitable planning locations; Silvicultural characteristics; Growth and rotation length. The subchapter: Traditional and modern uses is dealing with broad practical utilization of the discussed tree species. The subchapter: Research on Fraxinus excelsior under FRAXIGEN is oriented on research into tree genetic diversity in several European countries. In Great Britain was implemented RTE – reciprocal transplant experiment oriented for molecular studies of genetic changes. The subchapter: Genetic variation is divided into paragraphs: Background previous research; FRAXIGEN findings on genetic variation (nuclear diversity). The subchapter: Reproductive biology and gene flow comprises the paragraphs: Flower types; Defining the gender of trees; Seed set; Selfing and seed germination in controlled pollination experiments; Paternity testing and pollen flow; Sex ratios and phenology of flowering, fruiting and leafing (appended with a summary of results) and Local adaptation.

Chapter 5 is devoted to the narrow-leaved ash (*Fraxinus angustifolia* Vahl). The subchapter: Distribution and systematics, deals also with detailed differences between the common ash and the narrow-leaved ash. The subchapter: Reproductive biology presents observations on the phenology of both ash species carried out in 2003–2004, included are also data from a seed orchard with narrow-leaved ash trees in southern Slovakia. The chapter is supplemented with a map and a table of seed collection in Greece in the end.

Chapter 6 gives information obtained in research on the manna ash (*Fraxinus ornus* L.). This species has the most southern distribution (from Italy to Romania), it occurs also in South Slovakia where it reaches the northern distribution boundary, its occurrence is limited by low temperatures. The latex liquid manna, contains alkaloid manitol has utilization in pharmacy. Its wood substance is lighter than the other two ash species. It is used in handicraft and carving. This chapter provides also new results in branch of reproductive biology. The RTE experiment has been done also for manna ash, what is subject of the subchapter Local adaptation.

Chapter 7 is entitled Practical guidelines and recommendations for sustainable use is closing the elaborated problems. It summarises the obtained results of FRAXIGEN project and it proposes strategic measures for ash silviculture and obtaining high-quality seed.

The quickly expanding knowledge obtained in ash study means a noticeable scientific contribution also in context of international cooperation and participation in the project solving. This publication is an excellent material for specialists dealing with the topic and researchers in related areas. The book is written at a high professional level, however, presentation of particular results in more graphs and tables could be profitable. The book is the scientific outcome of the FRAXIGEN project, launched by 5th Framework programme of European Union with participation of the Department of Phytology of Faculty of Forestry of the Technical University in Zvolen.

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