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Growth of *Robinia pseudoacacia* L. on a reclaimed terrain in Bulgaria studied over a period of climatic anomalies

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Abstract

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Reclamation of post-industrial land through forest planting provides conditions for formation of fertile soils, protection of the landscape against winds and water erosion, and restoration of the flora and fauna. We studied the process in a region damaged by mining industry. Over a period of three years (1999–2001) we examined the growth dynamics of a stand of *Robinia pseudoacacia* L. planted in post-industrial soil. The study period was characterised by climatic anomalies (extremely high average daily temperatures caused by masses of warm air transported from Northern Africa) in the growing season. The trees were clustered in 10 bio-groups consisting of dominant (D), co-dominant (CD), subdominant (SD) and suppressed (SP) trees. Air temperature and precipitation was monitored simultaneously with the measurement of stand variables.

Key words

Robinia pseudoacacia L., diameter increment, reclaimed land, tree class, precipitation

Introduction

Reclaimed land is an attribute of post-industrial landscapes in regions with mining activity, ore processing and power industries. The soils in such a land are formed by accumulation of different geological substrata with either homogenous or heterogeneous structure.

The soils in post-industrial land have an anthropogenic layer of significant depth and characteristic structure, low water-keeping capacity and low amounts of nutrients.

In this context, the black locust growing in a reclaimed land has been given increasing interest in many countries. We present here an overview – compilation of the results obtained through experience and research on this topic in Bulgaria.

Material and methods

The studied experimental plot is placed in a black locust stand established in 1974 on an embankment build up in the process of exploitation of the open iron ore mine MP Kremikovtsi (near Sofia). The forest soil at the site belongs to chromic luvisols. The locality is situated at 510 m a.s.l.

The plot is situated in the low-elevation forest zone, the sub-zone of hilly-far-mountain oak forests, characterized by an average annual temperature of 9.9°C and an average precipitation total of 590 mm (Zahariev et al., 1979).

The forest litter layer is 2–3 cm thick, and it consists of dead leaves and branches. The herb layer is dense, regularly distributed over the whole area, and it is composed of *Dactylus glomerata* L., *Bromus sterilis* L., *Taraxacum officinale* L., *Teucrium chamaedris* L., *Cirsium arvense* L. (Scop.), *Potentila argentea* L., *Geum urbanum* L., *Artemisia annua* L., *Plantago media* L., *Achillea millefolium* L. and other species.

As a result of the forest biological restoration the humus horizon is formed, the total nitrogen content is increased and the alkaline reaction of the substrate is lowered.

The study was launched in 1999 on 10 bio-groups selected at the plot with together 172 black locust trees. From this number, 156 (90.6%) were trees with single stems and 16 (9.4%) with stems branching in two at a 50–60 cm height. Which consist of dominant (D), codominant (CD), subdominant (SD) and suppressed (SP) trees – their total number in bio-groups is 40 (Fig. 1).

The growth parameters, dendrometric variables and wood assortment structure of the stands were studied using forest inventory methods of analysis and synthesis. The measurements were performed weekly in rainy periods, and each two weeks over the periods without rain. Control measurements of air temperature and relative air humidity were performed using an Assman´s psychrometer (Alexandrov and Shipkovenski, 2002).

The distribution of precipitation water was measured in the open air, below forest canopy (including stem flow) and in the surface soil layers (seepage below litter and below +5 cm mineral soil).

Results and discussion

Growth of black locust trees

The mean diameter of the studied trees is 15.9 cm. The first bio-group has the smallest diameter (14.6 cm), deviating 8.2% from the overall mean diameter. The sixth bio-group has the biggest average diameter, exceeding the overall mean of the studied stand by 16.9%. The mean diameters of the fifth and the seventh bio-groups are very similar to the overall stand mean. The mean height of all the studied trees is 13.8 m. The fourth and fifth bio-groups have the same values – 13.5 m. The maximum height (15.6 m) was found in the trees with the highest d. b. h. diameter (18.6 cm). The thickest tree N 102 is also the tallest one (21.0 m). The less developed tree N 130 (suppressed) is at the same time the shortest – 3.2 m.

The dominant trees occupy 47.8% of the area, 28.3% is covered by the co-dominant trees. The subdominant and suppressed trees represent 16% and 8% of the area, respectively. The average projection area of a black locust tree belonging to the biogroups is 12.8 m^2, for the entire sample plot is the corresponding value 11.4 m^2. The dominant tree N 56 has the largest growth surface – 43.2 m^2, while the tree N 130 has the smallest one – 1.2 m^2 (Tsakov and Dimitrova, 2003).

Table 1 shows the dynamics in the mean annual diameter increment of the studied black locust trees, recorded over the growth periods of 1999, 2000 and 2001. Evident is considerable variability in connection with various hierarchical positions in the stand canopy.

The comparison of the increment values of the black locust trees grouped according to the social classes shows that the dominant trees had the highest diameter increment in 1999 and 2000, representing 37.0–42.5% of the total by trees of social groups accumulated increment.

The total accumulated diameter increment was shared in the following way: dominant trees by 37%, co-dominant trees by near 30%, subdominant by 20%, and suppressed by 10–15% (13%). There is evident an abrupt decrease in the increment of the dominant trees over the vegetation period 2001, however the proportion to the total (31.5%) is still fairly high, almost reaching the increment value created by the codominant trees (33.4%).

The crown die-back found in some dominant trees shows that the stand has already reached its quantitative maturity stage, and that the growth potential of the dominant stems appears to be exhausted.

The comparison of the black locust diameter increment values in 1999 between the social classes reveals that the lowest growth rate was connected

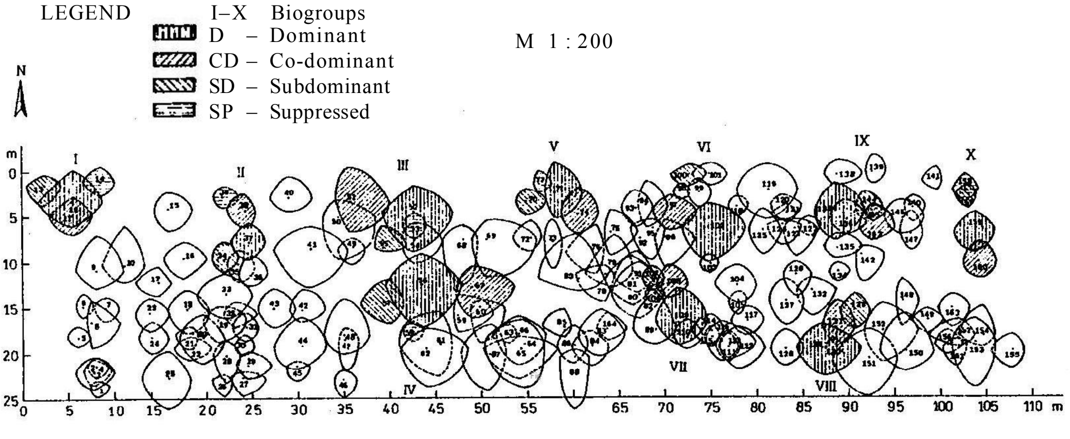

Fig. 1. Profile diagram of the crowns of *Robinia pseudoacacia* L. - sample plot no. 1 – Kremikovtsi

Table 1. Growth of Black locust trees on experimental plot Kremikovtsi in growing seasons 1999–2001

Year	Precipitation in the rest and in growth periods				Mean annual diameter increment								Average breast-height diameter							
					Social classes															
	Rest Nov-Apr	Intensive May-Jul	Completion Aug-Oct	Total	Dominant		Co-dominant		Subdominant		Suppressed		Dominant		Co-dominant		Subdominant		Suppressed	
	(mm)				(mm)	(%)	(mm)	(%)	(mm)	(%)	(mm)	(%)	(cm)	(%)	(cm)	(%)	(cm)	(%)	(cm)	(%)
1999*	155	225.0	106.5	486.5	17.5	42.5	11.5	27.9	8.0	19.4	4.2	10.2	23.0	100.0	16.9	100.0	12.8	100.0	9.0	100.0
2000	167	94.2	121.8	383.0	14.8	37.0	12.0	30.0	7.5	18.8	5.7	14.2	23.8	+3.4	17.4	+ 3.0	13.2	+3.1	9.2	+2.2
2001	259	232.7	90.8	582.5	9.7	31.5	10.3	33.4	6.8	22.1	4.0	13.0	24.5	+6.5	18.2	+7.6	13.6	+6.3	9.5	+5.5

with the lowest average height. In the year 2000, the height of the dominant (D) and the suppressed (SP) trees increased by about 1% (1.2%).

The average height of suppressed trees is two times smaller compared to the dominant trees. The depressed trees are characterized by asymmetrically developed crowns, situated within the lower canopy layer with only limited supply of light and water. Consequently, the diameter increments in these trees are lower.

The same tendency in the height growth and development was also recorded during the growth period 2001.

In spite of the dry periods, the growth rate and wood mass accumulation was fairly massive in co-dominant (CD) and subdominant (SD) trees. The diameter increment in these classes expressed to average breast-height diameter during the growth periods 2000 and 2001 ranged from 5.0 to 6.9%. At the same time, these trees showed better vitality compared to the others.

Water cycles

The total sum of open air precipitation in 2000 was only 383.5 mm, representing 65.7% of the precipitation total in 2001 (close to the average annual precipitation). The distribution of the precipitation over the growing periods 1999, 2000 and 2001, separately for the period of rest (November–April), period of intensive growth (May–July) and period of growth completion (August–October) shows Table 1. The different quantities of total precipitation from 383.5 mm (1999) to 583 mm (2001) are to be noticed.

The water cycles on the sample plot for the years 2000 and 2001 are summarised in Tables 2 and 3. The average annual throughfall for the two seasons was about 75% (74.3–75.8%), the stem flow 7% (6.8–7.1%) and the amount of water reaching the mineral soil surface was 50% (47.2–51.2%).

The maximum precipitation in the growing period 2000 fell in June (58 mm), representing 15.1% of the total annual precipitation. From this amount, 77.1% passed through the canopy, 48.8% below litter and 39.3% below 5 cm thick mineral soil layer. In the litter was therefore absorbed 28.3% of June precipitation. The minimum amount of precipitation fell in August – only 4.4 mm (1.1%), from which the throughfall represented 50%, and water amounts passed through the litter and 5 cm thick mineral soil layer were 6.8% and 0%, respectively.

The absolute biggest quantity of precipitation was recorded to the end of the growing season in September 2000 (77.1 mm, i.e. 20.1%). The throughfall was 78.5%, water amount passed below the litter 56.0% and below 5 cm thick mineral soil layer 45.3% (unlike

Table 2. Water cycle experimental plots "Kremikovtsi", year 2000

Amount of water	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug (mm)	Sep	Oct	Nov	Dec	Total	%
Open air precipitation	12.8	23.4	52.6	54.4	20.0	58.0	16.2	4.4	77.1	40.3	16.6	7.7	383.5	100.0
Througfall	10.2	16.8	39.6	40.2	14.3	44.7	11.5	2.2	60.5	27.8	12.1	5.1	285.0	74.3
Stemflow	1.1	1.7	2.9	2.6	0.7	3.3	0.8	0.0	8.9	4.1	1.1	0.2	27.4	7.10
Seepage below litter	5.1	10.5	24.5	28.0	9.2	28.3	5.1	0.3	43.2	17.1	9.3	0.7	181.3	47.2
Seepage below 5 cm mineral soil	2.2	8.0	16.6	23.0	6.1	22.8	3.7	0.0	35.0	9.7	6.7	0.4	134.2	35.0

Table 3. Water cycle experimental plots "Kremikovtsi", year 2001

Amount of water	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug (mm)	Sep	Oct	Nov	Dec	Total	%
Open air precipitation	9.3	34.5	62.5	69.2	118.7	98.1	15.9	57.5	30.5	2.8	55.1	29.3	583	100.0
Througfall	7.3	27.3	48.8	59.0	90.8	73.0	10.5	38.5	21.5	0.3	41.8	23.6	442	75.8
Stemflow	0.1	2.8	3.6	3.0	10.8	6.1	1.2	4.2	3.0	0.0	3.4	1.9	40	6.8
Seepage below litter	6.0	17.8	35.0	32.0	65.6	40.7	5.7	36.7	17.8	0.5	29.8	12.1	299	51.2
Seepage below 5 cm mineral soil	4.6	15.7	31.0	24.5	46.2	37.3	1.8	30.7	16.3	0.0	26.7	9.4	244	41.8

an average annual seepage of 35%). However, such an abundant precipitation following the driest month August (1.1% of the annual precipitation total) only played an insignificant role for the normal growth of the stand.

On the other hand it is evident that the low precipitation in the region of Kremikovtsi in the year 2000 (65% of the long term annual mean 590 mm) seriously influenced the diameter increment in 2001. This could also be the reason for the abrupt decrease in the increment of the dominant trees (from 14.8 to 9.7 mm), and also for the reduced increments observed for the other social classes in the recent years. TOPÇIOGLU (by ASSMAN, 1961), DUHOVNIKOV (1971), NEDYALKOV (2003) and other authors also suggest that the dry periods influence the diameter increment for the next growing season.

In 2001 the maximum precipitation was in May and made 118.7 mm or 20.3% of the annual total of 583 mm. The throughfall represented 76.5%, the amount of water passed through the litter was 55.3% and below 5 cm thick mineral soil layer 38.9%. The minimum precipitation was in October – 2.8 mm (0.5%). In this month the throughfall made 10.7%, water amount passed below the litter 17.8% and below 5 cm thick mineral soil layer 0%.

The average annual temperature in 2001 was 10.9 °C, i.e. by 1°C (10.1%) above the long-term mean. In this year, July and August were the hottest months with average temperatures 22.2°C and 20.9°C, respectively. The coldest month was December (–4.1°C). The mean temperature in January was above zero (0.9°C).

In the year 2002, the average annual temperature was 11.9°C, i.e. 2°C (20.2%) above the long term annual mean (9.9°C). The average annual temperature in the stand was by 1.12°C (9.4%) lower than in the open air. The warmest month was also July (24.4°C) and August (23.4°C), and the coldest one was January (3.1°C).

Conclusions

The study of the black locust planted in post-industrial soil in the reclaimed landscape near the Sofia town has revealed that:

- In spite of the specific growth conditions, the stand seems growing quite vigorously. Concerning the tree classes, the proportions of the area covered by the trees belonging to the particular class are following: dominant 47.8%, co-dominant 28.3%, subdominant 16% and suppressed 8%.
- Dominant trees show the highest diameter increments in 1999 and 2000, representing 37.0–42.5% of the total increment accumulated by the trees of social groups diameter increment in the vegetation

period 2001 is lower but also represents a large proportion (31.5%) of the total diameter increment. The increment value found in the co-dominant trees was very similar (33.4%).

- The precipitation total in 2000 was 383.5 mm, representing only 65.7% of the precipitation total in 2001. The value of this parameter in 2001 was very similar to the long-term mean.
- Percentages of the throughfall (74.3% and 75.8%) and the stem flow (7.1% and 6.9%) did not significantly differ for the two successive years (2000–2001).
- The average value of the interception during the period with foliage (from May until October) reached 19.7% while in the leafless period (from November until April) it was 14.3% (2001).
- The analysis of the growth dynamics of the concerned black locust stand shows that it is not possible to make general conclusions from such a short period.
- Variable tendencies of local climatic values could be deduced that reflect the unique microclimatic patterns in the surroundings.

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Rast *Robinia pseudoacacia* L. na rekultivovonom území v Bulharsku v období klimatických anomálií

Súhrn

V oblasti poškodenej banskou činnosťou vytvára rekultivácia prostredníctvom lesných kultúr priaznivé podmienky pre zvýšenie pôdnej úrodnosti, ochranu krajiny pred veternou a vodnou eróziou a obnovu flóry a fauny. Dynamika rastu porastu *Robinia pseudoacacia* L. vysadeného na technogénnej pôde sa sledovala v období klimatických anomálií rokov 1999–2001 (extrémne vysoké priemerné denné teploty vzniknuté v dôsledku prechodu teplých vzdušných hmôt zo severnej Afriky). V desiatich biogrupách agáta sa skúmali nadúrovňové, úrovňové, podúrovňové a potlačené stromy. Výskum zahŕňa aj sledovanie zrážok a teplôt vzduchu.

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Storage proteins and enzyme activity during somatic embryogenesis in Algerian fir (*Abies numidica* De Lann.)

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Abstract

KORMUŤÁK, A., VOOKOVÁ, B. 2005. Storage proteins and enzyme activity during somatic embryogenesis in Algerian fir (*Abies numidica* De Lann.). *Folia oecol.*, 32: 6–10.

The dynamics of storage protein synthesis and enzyme activity during somatic embryogenesis of the Algerian fir (*Abies numidica* De Lann.) was studied beginning with the embryonic suspensor mass (ESM). Storage proteins comprised major protein fractions 47, 43, 25, 20 and 10 kDa in size and numerous minor proteins – in their profiles similar to storage proteins in somatic embryos of *Picea glauca*. Stage-specific nature of storage proteins was observed during differentiation of somatic embryos within ESM and during desiccation of mature somatic embryos. Peroxidase activity was relatively constant in ESM, precotyledonary and cotyledonary embryos, but no activity was detected in desiccated embryos. Esterase activity exhibited increased tendency during somatic embryogenesis. Both isoperoxidases and isoesterases exhibited stage-specific profiles what makes them a perspective tool in studying individual stages of *Abies numidica* somatic embryogenesis.

Key words

Abies numidica, somatic embryogenesis, proteins, enzymes

Introduction

Somatic embryogenesis is a useful technique for breeding and large-scale propagation of elite trees. In Pinaceae, its potential for mass multiplication has been eventful demonstrated for the genera *Picea* (HAKMAN, 1993; ARNOLD et al., 1995), *Pinus* (GUPTA and DURZAN, 1991; SALAJOVA et al., 1995), *Larix* (BONGA et al., 1995) and *Abies* (NØRGAARD and KROGSTRUP, 1995). The effort has preferentially been focused on induction of somatic embryogenesis and regeneration of mature somatic embryos by means of specific media. Less attention has, however, been paid to the biochemical changes accompanying somatic embryo development. Storage proteins and their dynamics during *Picea abies* and *Picea glauca* somatic embryo development have for example been characterized by HAKMAN (1993) and FLINN et al. (1991), respectively. The protein fraction 42, 33, 22 and 14 kDa size were found dominating under conditions reducing the protein profiles in both above mentioned species. The stage-specific proteins were observed in the early stage embryos, mid cotyledon and cotyledonary stages of *Picea glauca*. Both zygotic and somatic embryos displayed similar patterns of proteins storage. *Abies* seed protein profile was found different from other Pinaceae, mainly because of the lack of legumin-like proteins which constitute a major fraction of storage reserves in angiosperms and gymnosperms. According to JENSEN and LIXUE (1991), this lack can be used as a diagnostic feature for the genus *Abies*.

In order to characterize this aspect of seed biochemistry in more detail, the dynamics of protein synthesis was studied during somatic embryo development of Algerian fir. Also, the kinetics of enzyme activity has in addition been registered throughout the process aimed at better understanding of somatic embryogenesis in the *Abies* species.

Material and methods

Induction of somatic embryogenesis

The experiment was launched in 1998 when we removed embryonic suspensor mass (ESM) from immature zygotic embryos. The cones were collected from an Algerian fir (*Abies numidica* De Lann.) tree growing in the Arboretum Mlyňany. Immature seeds were surface-sterilized for 10 min in 10% H_2O_2. Megagametophytes containing embryos were cultured on SH medium (Schenk and Hildebrandt, 1972) with 1 mg l^{-1} 6-benzylaminopurine (BAP). The obtained embryogenic tissue was maintained at 24°C in the dark on a proliferation medium supplemented with 1 mg l^{-1} BAP, 1 g l^{-1} casein hydrolysate and 500 mg l^{-1} L-glutamine and subcultured in 3-week intervals.

Maturation of somatic embryos was achieved culturing the ESM on a modified MS medium (Murashige and Skoog, 1962) supplemented with 40 g l^{-1} maltose, 100 g l^{-1} polyethylene glycol-4000 and 10 mg l^{-1} abscisic acid. After 8 weeks of culturing on the maturation medium, cotyledonary somatic embryos were obtained. Media for the different stages of somatic embryogenesis were gelled with 3 g l^{-1} phytagel. Cotyledonary somatic embryos were subjected to a partial desiccation during three weeks at 24°C in the dark (Vooková et al., 1997/1998).

Biochemical analyses

Embryonic suspensor mass (ESM), precotyledonary, cotyledonary and desiccated cotyledonary somatic embryos of *Abies numidica* were used for isozyme and SDS-polyacrylamide (SDS-PAGE) analyses. The weight of analysed tissues and embryos ranged between 0.05 and 0.1 g. For the purpose of enzyme activity, the material was extracted in 1.5 ml of 100 mM TRIS-HCl buffer, pH 8.3, containing 5 mM cysteine-HCl, 5 mM Na_2EDTA, 500 mM sucrose and 0.5% (w/v) polyvinylpyrrolidone. The crude homogenate was centrifuged for 15 min at 20.000 g and 4°C. The supernatant was dialyzed through a Sephadex G-25 coarse column and then used as a source of enzymes. Proteins were quantified according to the Bradford's method (Bradford, 1976). Peroxidase activity was measured spectroscopically at 470 nm by means of the quajacol-H_2O_2 method proposed by Erdelsky and Frič (1979). Esterase activity was measured at 405 nm using 100 mM phosphate buffer, pH 7.4, p-nitrophenylacetate substrate dissolved in ethanol (5 mg per ml) and enzyme solution. Three repetitions were made for each measurement. Specific activity of the enzymes was expressed as a change in optical density per mg of proteins.

Isoenzyme composition of both above discussed enzymes was analyzed by polyacrylamide disc electrophoresis as described originally by Ornstein and Davis (1960) and modified by Frič (1971). Isoperoxidases were visualized using saturated benzidine solution and 1.7% H_2O_2 in 100 mM sodium acetate buffer, pH 4.6. Isoesterases were stained in 100 mM sodium phosphate buffer, pH 6.0 containing 5 mg of each Fast Blue RR and α-naphtylacetate in 100 ml volume.

For SDS-electrophoresis, the material was homogenized in 0.125 M TRIS-HCl extraction buffer, pH 6.8, containing 22.5% (v/v) mercaptoethanol, 22.5% (v/v) glycerol and 9% (w/v) SDS. The crude homogenate was heated for 3 min at 95°C, clarified by centrifugation at 15,000 g for 10 min and subjected to SDS-PAGE (Laemmli, 1970).

Results and discussion

Protein structure of embryonic suspensor mass and developing somatic embryos was similar but not identical. As seen in Fig. 1, the overwhelming majority of proteins characteristic for precotyledonary and cotyledonary somatic embryos were already detected in the embryonic suspensor mass. The only exception was 20 kDa protein which appeared in the precotyledonary embryos, persisting until their maturity. It seems that this protein is decisive for differentiation between the embryos in embryonic suspensor mass. Also, in the desiccated embryos two additional polypeptides with approximate molecular masses of 3 and 6 kDa were present which were not detected at earlier stages. We may only speculate whether they belong to the category of late embryogeny abundant (LEA) proteins involved in seed desiccation when the embryo lapses into a state of quiescense or dormancy (Raghavan, 1997). All the above mentioned proteins exhibit a stage-specific nature as reported also for *Picea glauca* by Flinn et al. (1991). However, in contrast to the *Picea*, it is a 20 kDa protein which appears in the early stage embryos of *A. numidica* instead of 22, 24, 33 and 35 kDa fractions detected in *Picea glauca*. As to the total protein pattern in *A. numidica* somatic embryos, it is similar to that of *Picea glauca* containing major proteins of 47, 43, 25, 20 and 10 kDA in size, together with numerous minor protein components (Fig. 1). Most of the major protein components mentioned here were reported as providing storage reserves in conifers. In particular, it is true for the 43, 25 and 10 kDa sized proteins the presence of which was also confirmed in 12 *Abies species* (Jensen and Lixue, 1991). It seems that in the Algerian fir are present some additional proteins complying the abundance criterion (47, 30, 13 kDa). Most probably, there exist species-specific patterns of storage proteins in the genus *Abies.*

Considering the metabolic processes, the development of somatic embryos was accompanied by a relatively constant peroxidase activity and a varied level of esterase activity. It follows from Table 1 that the highest values of peroxidase activity were registered in the developing cotyledonary embryos – reflecting their active growth. A relatively high level of peroxidase activity in embryonic suspense mass may result of an increased content of phenolic compounds which serve as substrates in peroxidase catalysed reactions (Hrubcová et al., 1994). Practically undetectable level of peroxidase activity was characteristic for the desiccated embryos but the presence of isoperoxidases in these embryos was proved electrophoretically. Most probably, the desiccation reduced some metabolic processes in the embryos to a minimum and also suppressed activity of the involved enzymes below the threshold for their spectroscopic detection. With the outlined peroxidase activity levels was closely correlated the isoperoxidase pattern. As it is shown in Fig. 2, the highest number of isozymes was detected in ESM and in the cotyledonary embryos, the lowest in precotyledonary embryos and in desiccated embryos. The transition from ESM to precotyledonary embryos is accompanied by a conspicuous reduction in the number of isoperoxidases (Fig. 2, bands A, B); whereas the subsequent differentiation of cotyledons is connected with reappearing of the isoenzymes that were already observed in the ESM and which are placed around R_m 0.3 on the gel (Fig. 2, band C). The two major isozymes dominate the peroxidase pattern during *A. numidica* somatic embryogenesis of R_m 0.3 and 0.6.

Contrary to peroxidase, the esterase activity exhibited an increasing tendency throughout all the analysed stages with the lowest activity level detected in the ESM and the highest activity detected in the desiccated somatic embryos (Table 1). The outlined course of esterase activity has also been responded by the isoenzyme number. The ESM and precotyledonary embryos contained the same number of isoesterases positioned at R_m 0.5 and 0.7 (Fig. 3, bands A, B). Conversion of precotyledonary embryos into cotyledonary ones was connected with appearing of new isoesterases of R_m 0.3 and 0.4 (Fig. 3, band C). Desiccated mature embryos contained additional isoesterases located on the gel between R_m 0.5 and 0.7 (Fig. 3, band D, arrow). The question concerning possible identity of this isoesterase with LEA proteins remains to be verified.

Regarding the fact that somatic embryos were derived from seeds of one tree only, it is reasonable to expect somewhat modified figure on the initial isoenzyme composition of ESM and subsequent developmental stages of somatic embryogenesis, mainly because of the isozyme variation between individual trees. However, we do not assume major changes in the observed tendency of enzyme activity during somatic embryogenesis based on seed material from different donor trees.

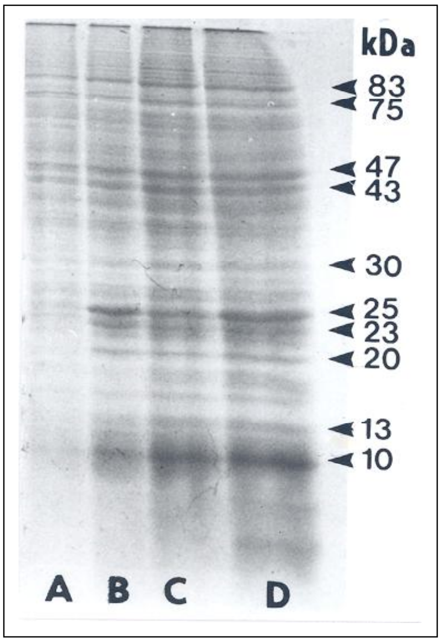

Fig. 1. SDS-PAGE profiles of proteins storage in embryonic suspensor mass (A), precotyledonary embryos (B), cotyledonary embryos (C) and desiccated mature somatic embryos (D)

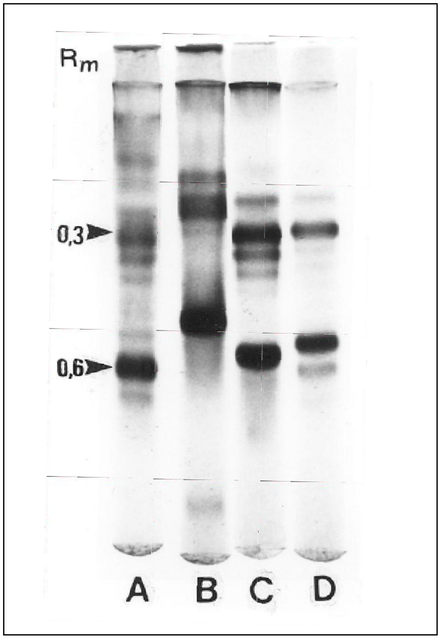

Fig. 2. Isoperoxidase patterns revealed in embryonic suspensor mass (A), precotyledonary embryos (B), cotyledonary embryos (C) and desiccated mature somatic embryos (D)

Table 1. Changes in peroxidase and esterase activities during somatic embryogenesis of Algerian fir

Developmental stage	Specific activity	
	Peroxidase	Esterase
	Mean ± SD	Mean ± SD
Embryonic suspension mass	4.29 ± 0.08	1.79 ± 0.04
Precotyledonary embryos	4.17 ± 0.05	2.31 ± 0.14
Cotyledonary embryos	4.78 ± 0.10	2.22 ± 0.09
Desiccated mature embryos	0	3.16 ± 0.19

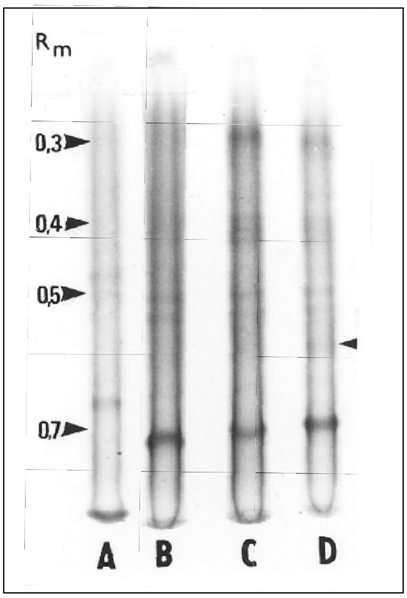

Fig. 3. Isoesterase patterns revealed in embryonic suspensor mass (A), precotyledonary embryos (B), cotyledonary embryos (C) and desiccated mature somatic embryos (D)

Conclusions

The presented results allow us to suggest that the isozyme pattern is a more suitable tool than storage protein profiles for delineation of the individual stages of somatic embryo development in *A. numidica*. In spite of reflecting metabolic potential of the developing somatic embryos, the enzyme activity was found lacking the capacity to distinguish unambiguously between the individual stages of embryogenesis. Nevertheless, there exists certain analogy between *A. numidica* somatic embryos and an increased invertase activity during the maturation stage in *Picea mariana* somatic embryos as reported by Iraqi and Tremblay (2001). An increased activity of the adenosine and uridine protection enzymes were also observed during conversion of somatic embryos of *Picea glauca* into plantlets as well as an increase in dehydroascorbate activity during maturation and germination of somatic embryos of the species (Stasolla et al., 2001; Stasolla and Yeung, 2001). Therefore, further investigation is necessary to bring more details concerning the enzymatic aspects of somatic embryogenesis in *Abies*, involving some additional enzymes.

Acknowledgement

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Zásobné bielkoviny a enzýmová aktivita v priebehu somatickej embryogenézy jedle alžírskej (*Abies numidica* De Lann.)

Súhrn

Od embryogénnej suspenzorovej masy (ESM) sa sledovala dynamika syntézy zásobných bielkovín a enzýmovej aktivity v priebehu somatickej embryogenézy jedle alžírskej (*Abies numidica* De Lann.). Zásobné bielkoviny obsahovali veľké proteínové frakcie o molekulovej hmotnosti 47, 43, 23, 20 a 10 kDa spolu s početnými malými frakciami bielkovín. Celkove sa spektrum zásobných bielkovín podobalo bielkovinovému profilu somatických embryí druhu *Picea glauca*. Vývinovo špecifický charakter zásobných bielkovín sa pozoroval v štádiu diferenciácie somatických embryí v ESM, ako aj vo vysušených somatických embryách. Peroxidázová aktivita bola relatívne stabilná na všetkých analyzovaných štádiách embryogenézy s výnimkou vysušených zrelých somatických embryí, v ktorých sa nepodarilo stanoviť žiadnu peroxidázovú aktivitu. Naproti tomu, esterázová aktivita vykazovala stúpajúcu tendenciu počas somatickej embryogenézy. Tak izoperoxidázy, ako aj izoesterázové spektrá však vykazovali vývinovo špecifický charakter, čo naznačuje možnosť ich využitia ako biochemických markerov pri analýze jednotlivých štádií somatickej embryogenézy jedle alžírskej.

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Soil temperature and moisture in beech stands of different density

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Abstract

ŠIRÁŇ, M. 2005. Soil temperature and moisture in beech stands of different density. *Folia oecol.*, 32: 11–14.

The paper deals with the influence of various stand densities in submountain beech forests in central Slovakia on soil temperature and moisture content. The issue was examined over a humid growing season more than ten years after a regeneration cutting. The obtained results show evidently that the soil temperature changes were influenced by the time factor (seasonal factor – 66%), stand density (22%) and spatial factor (soil depth – 3%). Soil moisture values varied depending on soil depth, and, consequently, on soil physical properties connected with the depth (soil texture, humus content, etc. – 58.6%), time (during season – 15%) and, finally, stand density (7.5%). About ten years after the regeneration (shelterwood) performed to the original beech stand, the forest plots (0.9 and 0.3) do not differ either in air temperature or in soil conditions across the whole profile. As for the soil moisture content, the plot with the 0.3 stocking is moister in the topsoil (0.1 m) and in the subsoil (0.5 m). It is necessary to point out that our research did not included variability between the years (it was limited to one single year).

Key words

soil temperature, soil moisture, variability, beech forest, regeneration-cutting

Introduction

Forest stand density can have a considerable influence on soil temperature and moisture. In the case of soil temperature, the so-called active layer (the zone of transformation of solar energy to thermal) is shifted higher above the soil surface (to the crown space). Consequently, the temperature values, both mean and range, decrease in the stem space, on the soil surface as well as inside the soil. The extent of this influence is dependent on the stand density. In the case where the stocking is lower than 0.3, the major part of active surface is on the soil surface, not in the crown space (STŘELEC, 1992). In comparison with an open plot, a forest stand is characteristic with distinctly lower maximum and higher minimum temperatures (PETRÍK, 1988; STŘELEC, 1992). It is necessary to consider also seasonal variability of temperature and influence of soil physical properties, primarily the texture (MITSCHERLICH, 1971; ŠÁLY, 1998; LAVELLE and SPAIN, 2001; ŠIRÁŇ, 2003). In the case of soil moisture, the forest stand reflects the amount of water coming to the soil surface (INTRIBUS, 1977). The rhizosphere activity (extraction) can be an important factor (KODRÍK, 1993; GREGOR, 1997; TUŽINSKÝ et al., 1997). The seasonal dynamics (TUŽINSKÝ, 1984; GREGOR, 1997), and soil physical properties (soil texture, humus content) can also play a significant role in distribution of the soil water (GREGOR, 1992; ŠIRÁŇ, 2003).

Material and methods

Soil temperature and moisture were monitored at the Beech Ecological Experimental Site in the Kremnické vrchy Mts. (central Slovakia). The locality is situated at 450–475 m a. s. l. on a W-oriented slope with an inclination of 15°. The main task was to monitor the influence of different stocking (0.0, 0.3, 0.9 – control) on development trends in ecological factors, processes, etc. during one humid growing period more than 10 years after a regeneration cutting.

The soil type at the site is Tephri-Eutric Cambisol, in texture a medium heavy, loamy, medium skeletal soil. The humus content in the topsoil is high (plot 0.3) or very high (plot 0.9).

Soil temperature was measured according to the Pallmann´s method (Kubíková, 1970; Střelec, 1990b) once in a month (V.–VIII. 2002), at three depths: 0.05, 0.20, 0.50 m. The measurements were repeated three times. Soil moisture was evaluated once a week, near the spot of temperature measurement, gravimetrically, by means of gravimetric analysis. The material was sampled according to 0.1 m thick layers up to a depth of 0.50 m, in three repetitions.

For the statistical analysis we used the three-way analysis of variance and the test of paired comparisons.

Results and discussion

In this paper we present results of close examination of three factors causing the variability in soil temperature and moisture: 1. stand density (represented through plots with different stocking of 0.0, 0.3 and 0.9), 2. time (seasonal variability over V.–VIII. 2002) and 3. space (soil profile from 0.1–0.5 m). The studied period was about normal in temperature (111%) and precipitation (130%). The influence of the above-mentioned factors was tested through the three-way analysis of variance and the test of paired comparisons.

Soil temperature

The ANOVA results about soil temperature (Table 1) revealed that the fluctuation of this variable was mostly influenced by the seasonal factor (66%). Then followed the influence of stand density (22%) and finally soil depth (3%). The effects of these factors and their interactions were found high significant (with the exception of AB interaction – significant). The residual error was low. It means that these three factors can cover 99% of the total variability. The detailed analysis of the seasonal temperature variability revealed very significant differences between summer (VII, VIII), spring and autumn months, at the soil depth next to the top layer. As for the stand density (Table 2), high significant differences in temperatures values were only found between the forest stands (0.3, 0.9) and the open area (0.0), in contrast to the results obtained by Střelec (1993) immediately after the cutting. Non-significant difference between the forest stands is probably consequence of the dense crown canopy of beech stand with stocking 0.3 developed after the regeneration-cutting in 1989 (Barna, 2000).

Soil moisture

In the case of soil moisture content, the analysis of variance (Table 3) explained the major part of the total variability by the spatial factor (soil profile variability – 58.6 %) followed by time factor (seasonal – 15%)

Table 1. Soil temperature, three-way analysis of variance (influence of stand density, soil depth and time)

Variability	S	f	MS	F	% of total variability (T)
Stand density, A	178.437	2	89.218	454.602**	22.1
Soil depth, B	24.751	4	6.187	31.529**	3.0
Time, C	534.562	5	106.912	544.759**	66.2
Interaction, AB	3.765	8	0.470	2.398*	0.5
Interaction, AC	24.515	10	2.451	12.491**	3.0
Interaction, BC	33.966	20	1.698	8.653**	4.2
Residuum, e	7.850	40	0.196	–	1.0
Sum, T	807.847	89	–	–	100.0

Explanations: S – sum of squared deviations, f – degrees of freedom, MS – variance, F – F-test value

Table 2. Soil temperature, t-test of paired comparisons between plots 0.0, 0.3 and 0.9 for individual sampled items

Item		d (0.0–0.9)	α	d (0.0–0.3)	α	d (0.3–0.9)	α
Air temperature		3.1**	0.002	3.2**	0.001	–0.1	0.219
Soil surface		9.5**	0.004	10.0**	0.005	–0.5	0.316
Soil	0.05 m	3.5**	0.006	4.0**	0.002	–0.5	0.244
	0.20 m	2.9**	0.005	3.0**	0.003	0.0	0.351
	0.50 m	2.8**	0.003	2.7**	0.004	0.1	0.636
Whole soil profile		3.1**	0.002	3.2**	0.001	–0.1	0.197

Explanations: d – difference between plots (...), α – level of significance, 0.0–0.3–0.9 stocking grade (also plot identification) and stand density (7.3%). Similar to the temperature, the influence of each factor was found very important (with exception of AC interaction – non-important). In the topsoil (0–0.20 m) was the moisture content significantly higher than in the deeper layers. It can be caused by soil physical properties varying downwards the profile (clay content, sandy component increase with depth), higher humus content in the top soil but also, according to Gregor (1997), the tree rhizosphere activity in the deeper (0.20–0.50 m) layers. Thanks to the higher than normal precipitation during the following period, the soil moisture content was relatively stable. The highest moisture content was measured in May, the lowest in September. The forest stand also influences the distribution of precipitation. High significant difference was only found between the control plot (0.9) and open plot (0.0), significant between the plots with stocking of 0.9 and 0.3, as well as between the plots with stocking 0.0 and 0.3. As for the precipitation amount coming into soil, the plot with stocking of 0.3 was found between plots of 0.0 and 0.9 (nearer to plot of 0.0). The variability in precipitation amount was higher in the fully unconnected beech stand that also transmitted more water. Concerning the influence of different stand density on soil moisture content (Table 4), the significant differences were found in the deepest examined (0.50 m) layer only between the plots with stocking 0.0 and 0.9 and the plots with stocking 0.3 and 0.9 and in the top layer between the plots with stocking 0.3 and 0.9. In the first case, it was probably in association with higher clay content to the exclusion of sand on the 0.3 plot as well as 0.0 plot against 0.9; in the second case, it was probably a result of higher precipitation on the plot with stocking 0.3 (compared with 0.9) and the shading effect of the beech stand shelter (compared with 0.0). In total, the 0.3 plot with its moisture contents in all examined layers was more similar to 0.0. Similar soil moisture values over the vegetation period on the same plots were also confirmed by other authors (Gregor et al., 1998).

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Table 3. Soil moisture content, three way analysis of variance (influence of stand density, soil depth and time)

Variability	S	f	MS	F	% of total variability (T)
Stand density, A	93.606	2	46.803	65.175**	7.3
Soil depth, B	746.984	4	186.746	260.052**	58.6
Time, C	191.535	5	38.307	53.344**	15.0
Interaction, AB	23.011	8	2.876	4.006**	1.8
Interaction, AC	9.744	10	0.974	1.357	0.8
Interaction, BC	181.238	20	9.062	12.619**	14.2
Residuum, e	28.724	40	0.718	–	2.3
Sum, T	1274.840	89	–	–	100.0

For the symbols see Table 1.

Table 4. Soil moisture, t-test of paired comparisons among plots 0.0, 0.3 and 0.9 for the individual items

Item		d (0.0-0.9)	α	d (0.0-0.3)	α	d (0.3-0.9)	α
Rainfall		17.6**	0.004	7.9*	0.039	9.7*	0.023
Soil	0.10 m	1.7	0.317	-1.5	0.414	3.1*	0.016
	0.20 m	2.1	0.202	0.7	0.677	1.3	0.235
	0.30 m	2.3	0.114	1.3	0.359	1.1	0.109
	0.40 m	2.4	0.128	1.3	0.333	1.1	0.106
	0.50 m	3.7*	0.028	1.6	0.222	2.2*	0.017
Whole soil profile		2.4	0.111	0.7	0.634	1.7*	0.024

For the symbols see Table 2.

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Teplota a vlhkosť pôdy v bukovom poraste rôznej hustoty

Súhrn

Príspevok analyzuje vplyv stredohorského bukového lesa rôznej hustoty v strednej časti Slovenska na teplotu a vlhkosť pôdy počas vlhkého (zrážkovo a teplotne nadnormálneho) vegetačného obdobia (V až VIII). Zo získaných výsledkov je predovšetkým vidieť, že zmeny teploty pôdy v sledovanom období sú zapríčinené faktorom času (vplyv sezónnosti – 66 %), hustotou porastu (22 %) a nakoniec priestorovým faktorom – hĺbkou pôdy (3,1 %). Variabilita vlhkosti pôdy je závislá na jej hĺbke, resp. na jej fyzikálnych vlastnostiach súvisiacimi s hĺbkou (napr. zrnitosť pôdy, obsah humusu – 58,6 %), ďalej na vplyve faktoru času (sezónnosť – 15 %) a hustoty porastu (7,5 %). Asi 10 rokov po obnovnom zásahu (úprave zakmenenia) bukového porastu preriedená a pôvodná plocha sa nelíšia teplotou vzduchu ani pôdy v celom jej sledovanom profile. V prípade pôdnej vlhkosti je preriedená plocha (zakmenenie 0,3) vlhšia v povrchovej (0,1 m) a spodnej vrstve (0,5 m).

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Harvestman communities on two hills in the Štiavnické Vrchy Protected Landscape Area, Slovakia (Opiliones)

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Abstract

Stašiov, S. 2005. Harvestman communities on two hills in the Štiavnické Vrchy Protected Landscape Area, Slovakia (Opiliones). *Folia oecol.*, 32: 15–21.

The influence of both exposure and type of biotope on harvestman communities was investigated on two hills in the Štiavnické vrchy Protected Landscape Area by pitfall trapping during 1999 and 2000. Three pitfall traps were placed in various biotopes (meadow, forest margin and forest) on both hills. All three studied biotopes have southern exposure on the Tanád hill, and northern exposure on the Kanderka hill. In total, 14 species of harvestmen were recorded. An influence of exposure on harvestman communities became only evident in the meadows and at the forest edge. *Dicranolasma scabrum* (Herbst, 1799) was the only species that preferred the same exposure (southern) in all habitat types. The most similar biotopes were the forest and ecotone with southern exposure and the meadow and ecotone with northern exposure.

Key words

harvestmen, Opiliones, ecology, community composition, Štiavnické vrchy Mts., Slovakia

Introduction

The structure of harvestman communities and their dynamics are influenced by various ecological factors. Several authors (e.g. Bokor, 1993; Bokor and Tóthmérész, 1998; Klimeš, 1997, 1999; Komposch and Gruber, 1999; Loch, 1999; Meyer et al., 1999; Schaefer and Schauermann, 1990) have studied the influence of temperature, moisture, light conditions, altitude, humus form, anthropic disturbance, herbicides, fire etc. on harvestmen. Exposure and type of biotope are among the factors that potentially influence the species spectrum of harvestman communities, too. The influence of the type of biotope on harvestmen has been studied by, for example, Bokor (1993); Bokor and Tóthmérész (1998); Gulička (1957); Klimeš and Sechterová (1989); Klimeš and Špičáková (1984); Kromp and Steinberger (1992); Kubovčík and Jarab (2002); Mihál (1995, 1997); Stašiov (2002a); Stašiov and Bitušík (2001); Stašiov et al. (1997). An analysis of the influence of exposure on these communities has not been presented in the literature up to now.

The presented work seeks to detect the influence of both exposure and type of biotope on the species structure of harvestman communities in selected sites in the Štiavnické Vrchy Mts. The obtained results can extend our knowledge of the indication potential of harvestmen in biomonitoring of the environment.

Materials and methods

Study area

The Štiavnické Vrchy Mts. represent the largest mountains of volcanic origin in Slovakia. This area has varied geological composition. A major part of this area has been changed by intensive mining in the past and is deforested at present.

The Štiavnické Vrchy Mts. are situated on the boundary between the Carpathian Mts. and the Pannonia lowland. Therefore, many thermophilous elements of Pannonian flora and fauna integrate here with mountain Carpathian elements in a relatively small region, that results in high species diversity of the local biocoenoses.

The investigation was carried out on the Tanád hill and Kanderka hill (48°26' N, 18°52' E). Both hills are located on major bends of the caldera north-west of Banská Štiavnica.

The altitude of Tanád hill is 938.8 m a.s.l. The cultivated forest stand on the top of this hill is formed of an assorted mixture of hardwoods and conifers. All three pitfall traps were placed at each site (T1, T2 and T3) with southern exposure.

Kanderka hill is situated 1.5 km west of Tanád hill. Its altitude is 862.4 m a.s.l. Artificial spruce monoculture forms the dendroflora of its top. Three pitfall traps were placed on sites (K1, K2 and K3) exposed to North.

Sites

T1: 840 m a.s.l., xerothermophilous meadow.
T2: 850 m a.s.l., margin of the 40-year-old beech forest adjacent to the xerothermophilous meadow.
T3: 930 m a.s.l., forest composed of spruce, fir, beech, hornbeam and various shrubs.
K1: 760 m a.s.l., meadow.
K2: 780 m a.s.l., margin of mature spruce forest adjacent to meadow.
K3: 730 m a.s.l., beech forest with admixture of fir and spruce.

Methods

Harvestman communities were investigated at the studied sites during 1999 and 2000 by pitfall trapping. The traps were installed on 2.4.1999 and 26.4.2000 and the material was collected from the traps on: 26.4. 26.6., 30.7., 26.8., 26.9., 30.10. (in 1999) and on 20.6., 27.7., 26.8., 29.9. and 30.10. (in 2000). Cylindrical glass cans, a mouth of 7.5 cm, a depth of 14 cm, were used as the pitfalls and were filled with 4% formaldehyde to one-third of their capacity.

The collected harvestmen were classified to the species according to Martens (1978) and Šilhavý (1956, 1971). Animals of early ontogenetic stages were excluded from classification. Harvestmen names follow Martens (1978). Sex was determined only for the adults. Material was stored in 70% alcohol at the author's institution.

The similarity of sites and species was evaluated by hierarchical clustering and by Principal Components Analysis (PCA) based on the data on the total species abundance found in the individual sites over the entire period of investigation. The data were transformed before their analysis by log (n + 1) transformation (n = number of captured individuals). The dendrograms of cluster analysis were produced using the software STATISTICA for Windows 5.1. (StatSoft, Inc., 1999) with Euclidean distance and Ward´s clustering algorithm. Principal Components Analysis was performed by the software Canoco for Windows (Ter Braak and Šmilauer, 1998). The index of species diversity (*H'*) and the index of species equitability (*E*) were calculated according to Odum (1971) using natural logarithm *ln*.

Results

In total, 1.080 harvestmen individuals belonging to 14 species from 4 families were obtained. 1.014 ind. have been assigned to the species. Most species (10) belonged to the family Phalangiidae. The most abundant species was *Zachaeus crista* (263 ind., i. e. 24% of all individuals obtained). Selected parameters for the species and harvestman communities are shown in Table 1.

A higher number of individuals (611 ind.) was obtained in 1999 compared to 2000 (469 ind.). The decrease in the number of obtained individuals from 1999 to 2000 was especially evident in the hygrophilous species, for example *Platybunus bucephalus* (53 ind. in 1999 and 21 ind. in 2000). On the other hand, the xerothermophilous species *Zachaeus crista* was found in considerably higher numbers in 2000 (75 ind. in 1999 and 188 ind. in 2000).

Most species are considered as hygrophilous (*Nemastoma lugubre*, *Mitostoma chrysomelas*, *Dicranolasma scabrum*, *Trogulus nepaeformis*, *Lophopilio palpinalis*, *Lacinius ephippiatus* and *Astrobunus laevipes*), based on their preference to the wet habitats. A smaller number were of euryoecious species (*Phalangium opilio*, *Platybunus bucephalus*, *Oligolophus tridens*, *Mitopus morio*), and the smallest group was formed by xerothermophilous species (*Zachaeus crista*, *Lacinius horridus* and *Lacinius dentiger*). Only 4 species occurred in all sites (*Nemastoma lugubre*, *Zachaeus crista*, *Oligolophus tridens*, *Lacinius ephippiatus*). The xerothermophilous species dominated, especially in the uncovered sites T1 and K1 exposed to the sun. Hygrophilous species dominated in the sites situated in the forest (T3 and K3).

Based on the results of cluster analysis of similarity of species composition of harvestmen at different sites, the studied sites were divided into two main clusters (Fig. 1). The first cluster included two subclusters. Each of them comprised the meadow site and the ecotone site situated on the same hill. Sites K1 and K2 showed the highest level of similarity among all the compared sites. The same number of species (11) was recorded in these sites (Table 1). These sites were also similar in terms of the number of captured individuals. The second main cluster included the forest sites located on both hills. The same number of species (8) and similar values of the diversity and equitability indexes were found for these sites. The smallest numbers of individuals were obtained in these sites. In contrast, the highest numbers of individuals were obtained on the meadow sites T1 and K1.

Table 1. Parameters about harvestmen species and taxocenoses on the sites studied in 1999 and 2000 (number of individuals (n), dominance [%], total number of individuals (Σind.), number of species (Σspp.), Shannon-Weaver index of species diversity (*H'*), index of species equitability (*E*))

Taxon	T1		T2		T3		K1		K2		K3	
	n	[%]	n	[%]	n	[%]	n	[%]	n	[%]	n	[%]
Nemastomatidae												
Nemastoma lugubre (Müller 1776)	81	27.7	7	5.2	5	7.5	39	18.1	58	27.5	10	10.8
Mitostoma chrysomelas (Hermann 1804)	4	1.4	1	0.7			12	5.6	15	7.1		
Dicranolasmatidae												
Dicranolasma scabrum (Herbst 1799)			1	0.7	1	1.5						
Trogulidae												
Trogulus nepaeformis (Scopoli 1763)			15	11.0	1	1.5			2	1.0	1	1.1
Phalangiidae												
Phalangium opilio (Linnaeus 1761)	69	23.6	14	10.3			10	4.7	4	1.9		
Platybunus bucephalus (C. L. Koch 1835)			2	1.5	21	31.3	4	1.9	18	8.5	29	31.2
Lophopilio palpinalis (Herbst 1799)			1	0.7			11	5.1	28	13.3	15	16.1
Zachaeus crista (Brullé 1832)	89	30.5	31	22.8	21	31.3	84	39.1	36	17.1	2	2.2
Oligolophus tridens (C. L. Koch 1836)	24	8.2	50	36.8	8	11.9	33	15.3	29	13.7	28	30.1
Lacinius horridus (Panzer 1794)	21	7.2	3	2.2			13	6.0	6	2.8		
Lacinius dentiger (C. L. Koch 1848)							1	0.5				
Lacinius ephippiatus (C. L. Koch 1835)	3	1.0	8	5.9	9	13.4	4	1.9	7	3.3	6	6.5
Mitopus morio (Fabricius 1799)			2	1.5	1	1.5	4	1.9	8	3.8	2	2.2
Astrobunus laevipes (Canestrini 1872)	1	0.3	1	0.7								
Σ ind.	292		136		67		215		211		93	
Σ spp.	8		13		8		11		11		8	
H'	1.579		1.854		1.633		1.837		2.053		1.650	
E	0.598		0.703		0.619		0.696		0.778		0.625	

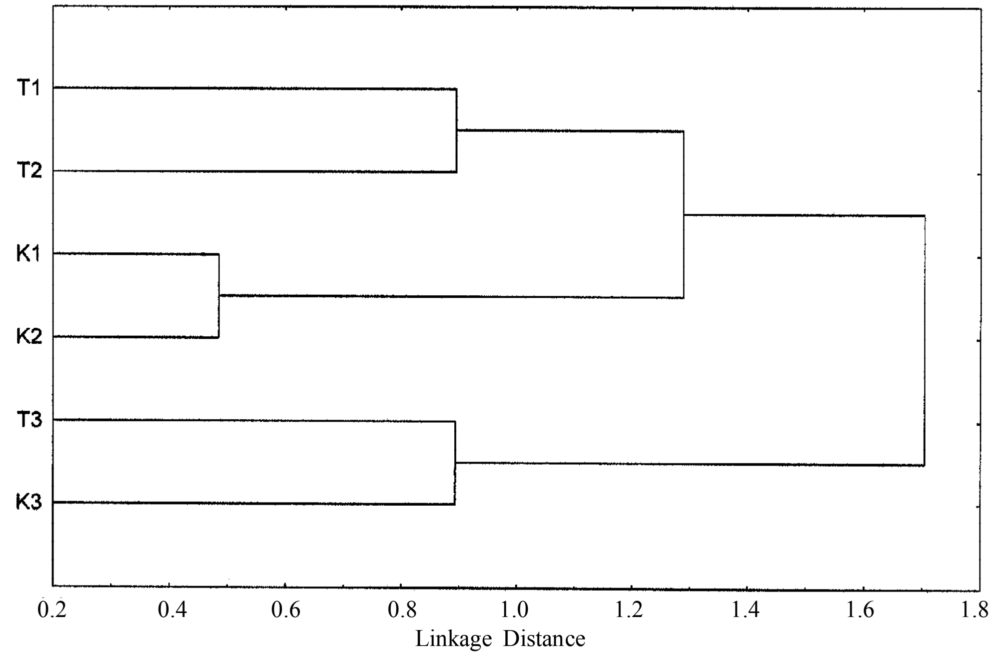

Fig. 1. Cluster analysis of the similarity of sites

Cluster analysis was used for the evaluation of species similarity as well (Fig. 2). The species with the lowest epigeic activity (*Dicranolasma scabrum*, *Astrobunus laevipes* and *Lacinius dentiger*) were not incorporated in the dendrogram. Among the other species, two main clusters (A and B) can be distinguished in the dendrogram. Cluster A was divided into two separate subclusters (A_1 a A_2). The first subcluster included the species with high epigeic activity on the meadows and in the ecotones (*Nemastoma lugubre*, *Oligolophus tridens* and *Zachaeus crista*). Subcluster A_2 included the other species, which differed according to their site preference. Cluster B comprised only one species, *Trogulus nepaeformis*, which preferred the ecotone sites (especially T3) and did not occur on the meadows.

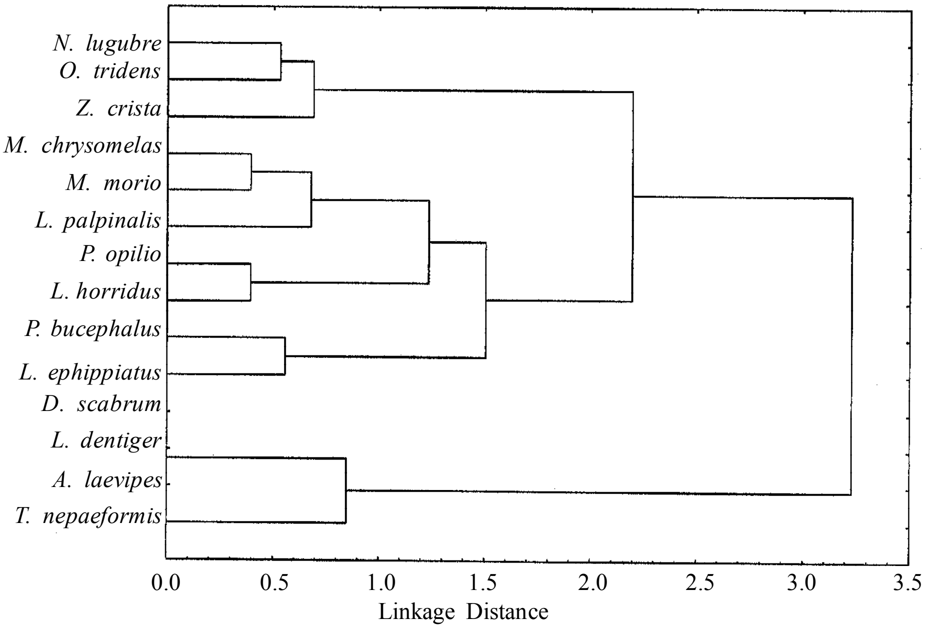

Fig. 2. Cluster analysis of the similarity of species

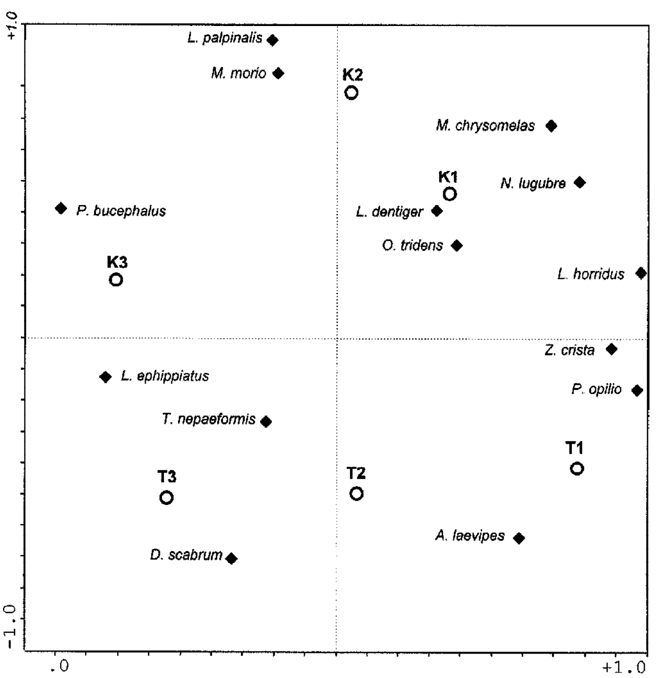

Fig. 3. Ordination (PCA) of species on individual sites

In the Fig. 3 produced using PCA, the species are distributed along Axis 1 according to their preferred biotope, and along Axis 2 according to their preferred type of exposure. Basically, in this distribution, the left part of the graph includes the species that were mainly typical for the forest sites on both of the studied hills. The right part of the graph includes the species that were typical mainly for the meadow sites. The rare Ponto-mediterranean species *Dicranolasma scabrum* and *Astrobunus laevipes*, which occurred only in the sites with the southern exposure on the Tanád hill (Table 1), are contained in the lower part of the graph. The species *Dicranolasma scabrum* preferred the forest sites or the ecotone sites, whereas the species *Astrobunus laevipes* preferred the meadows or the ecotone sites on this hill. The species with the highest epigeic activity on the sites situated on the Kanderka hill (exposed to North) are concentrated in the top part of the graph.

Discussion

The obtained results indicate that the exposure had influence on harvestman communities only for the meadows and for the ecotone sites, whereas the type of biotope influenced the species composition above all in the forest sites situated on both hills. This probably results from the differences between the microclimates of these biotopes. The influence of the exposure on the microclimate of the near-ground air layer is lower in forest stands than in open sites, where the heat from sun is not absorbed by the crown layer. The intensity of sunshine depends on the angle of its incidence on the surface, which depends on the exposure. Therefore, the exposure markedly influences the temperature conditions in the near-ground air layer in open sites. Open biotopes have also higher oscillations in temperature and humidity than covered forest biotopes. Gulička (1957) also found the highest similarity between ecotone biotopes and open biotopes in terms of the species composition of harvestmen when he compared between three biotopes (meadow, ecotone, forest) in Čierny Les Island near Gabčíkovo (Slovakia).

As to the species composition, the different similarity degrees between the meadow and the ecotone on the Tanád hill and on the Kanderka hill revealed by cluster analysis may be caused by differences in microclimate on these hills. There were probably greater differences in temperature and moisture conditions between the meadow and the ecotone site on the Tanád hill (exposed to South) than between the meadow and the ecotone site on the Kanderka hill (exposed to North). The meadow on the Kanderka hill has northern exposure and steep slope (circa 40°). Direct sunlight striking upon the herbaceous cover is only present for a very short part of day. Therefore, there are probably no great differences between the microclimate of the ecotone site and of the meadow in comparison with the Tanád hill.

The ecotone sites (T2 and K2) showed the highest diversity and equitability from all the studied sites. Several authors have studied harvestman communities of ecotone biotopes. For example, Stašiov et al. (1997) studied selected sites in the Kysuce PLA (Slovakia). The author showed that harvestman communities of the ecotone between a fir-beech forest with a mixture of spruce and a spruce forest were characterised by higher epigeic activity and also by higher species diversity than harvestman communities within the concerned forests. Bokor (1993) and Bokor and Tóthmérész (1998) showed that epigeic activity of harvestman communities was twice as high in an ecotone between a beech forest and a cutting as in the concerned beech forest in the Bükk Mts. (Hungary). Klimeš and Špičáková (1984) discovered the highest diversity and epigeic activity of Opiliones in an ecotone between a lime-oak forest with a mixture of hornbeam and a meadow near Mladeč (the Czech Republic).

This research upgrades our knowledge of the ecology of the studied harvestmen species, and presents new information about the preference of some species for certain biotopes. The highest epigeic activity of *Lacinius horridus*, *Phalangium opilio*, *Zachaeus crista* and *Nemastoma lugubre* recorded in the meadow on the both hills indicates that these species probably prefer the meadow biotopes. *Platybunus bucephalus* mainly preferred forest sites. On the other hand, *Mitostoma chrysomelas* avoided the forest sites and *Trogulus nepaeformis* avoided the meadow sites. The species *Phalangium opilio* and *Platybunus bucephalus* were generally considered to be euryoecious species and *Nemastoma lugubre* and *Mitostoma chrysomelas* have been considered to be hygrophilous species up to now. New information about the preference of these species for certain biotopes shows that their ecological description should be reevaluated. For example, Stašiov (2002a) reported the preference of *Nemastoma lugubre* for open sites. This author studied opiliocenoses in forest stands with various stocking in submontane beech forests in the Kremnické Vrchy Mts. (Slovakia). He recorded the highest epigeic activity of this species in the stand with the lowest stocking of all of the compared stands. Klimeš (1997) reported that the occurrence of *Mitostoma chrysomelas* is closely correlated with the light conditions of sites, based on an analysis of data from 117 localities in the Czech Republic. The occurrence of *Dicranolasma scabrum* and *Astrobunus laevipes* only at the sites situated on the Tanád hill strongly suggests these species preference for sites with southern exposure. The relationship of *Dicranolasma scabrum* to southern exposure has been noticed by Stašiov (2002b). The species *Lophopilio palpinalis*, *Mitopus morio* and *Mitostoma chrysomelas* especially preferred the sites with northern exposure.

Conclusions

In total, 14 species of harvestmen were recorded on two hills in the Štiavnické Vrchy Mts. during 1999 and 2000. An influence of exposure on harvestman communities became evident only on the meadows and at the forest edge. *Dicranolasma scabrum* was the only species that preferred the same exposure (southern) in all three habitat types. The most similar biotopes were the forest and ecotone with southern exposure and meadow and ecotone with northern exposure.

Translated by the author

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Spoločenstvá koscov na dvoch kopcoch v CHKO Štiavnické Vrchy (Opiliones)

Súhrn

Práca prináša výsledky výskumu zameraného na posúdenie vplyvu expozície a typu biotopu na spoločenstvá koscov realizovaného na dvoch kopcoch v CHKO Štiavnické vrchy metódou zemných pascí v rokoch 1999 a 2000. Na každom kopci boli umiestnené po tri zemné pasce, prvá na lúke, druhá v ekotone lúky a lesa a tretia v lese. Na kopci Tanad mali všetky biotopy južnú a na kopci Kanderka severnú expozíciu. Celkovo bol na sledovanom území zistený výskyt 14 druhov koscov. Vplyv expozície sa prejavil najmä na lúčnych a ekotonových biotopoch. *Dicranolasma scabrum* (Herbst, 1799) bol jediným koscom, ktorý preferoval južnú expozíciu na všetkých troch typoch biotopov. Z hľadiska druhovej štruktúry spoločenstiev koscov boli najpodobnejšími biotopmi les a ekoton s južnou expozíciou a lúka a ekoton so severnou expozíciou.

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Evaluation of nitrate and ammonium nitrogen concentrations in a water course in the Tribeč Mountains

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Abstract

NOSKOVIČ, J., SOZANSKÝ, P. 2005. Evaluation of nitrate and amonium nitrogen concentrations in a water course in the Tribeč Mountains. *Folia oecol.*, 32: 22–28.

We evaluated nitrate and ammonium nitrogen concentrations in the water course "Hostiansky potok" in the Tribeč Mountains. The study run over the years 1995–1998. The mean nitrate nitrogen concentration for the whole research period was found to be 1.06 mg dm^{-3}. The maximum monthly mean N-NO$_3^-$ concentration was observed in January, the minimum in August. No significant effect of the sampling sites on the N-NO$_3^-$ concentrations was manifested. Comparing to the nitrate nitrogen concentrations, the mean ammonium nitrogen concentrations were markedly lower over the whole period. The highest N-NH$_4^+$ concentrations were determined in July and December, the lowest in October and November. Based on the calculated N-NO$_3^-$ characteristic values (STN 75 7221), the waters in all the sampling sites were assigned to the second class of surface water quality (clean water) and on the basis of the calculated N-NH$_4^+$ characteristic values, the waters in all sampling sites belonged to the first class of surface water quality (very clean water).

Key words

water course, nitrate nitrogen, ammonium nitrogen, surface water quality

Introduction

Nitrogen compounds in surface and ground waters occur in both organic and inorganic forms that are represented by ammonium, nitrite and nitrate nitrogen. These forms can be transformed in terms of biology and chemistry (NOSKOVIČ, 1997).

The thermodynamically most stable and therefore most frequent forms of inorganic nitrogen include the nitrate nitrogen – very well soluble in water and persistent in aerobic conditions (BŰCHLEROVÁ and OLEJKO, 2002). The nitrate nitrogen concentrations in clear ground and surface waters are mg dm^{-3} by order. In the polluted waters they can reach from tens to hundreds mg dm^{-3} (PITTER, 1999). Most nitrate nitrogen in the water is secondary – originating by the nitrification of the ammonium nitrogen. The important sources of nitrate nitrogen in the surface waters are rinsing and sewage from agricultural soils fertilised with nitrogen fertilisers (GÁBRIŠ et al., 1998). Other nitrate nitrogen sources are atmospheric rainfall (NOSKOVIČ and GÁBRIŠ, 1995) and drainage waters (GERGEL, 1990). According to NOSKOVIČ (1992), as for the nitrate nitrogen concentration, water quality in a water course is also affected by the ecosystems in the catchment. The author observed the N-NO$_3^-$ concentrations in the waters of a water course were higher in an agricultural ecosystem with prevailing arable soils than in an ecosystem with permanent grass cover and a forest ecosystem, too.

Compared to the nitrate nitrogen, the concentrations of ammonium nitrogen are lower, with the values in clear ground and surface waters not higher than 0.1 mg dm^{-3} (Pitter, 1999). Under favourable conditions, ammonium nitrogen is oxidised by nitrifying bacteria to nitrites and nitrates. The nitrates are the final product of the mineralization of the organic-bound nitrogen (Štepánek et al., 1979).

The main sources of surface water pollution with ammonium nitrogen are sewage waters, wastes from the agricultural production (silage juices, dung-water), some industrial waste waters, atmospheric waters and nitrogen fertilisers (Gábriš et al., 1998). The ammonium nitrogen can originate directly in surface waters – by degradation of the organic nitrogen matter from dead plants and animals (Pitter, 1999).

Because higher nitrate and ammonium nitrogen concentrations in the surface waters can cause serious ecological problems, according to the STN 75 7221 – Classification of the surface water quality, they belong to the indicators through which the surface waters are classified to the classes of the water cleanness.

Material and methods

The catchment description

The nitrate and ammonium nitrogen concentrations were monitored and evaluated in the upper part of the Hostiansky potok. The upper part of the stream, together with its head, is situated in the Tribeč Mountains. The lower part is situated in the upland Žitavská pahorkatina. The water course belongs to the catchment area of the Žitava River, in which it issues under the town of Zlaté Moravce – part Chyzerovce. The whole catchment of the water course has an area of 120 km^2. The mean annual discharge to the Žitava River is 0.94 m^3 s^{-1}.

The catchment area of the water course in the Tribeč Mts. consists of a forest ecosystem and a permanent grass ecosystem. In the forest ecosystem are dominant these woody plants: *Fagus sylvatica, Quercus cerris, Quercus petraea, Quercus robur, Quercus daleschampii* and *Carpinus betulus*. In the lower part are characteristic: *Alnus glutinosa, Alnus incana, Fraxinus excelsior, Salix eleagnos* and *Salix triandra*.

The Tribeč Mts. belong to the Secondary zone of the Carpathians Mts. The soils are represented by ranker, rendzina, pararendzina, cambisol and luvisol.

As for the climate, the catchment in the Tribeč Mts. belongs to the transition and partially to the warm region which is represented by the subhumic lowland area. Depending on the relief, the transition region, which covers the biggest part of the catchment, is divided into the moderate warm subhumic valley – in winter a possible frost hollow and the mountain area.

Material sampling and processing

Water samples from the water course were taken regularly, always within the last ten days of the current month. The sampling ran over the period 1995–1998. The samples were taken from the streamline. In the observed segment of the water course we have established three sampling sites:

1. The forest ecosystem at an altitude of 300 m above sea level. The area is covered with a high forest.
2. Below the permanent grass ecosystem on the left side and the forest ecosystem on the right side of the water course. The length of the segment is 1.6 km.
3. Below the permanent grass ecosystem on both sides of the water course closely above the village Hostie. The length of the segment is 1.6 km.

In the samples we determined contents of N-NO$_3^-$ (using colorimetry with phenoldisulphonic acid) and N-NH$_4^+$ (colorimetry with the Nessler's reagent). The classification of the water from the sampling sites to the classes of the surface water quality was accomplished by comparing the calculated characteristic values of N-NO$_3^-$ and N-NH$_4^+$ with the corresponding limit values for the classes of surface water quality (STN 75 7221).

Results and discussion

From the Fig. 1 it follows that the mean nitrate nitrogen concentrations over the research period ranged from 1.02 mg dm^{-3} (years 1997, 1998) to 1.12 mg dm^{-3} (1996) and for the whole research period, the mean nitrate nitrogen concentration was 1.06 mg dm^{-3}. These values are higher than those obtained by Dubová and Bublinec (1997) for water courses in the Poľana Mts. This is probably related to different soil and climatic conditions and also to different wood species composition (in the Poľana Mts. are dominant coniferous trees) in the two mountain systems.

The mean nitrate nitrogen concentrations in dependence on the sampling time show (Fig. 2) that the highest values in the experimental years were generally reached in late autumn season, winter and early spring seasons. The only exception was the year 1998 when the highest value of N-NO$_3^-$ was observed in September. The maximum mean nitrate nitrogen concentration over the whole research period was reached in January (1.42 mg dm^{-3}) and minimum in August (0.63 mg dm^{-3}). Similarly, seasonal dynamics of the nitrate nitrogen concentration in some water courses of the East Slovak plain have also been determined by Ivančo and Paveleková (1999). Noskovič (1989) also reports the highest nitrate nitrogen values out of the vegetation period in water courses in the upper part of the Hornád River catchment.

The increase in the mean nitrate nitrogen concentrations in the water course out of the vegetation period is easy to explain because N-NO$_3^-$ occurring in the soil is not absorbed by the plants and, consequently, primarily the soil from slopes can be washed away to water courses.

The higher nitrate nitrogen concentration in September 1998 was probably related to the intensive rainfall running off the soil with nitrate nitrogen in the water course (Table 1). Several authors (Gábriš and Šujanská, 1985; Noskovič, 1989; Kvítek, 1999) agree that the N-NO$_3^-$ concentrations in water courses in-

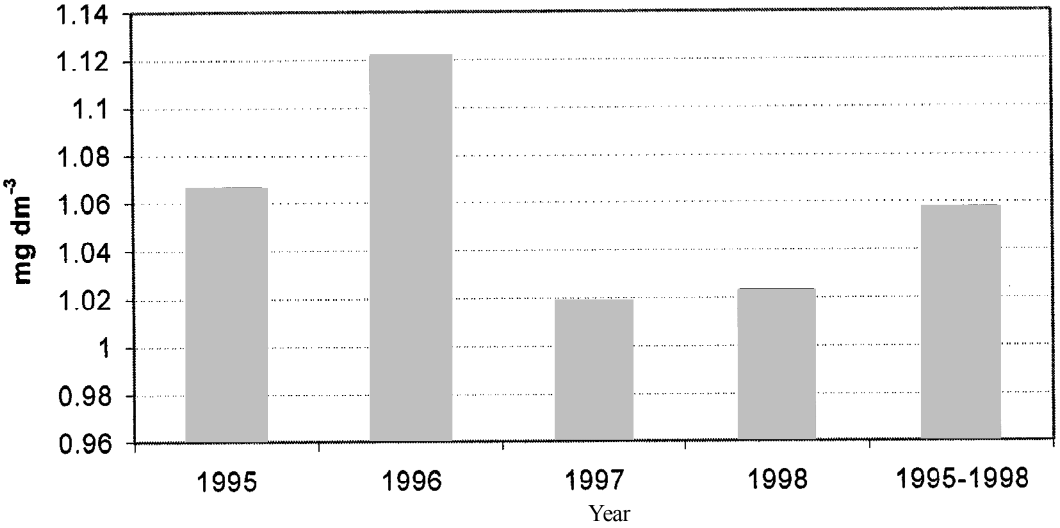

Fig. 1. The mean annual N-NO$_3^-$

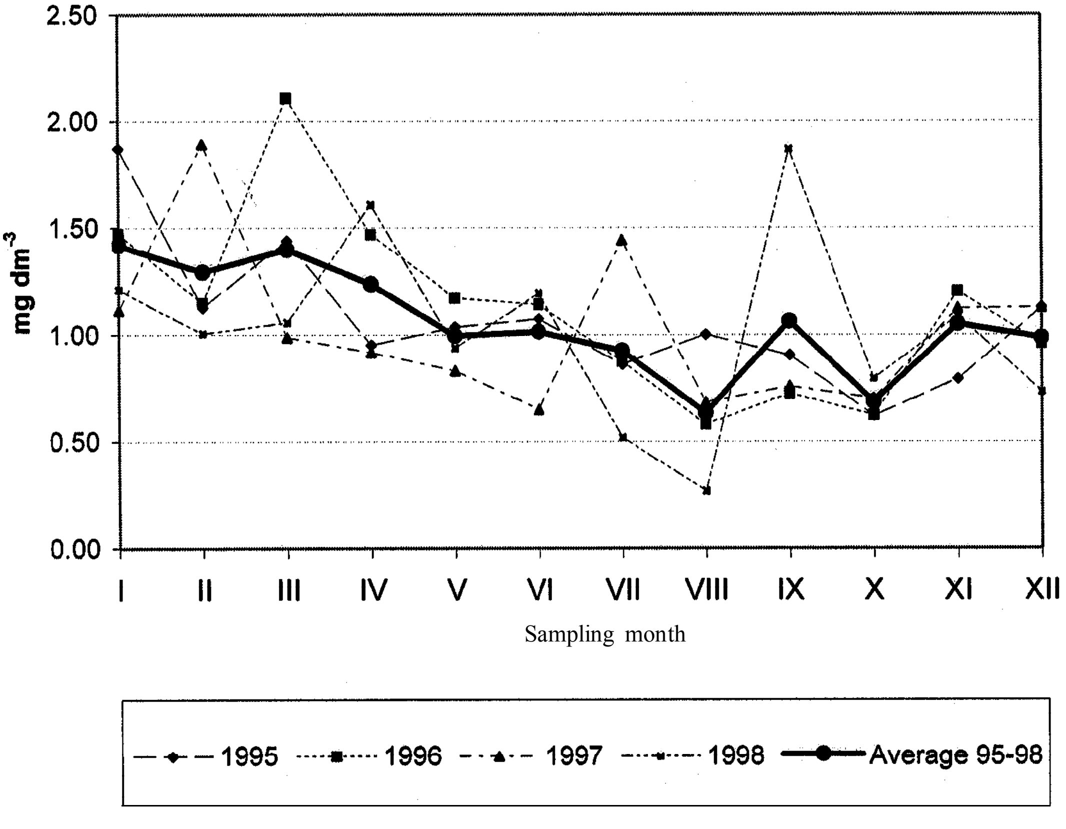

Fig. 2. The mean annual N-NO$_3^-$ concentrations depending on the sampling time

crease as a result of the increased rainfall. Other important source of the nitrogen (N-NO$_3^-$, N-NH$_4^+$) is the rainfall on its own (Noskovič and Gábriš, 1995; (Dubová and Bublinec, 1998; Pitter, 1999).

The effect of the sampling site on the nitrate nitrogen concentration was not found significant (Fig. 3). During the whole research period, its mean values in the observed part of the water course ranged

Table 1. Mean monthly and annual values of air temperature and rainfall over the period 1995–1998 (Tesárske Mlyňany)

Month	1995 Rainfall mm	1995 Temp. °C	1996 Rainfall mm	1996 Temp. °C	1997 Rainfall mm	1997 Temp. °C	1998 Rainfall Mm	1998 Temp. °C
January	44.70	–1.4	50.20	–2.0	18.20	–2.4	15.20	2.0
February	48.50	4.4	27.50	–2.8	28.20	1.4	0.10	4.6
March	52.00	4.1	12.00	1.8	10.00	4.5	15.10	3.7
April	59.70	10.2	69.10	11.1	41.80	7.0	50.90	11.6
May	90.10	14.4	97.90	16.2	58.40	15.8	34.10	14.9
June	69.40	17.5	71.10	18.9	58.70	18.5	29.40	19.5
July	6.90	22.8	75.10	18.0	93.30	18.9	41.10	20.9
August	60.10	19.5	65.60	19.2	16.90	20.4	38.80	20.5
September	67.90	13.8	56.00	11.8	14.80	15.1	114.10	14.9
October	9.10	10.9	27.20	10.5	32.70	7.3	89.90	10.5
November	31.40	2.2	41.20	7.1	109.40	5.3	33.10	1.8
December	52.60	0.2	25.90	–2.4	17.10	2.4	18.60	2.6
Annual rainfall	592.40		618.80		499.50		480.40	
Mean annual temperature		9.88		8.95		9.52		10.62

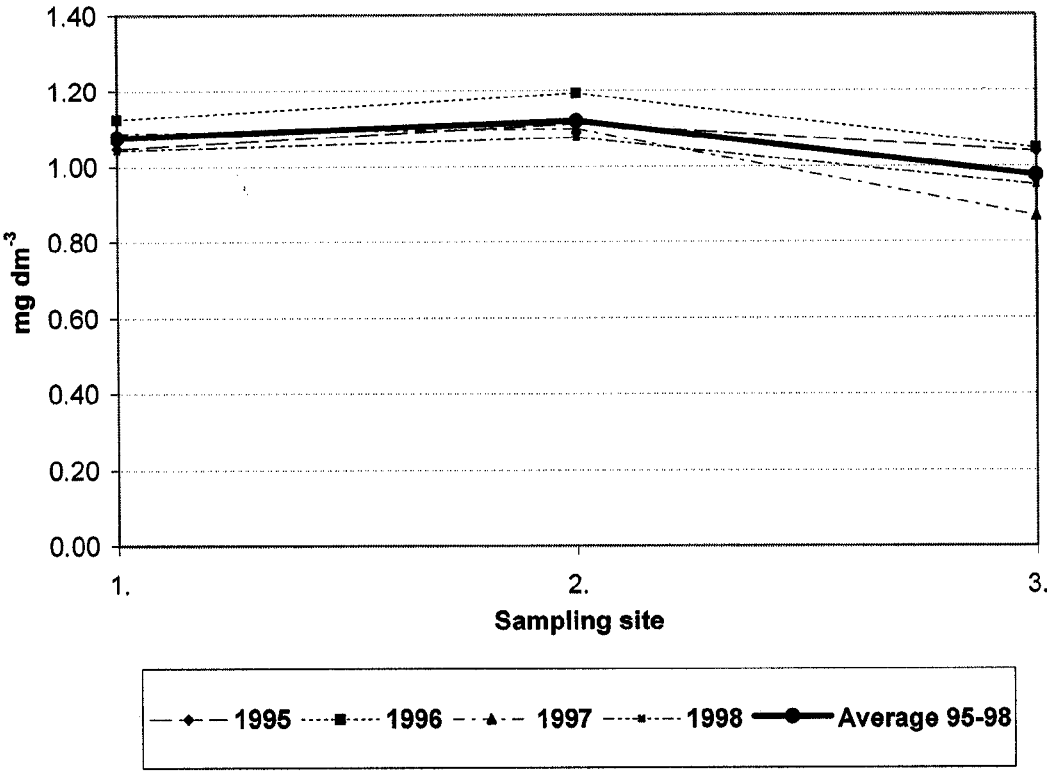

Fig. 3. The mean annual N-NO$_3^-$ concentrations depending on the sampling site

from 0.98 (3rd sampling site) to 1.12 mg dm^{-3} (2nd sampling site). These concentrations can be considered low, especially when compared to the concentrations determined by Nosković (1989) for water courses having in their catchments agricultural ecosystems with prevailing arable land and flowing across settled areas.

The calculated characteristic N-NO$_3^-$ values (Table 2) according to the STN 75 7221 – Classification of the surface water quality classify the waters in all the sampling sites in the studied part of the water course to the 2nd class of the surface water quality (clean water).

The ammonium nitrogen is a precursor of nitrite nitrogen (transition form) and nitrate nitrogen (Gábriš et al., 1996). This is probably the main reason why the mean N-NH$_4^+$ concentrations (Fig. 4) during the research period were markedly lower compared to the N-NO$_3^-$ concentrations. For the whole research period the mean N-NH$_4^+$ value was 0.06 mg dm^{-3}.

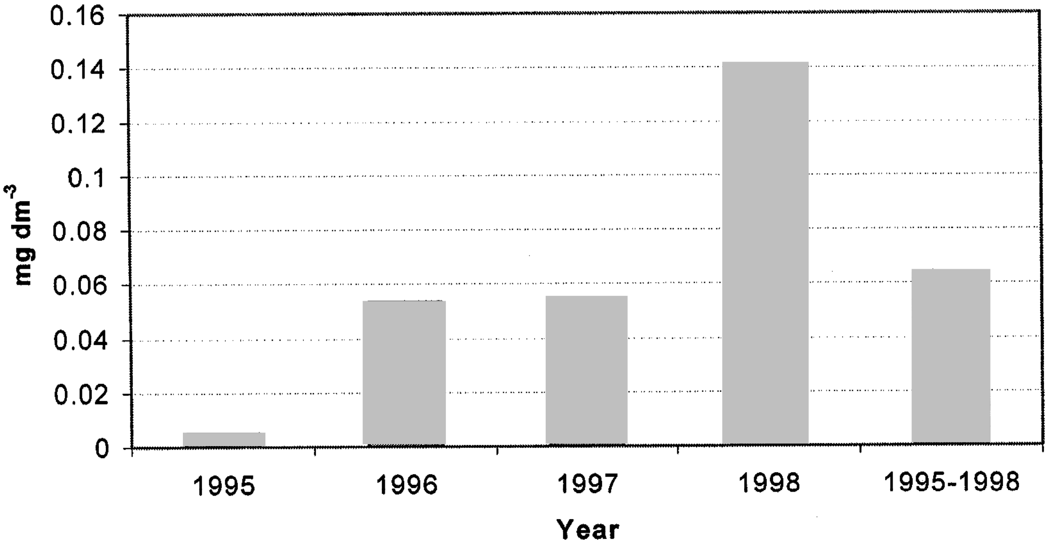

Fig. 4. The mean annual N-NH$_4^+$ concentrations

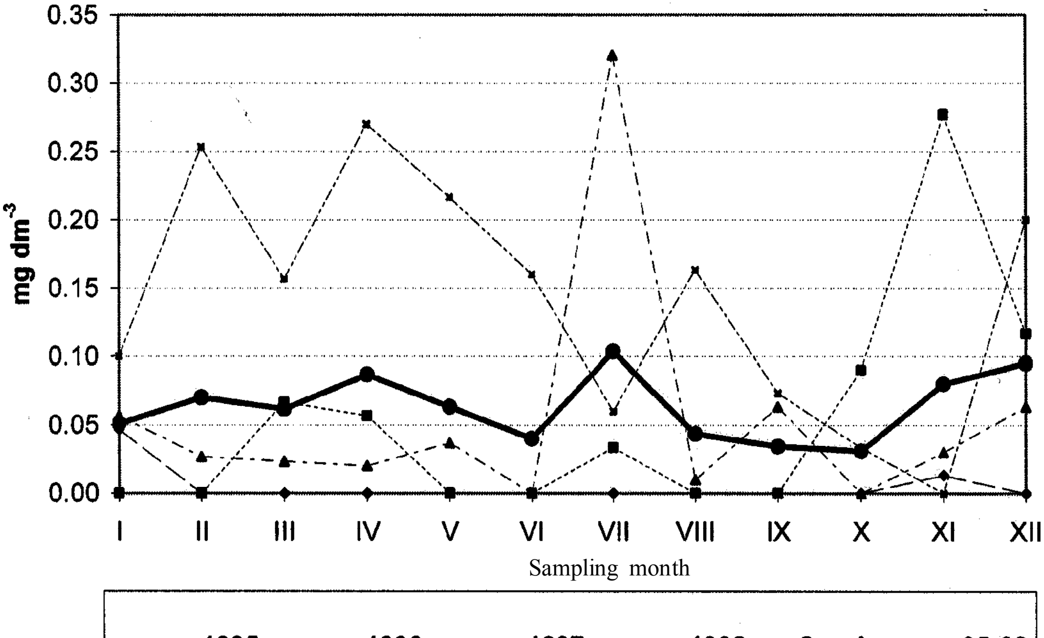

Fig. 5. The mean annual N-NH$_4^+$ concentrations depending on the sampling time

The mean ammonium nitrogen concentration values fluctuated and the fluctuation intervals were different in different years (Fig. 5). The highest N-NH4$^+$ concentrations during the whole research period were determined in July and December and the lowest in September and October.

Generally, in all the study years we observed an increase in the ammonium nitrogen concentration in the 2nd sampling site (Fig. 6). For the whole research period was the lowest concentration found in the 3rd sampling site and the highest in the 2nd sampling site.

Based on the characteristic values (Table 2) calculated according to the STN 75 7221, the waters of all sampling sites in the observed part of the water course belong the 1st class of the surface water quality (very clean water).

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Table 2. Calculated characteristic values of N-NO$_3^-$ and N-NH$_4^+$

Indicator	Sampling sites		
	1.	2.	3.
N-NO$_3^-$	1.63	1.76	1.48
N-NH$_4^+$	0.18	0.23	0.16

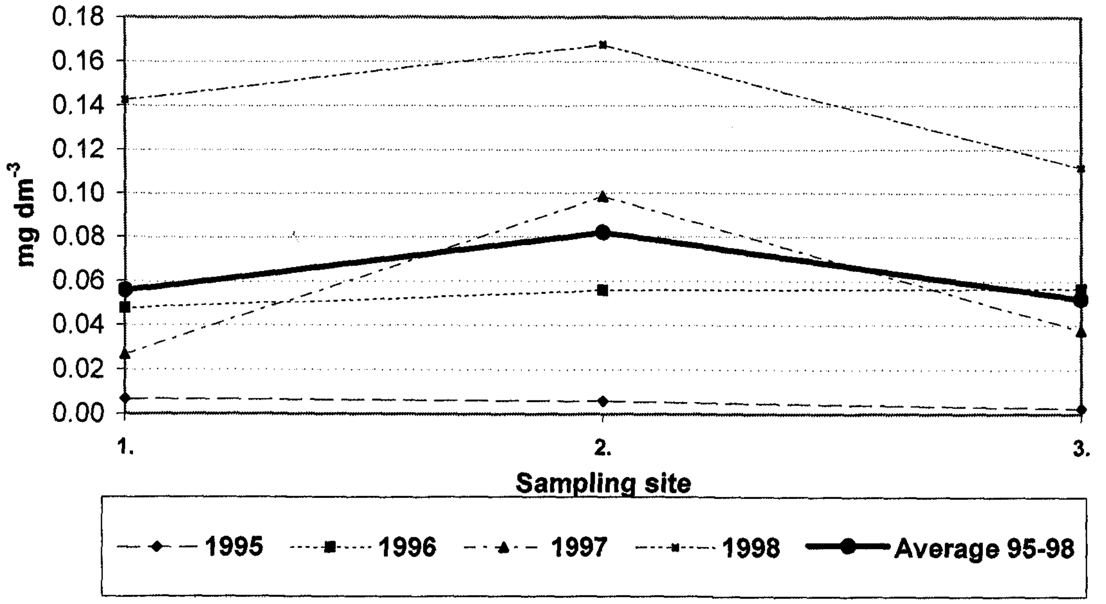

Fig. 6. The mean annual N-NH$_4^+$ concentrations depending on the sampling site

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Hodnotenie koncentrácií dusičnanového a amónneho dusíka vo vodnom toku v pohorí Tribeč

Súhrn

Vo vodnom toku Hostiansky potok v pohorí Tribeč sa v rokoch 1995–1998 hodnotila koncentrácia dusičnanového a amónneho dusíka. Z výsledkov vyplýva, že priemerná koncentrácia dusičnanového dusíka za celé obdobie bola 1,06 mg.dm^{-3}. Maximálna priemerná koncentrácia N-NO$_3^-$ za celé pokusné obdobie bola v mesiaci január a minimálna v mesiaci august. Vplyv odberových miest na koncentráciu dusičnanového dusíka sa výraznejšie neprejavil. Priemerná koncentrácia amónneho dusíka za celé pokusné obdobie bola v porovnaní s dusičnanovým dusíkom výrazne nižšia. Najvyššia koncentrácia N-NH$_4^+$ za celé pokusné obdobie sa zistila v mesiacoch júl a december, najnižšia v mesiacoch október a november. Vypočítané charakteristické hodnoty N-NO$_3^-$ (STN 75 7221) zaraďujú všetky odberové miesta do II. triedy kvality (čistá voda) a vypočítané charakteristické hodnoty N-NH$_4^+$ zaraďujú všetky odberové miesta do I. triedy kvality (veľmi čistá voda).

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Comparison between biomass production in *Galium odoratum* L. in beech stands with different intensity of load by airborn pollutants

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Abstrakt

Havranová I. 2005. Comparison between biomass production in *Galium odoratum* L. in beech stands with different intensity of load by airborn pollutants. *Folia oecol.*, 32: 29–32.

We observed aboveground and belowground biomass production in *Galium odoratum* growing in beech stands belonging to the group of forest types Fagetum pauper. The research run in 1999, in localities with different intensity of load by airborn pollutants. We observed also length parameters of the examined species. From the results it follows that the lowest production (aboveground, belowground and total) was recorded next to the aluminium plant in Žiar nad Hronom where was the total biomass production 1.651 g m^{-2} and the proportion of the aboveground biomass was 68.9% (1.137 g m^{-2}). The other localities, situated at greater distances from the pollutant source had larger production values (except to locality 4), ranging from 2.823 g m^{-2} (EES Kremnické vrchy Mts.) to 4.787 g m^{-2} (Hudcov vrch). The mean height of the individual plants ranged from 14.57 cm (Žiar nad Hronom) to 25.3 cm (Gráfovská).

Keywords
production, *Galium odoratum*, beech stands, airborn pollutants

Introduction

At present, airborn pollutants and the overall anthropic load become to be more and more pressing problems. An important indicator reflecting the changes in the immission situation is the biomass production. In areas with worsened air quality, changes in qualitative and quantitative composition of the phytocoenoses correspond to the different resistance and sensibility of the relevant plants. In our work we compare the production capacity of the species *Galium odoratum* in sites with different intensities of loading by airborn pollutants. The obtained knowledge can contribute to better understanding of processes running in forest ecosystems.

Material and methods

The study into the biomass of *Galium odoratum* was performed in beech stands, in sites situated at different distances from the pollutant sources. The field study was accomplished in June 1999. The monitoring plots were chosen in such a way as to reflect the supposed immission load on the area and the prevailing wind direction and, simultaneously, to represent the same permanent ecological conditions. Several authors mean that the control plot situated in the Beech Ecological Experimental Stationary (BEES) Kremnické vrchy Mts. (Kontriš and Kontrišová, 1993; Ditmarová, 2001; Machava, 2002) can be considered as almost without any pollutant load. The basic characteristics of the research plots are listed in Table 1. With respect to a considerable heterogeneity in species and non-uniform herbal cover in the forest community at the site, the total biomass amount was determined using the method of indirect sampling (Kubíček, 1977). We measured the biomass on a plot of a phytocoenological relevé, 20 x 20 m in dimensions, on which we selected by random choice (Šmelko, 1998) 7 representative squares, each with dimensions of 1 x 1 m. The number of the species and the numbers of individual plants belonging to each species were determined on each square.

The plant material sampling was performed over the whole relevé plot. We collected simultaneously aboveground and belowground biomass. The sample size in each species was chosen in such a way (30) as to ensure the required sensitivity of the experiment (Brechtl and Kubíček, 1968). In the laboratory, we separated the material into aboveground and belowground fractions, measured the length of the aboveground parts, dried at 85°C and weighed. The oven-dried mass is obtained at 105°C, on the other hand, the temperature of 85°C is still not associated with organic material decomposition, and for the future we also plan to subject the collected plant material to chemical analyses (Jakrlová in Dykyjová, 1989).

From the total weight of the plants of *Galium odoratum* we calculated the mean weight of a plant, and after the multiplication by the number of plants on the plot we obtained the total weight of the given species per unit area.

Results and discussion

The total biomass production on the permanent monitoring plot (PMP) Žiar nad Hronom is 1.651 g m^{-2}, from which is the aboveground biomass proportion 68.9% (1.137 g m^{-2}). In the BEES Kremnické vrchy Mts. is the aboveground biomass proportion (1.837 g m^{-2}) 65.1% from the total production amount (2.823 g m^{-2}, Table 2). Kováčová and Schieber (2002) report for the total production in the same species in the BEES a value of 2.088 g m^{-2} in year 1994 and a value of 3.62 g m^{-2} in year 1995. The June values were 2.175 g m^{-2} in 1994 and 2.944 g m^{-2} in 1995. Their results well correspond to our results. On the same plot in the BEES, in the spring aspect 1993, found Janík (1996) a total production value in *Galium odoratum* 2.4 g m^{-2} and in year 1993 a value of 0.9 g m^{-2}. From these results it follows that the total biomass production in *Galium odoratum* in the BEES Kremnické vrchy Mts. is by 1.172 g m^{-2} higher than in proximity of the pollution source. The lower production on the PMP is also influenced by a considerable drop in the soil pH value, which is by 1° lower compared to the BEES (Table 1). Similar was the opinion of Kontriš, Kontrišová (Kontrišová, 1998) in the case of the species *Gladiolus gandavensis*. The creation of dry matter was lower on the plot loaded by airborn pollutants than on the control plot (BEES), because of the overall weaker health stand of trees on the loaded plot. The same reports Kontrišová (1998) for the creation of dry matter and for needle length in *Pinus nigra* (both values increase with increasing distance from the pollution source). Similar situation was in our case where the highest biomass production (aboveground and underground) was found on the plot Hudcov vrch, most remote (in the prevailing wind direction) from the pollutant source. The total biomass production in this site was 4.787 g m^{-2}. A high value of biomass production was also found on the plot in Gráfovská (3.008 g m^{-2}). The last

Table 1. Basic characteristics of studied geobiocoenoses

Geomorph. unit	Štiavnické Vrchy Mts.				Kremnické vrchy Mts.
Plot	PMP (1 Žiar n. Hr.	Gráfovská	Vydričná valley	Hudcov vrch	BEES (2 Kováčová
	1	2	3	4	5 (Control)
Immission source [km]	2	3	5	7	18
Slope situation	Turned towards	Reverse	Turned towards	Reverse	Turned towards
Exposure	NNW	WSW	NNW	SW	WSW
Altitude[m]	470	204	433	510	470–490
Inclination[?]	5–10	15	25	20–25	20
Annual precipitation [mm]	750	750	750	750	778
Annual temperature [° C]	7.6	7–8			6.8
Parent rock	Loess loam, rhyolitic tuff agglomerates		Andesite tuff agglomerates		
Soil Type	Cambisol				
Subtype	Luvisol, psedo-gley		Modal		
Group of forest types	Fagetum pauper inferiora				
Stand age [y.]	70	80	70	80	96
Stocking	0.7–0.8	0.7	0.7	0.6–0.8	0.9
Canopy[%]	80	90–100	90	90–100	90–100
pH H_2O [at 10 cm]	4.96	5.71	5.48	5.71	5.92

(1 PMP – Permanent monitoring plot

(2 BEES – Beech Ecological Experimental Stationary

two plots had values of both total and aboveground biomass production even higher than our control plot (BEES). The only exception was the plot in the Vydričná valley, where we found the smallest value in *Galium odoratum* production from all the sites. At the same time, on this plot was also found the lowest amount of this species – only 12 ps m^{-2}. This state can be a consequence of worse light conditions at the site (not measured but pointed out by greater length of the individual plants). An important contribution could be expected from chemical analysis of the individual plant organs planned in the course of the future research.

The vitality of *Galium odoratum* growing in the individual examined localities is reflected on the length characteristics of the aboveground plant organs (Fig. 1). The mean height ranged from 14.57 cm (PMP Žiar) to 25.3 cm (Gráfovská). The maximum height (38 cm) was found in the locality Gráfovská, the minimum (6 cm) in Žiar na Hronom. As we can see in the graph, the lowest values were measured on the PMP Žiar. The plants on the other plots were longer. Also in this case, was, similar to the production, plant length lower on the control plot. Supuka and Chladná (1996) evaluated the degree of loading by pollutants in 35 urban settlements. The highest amounts of sulphur (in needles of *Pinus sylvestris*) were found in Nová Baňa (1.4–3.08 mg g^{-1}) and Zvolen (1.5–2.9 mg g^{-1}). The highest amounts of fluoron were found in Žiar nad Hronom (0.032 mg g^{-1}). The value measured in Zvolen (0.025 mg g^{-1}), was the third highest, which well corresponds to lower values of plant characteristics on the control plot situated near the town.

Conclusions

In the research on the species *Galium odoratum* performed in 1999 we found the lowest aboveground (1.137 g m^{-2}) and belowground (0.514 g m^{-2}) biomass production in proximity of the aluminium plant in Žiar nad Hronom. With increasing distance (in prevailing wind direction) increased the production values and also the plant vitality. The highest total production,

Table 2. Biomass production in *Galium odoratum* L.

Locality	Weight of individual plant [g]		Total production [g m^{-2}]		Number ps m^{-2}
	Abovegr.	Undergr.	Abovegr.	Undergr.	
EES Kremnické v.	0.110	0.059	1.837	0.986	16.71
PMP Žiar	0.073	0.033	1.137	0.514	15.57
Gráfovská	0.152	0.036	2.432	0.576	16.0
Vydričná valley	0.046	0.014	0.552	0.168	12.0
Hudcov vrch	0.108	0.043	3.424	1.363	31.7

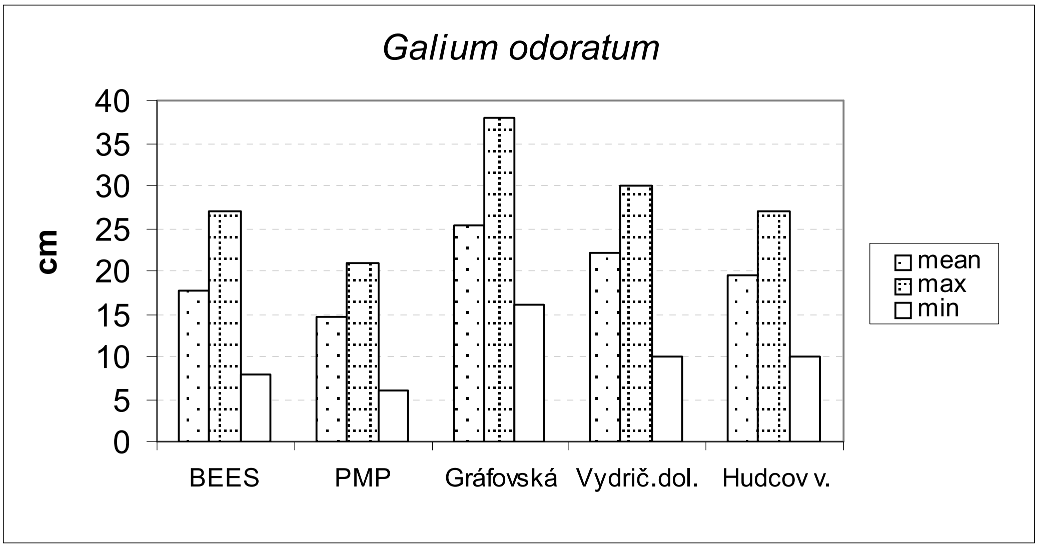

Fig. 1. Heigth parameters of *Galium odoratum*

4.787 g m^{-2}, was recorded in a locality situated 7 km from the pollution source. The values of biomass production in the BEES Kremnické vrchy Mts. were: 1.837 g m^{-2} for aboveground biomass and 0.986 g m^{-2} for belowground biomass. The mean plant height values were in all localities higher than on the PMP Žiar and ranged from 14.57 cm Žiar to 25.3 cm (Gráfovská).

Translated by D. Kúdelová

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Porovnanie produkcie biomasy *Galium odoratum* L. v bukových porastoch na stanovištiach s rozdielnou intenzitou imisného zaťaženia

Súhrn

V skupine lesných typov Fap na lokalitách s rozdielnou intenzitou imisného zaťaženia sme v roku 1999 sledovali produkciu nadzemnej a podzemnej biomasy druhu *Galium odoratum* L. Skúmali sme aj dĺžkové parametre daného druhu. Z výsledkov vyplýva, že najnižšiu produkciu (nadzemnú, podzemnú aj celkovú), sme zistili v blízkosti závodu na výrobu hliníka na TMP v Žiari nad Hronom. Celková produkcia tu dosahovala hodnotu 1,651 g m^{-2}, z toho na produkciu nadzemnej biomasy pripadá 68,9 %, čo je 1,137 g m^{-2}. Ostatné lokality, vzdialenejšie od zdroja znečistenia mali vyššiu celkovú produkciu (až na lokalitu č. 3), ktorá sa pohybovala od 2,823 g m^{-2} (BEES) do 4,787 g m^{-2} (Hudcov vrch). Priemerná výška jedincov bola na všetkých lokalitách vyššia ako v Žiari nad Hronom.

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Phenological observations on selected introduced oak species in the Arboretum Mlyňany

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Abstract

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The knowledge about timing of biological events in woody plants is important from many viewpoints. We sought to contribute to the area with the data concerning several oak species introduced in Slovakia. In the Arboretum Mlyňany, we studied three healthy adult trees of *Quercus rubra*, three somewhat younger individuals of *Q. macranthera* and one adult tree of *Q. phellos*. The phenological events in the selected trees were observed over the period 1986–1989. The results have been summarised in several figures and tables. In the course of study, we recorded differences in the timing of the first spring phenological phases between the years. Similar was the situation in autumn leaf fall and other phenological phases.

Key words

Quercus rubra, *phellos*, *macranthera,* phenology, Arboretum Mlyňany

Introduction

Phenological observations are mostly oriented on plant and animal species with features of special interest: not only aesthetic (flowering, habitus, autumn leaf colouring) or commercial (timing of flowering, fruit ripening and fruit collection) – they have also a considerable scientific value on their own. We focussed our research on three introduced oak species in the Arboretum Mlyňany, i.e. in conditions of SW Slovakia. Two of the studied oak species have their origin in North America (*Quercus rubra* L. and *Q. phellos* L. (Elwes and Henry, 1971), the third is from the Caucasus Mts. (*Q. macranthera* Fisch. et Mey. ex Honen).

We carried out phenological observations according to the method by Łukasiewicz (1968), and we also profited from some results obtained in research at the site by several other authors (Benčať and Tokár, 1978; Mercel, 1978; Požgaj and Mercel, 1999 et al.).

Methods

The Arboretum Mlyňany is situated close to the left border of the Žitava River, at 160–204 m a. s. l. The original biocoenological communities at the site are, according to Zlatník (1959), Carpineto-Quercetum and Fageto-Quercetum, with illimerized soils (Forest Management Institute Zvolen, 1975). The studied trees were labelled as follows: *Q. rubra*: 11, 18, 19, *Q. macranthera*: 7, 27, 28 and *Q. phellos*: 6 (Fig. 1, Table 1). We itemized the following phenophases (Fig. 2):

1. Beginning of bud development
2. Full developed buds
3. Bud-burst
4. Full leaf unfolding
5. Beginning of autumn coloration
6. Full autumnal colour change
7. Beginning of leaf fall
8. Total leaf fall

9. Beginning of catkins sprouting
10. Pollen release
11. Beginning of catkins fall
12. Total catkins fall
13. Beginning of fruit development
14. Beginning of fruit fall
15. Total fruit fall.

Phenological lists were provided separately for each tree and each year of study. Meteorological data were obtained from the Hydrometeorological Station situated in the Arboretum. We have elaborated a climate-diagram of the locality (Walter et al., 1975) for years 1986–1998 (Fig. 3). Climatical situation in the Arboretum Mlyňany was also supplemented by Hrubík (1992), Požgaj and Tomaško (1999), Požgaj and Mercel (1999) and others.

The results of four years of study (average values) are summarised in a specific way – as average values and year cycles. For the months we used the following abbreviations: J – January, F – February,

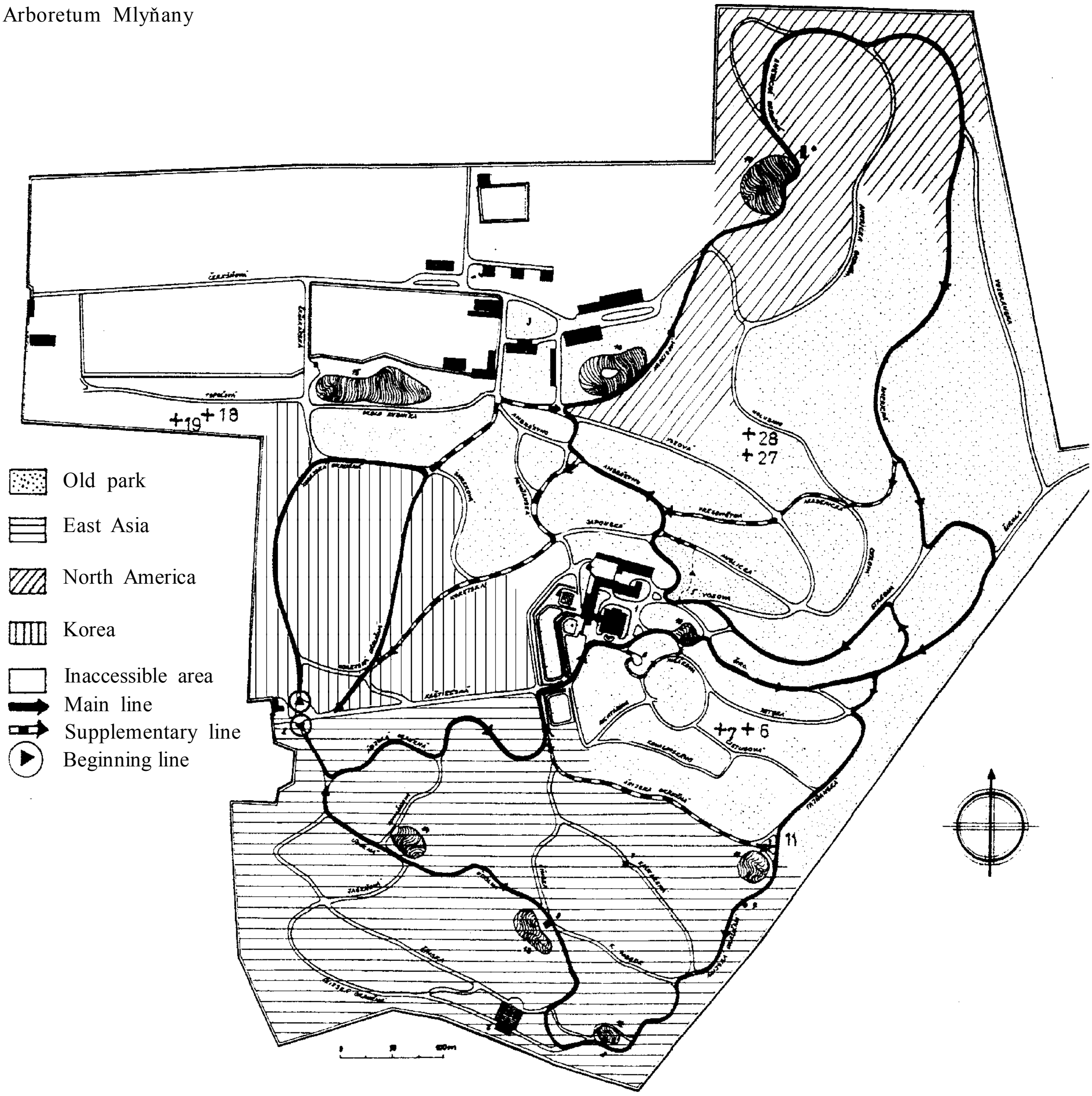


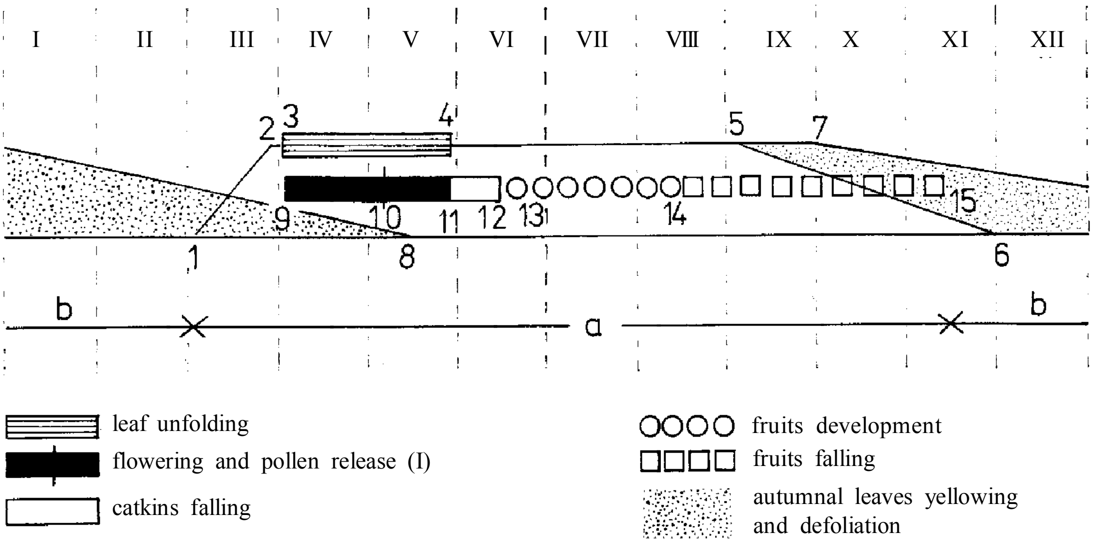
Fig. 1. Situation of the observed individuals in Arboretum Mlyňany

M – March, A – April, My – May, Jn – June, Jl – July, Ag – August, S – September, O – October, N – November, D – December. One month is represented in the decimal system (e.g., A4.5 means 13–14 April).

The statistical evaluation was carried out on two separate groups of phenophases as concerning:
1. Assimilatory organs,
2. Generative organs.

The first group involved the phenophases from number one to eight (Fig. 2), the second also the first two and the other phenophases from nine to fifteen.

The assimilatory organs were evaluated on all examined trees. The generative organs were evaluated with exception of two not yet fertile trees of *Q. macranthera* (27, 28).



a – growing season, b – period of dormancy

Fig. 2. Phenological phases

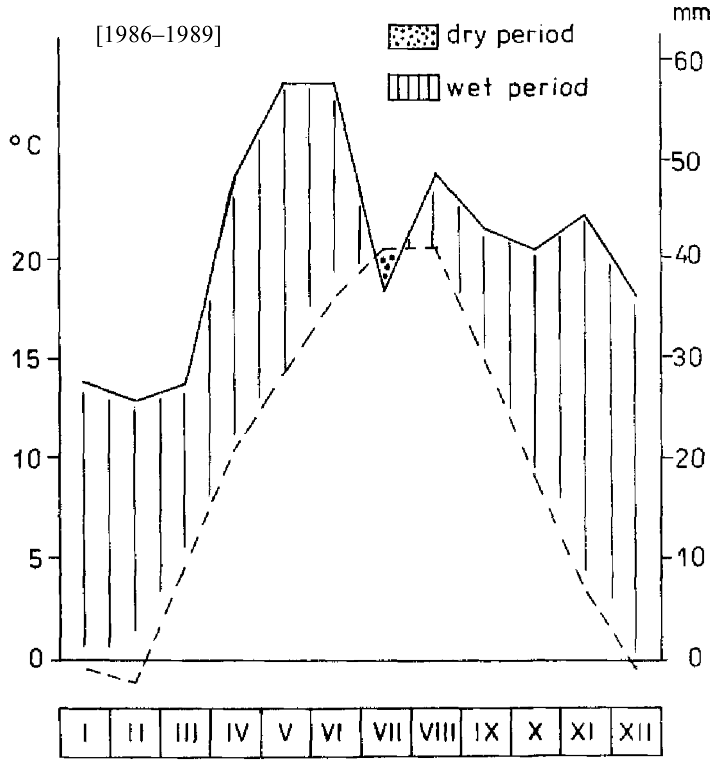


Fig. 3. Climate diagram of the Arboretum Mlyňany

The obtained values were processed using the variance analysis.

Results

Phenological descriptions for the separate years are given in Figs 4–7. From these figures, it is possible to obtain data about separate phenophases for the individual trees. In 1986, started the bud swelling in all the observed trees in March – beginning with *Q. rubra* 18 (M3) and ending with *Q. macranthera* 7 (M3), *Q. macranthera* 27 (M7). The full swelling of buds was reached as the first in *Q. rubra* 18, 19 (A4.5), the last was *Q. macranthera* 27 (A8). The budburst started with *Q. rubra* 11 (A7.5), the last were *Q. phellos* 6 and *Q. macranthera* 27 (A9). The full leaf development proceeded from *Q. macranthera* 28 (My 3.5) and 27 (My4), to *Q. rubra* 11 (My8). The beginning of autumnal yellowing started in *Q. phellos* 6 and *Q. rubra* 11 (S6.5), ended with *Q. macranthera* 7, 28 (O3). The total autumnal colouring was first in *Q. rubra* 11 (O3.5), the last was *Q. phellos* 6 (O4). The leaf fall started in *Q. rubra* 11 (S9.5) and 18, 19 (S10), ended with *Q. macranthera* 7 (N3.5). *Q. phellos* 6 (N3) was the first without leaves, *Q. macranthera* 7 (D9.5) the last. As for the catkins sprouting, the first was *Q. rubra* 11 (A5), the last *Q. rubra* 18, 19 (A7.5). *Q. macranthera* 27, 28 was without catkins. *Q. rubra* 11, 18, 19 (A9) began with pollen release, followed by *Q. macranthera* 7 (My0.5), the last was *Q. phellos* 6 (My1). The catkins began to fall at the same time from all the trees (My3), with exception of *Q. macranthera* 7 (My6). The catkins were first removed from *Q. robur* 11 (My6), the last was *Q. macranthera* 7 (My10). The first ripe acorns began to fall from *Q. macranthera* 7 (S5), the fruitfall ended with *Q. phellos* 6 (S10). The total fall of fruits was observed first in *Q. macranthera* 7 (S7.5), the last in Q. phellos 6 (O5). In a similar way, we can also read the values for the other years of study (1987, 1988, 1989) from the other Figs: 5, 6, 7, respectively.

From all four years of study, the spring phenophases started earliest in 1986. Somewhat later was the start shifted in 1987, more later in 1989, and similarly in 1988. This situation held for all the studied species. *Q. rubra* began with bud swelling in 1986 on M3, in 1987 – on M8.5, in 1988 – A1, 1989 – on A0.5, *Q. phellos* (M6.5, M6.5, A1.5, A1) and *Q. macranthera* (M3, M8, A2, A2). We have not managed to find out why there was not maintained the same order in ending of the individual phenophases each year. There can be several factors influencing the state of art. We can hypothesize about the beginning of spring, crop quantity, health status and presence of pests.

In the following we will provide a comprehensive piece of information in form of average figures and their ranking over the whole period of study (Fig. 8). In the figure are illustrated average data for the individual species. There were evident shifts from these mean values in several phenophases in certain species (phenophases 1, 5, 6, 7, 15), in another group of phenophases, only one of the species was distinctly different from the others (2, 3, 4, 11, 14), in the third

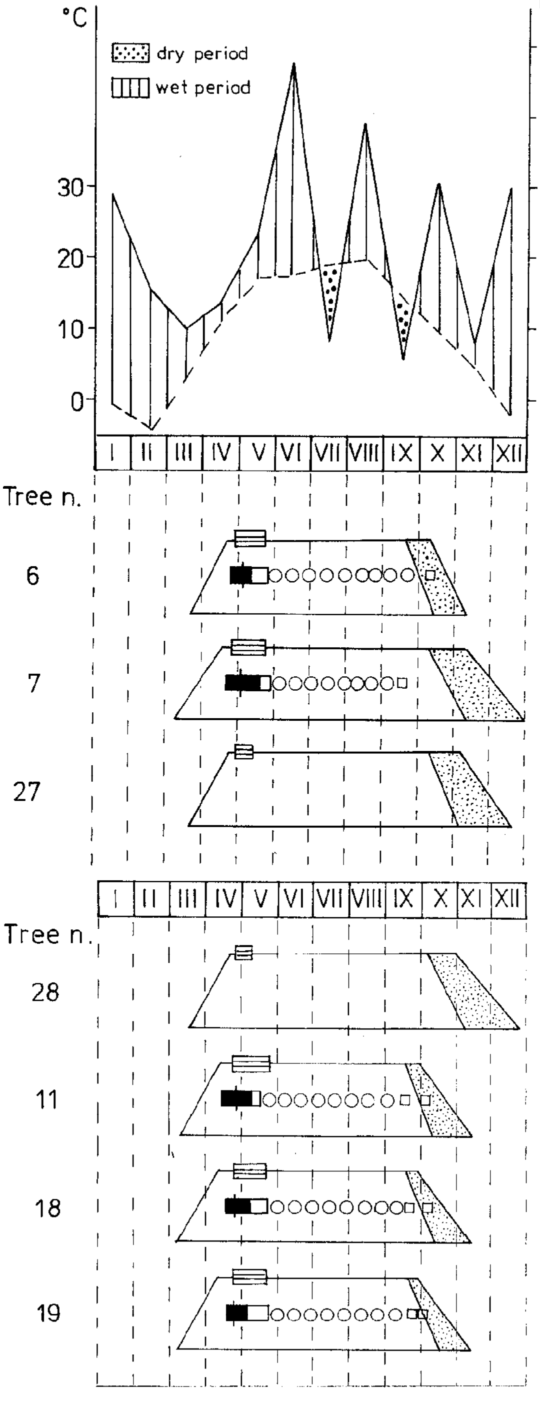


Fig. 4. Phenological data in 1986

group of phenophases, all the species were more or less similar (9, 10, 12), in this case catkins were considered.

Considering the fructification, it is necessary to point out that from three individuals of *Q. macranthera*, only the tree number 7 was fructifying – and only in year 1986; on the other hand, the same tree was flowering each year. The trees No. 27 and 28 belonged to the younger, however, they were fructifying one year before the beginning of observations. *Q. phellos* was flowering and fructifying yearly, similar to all the trees *Q. rubra*.

Based on the average values from the all four years of study it follows that *Q. phellos* and *Q. rubra* began with bud swelling the first, however, the full-swollen buds were observed first in *Q. rubra*, the

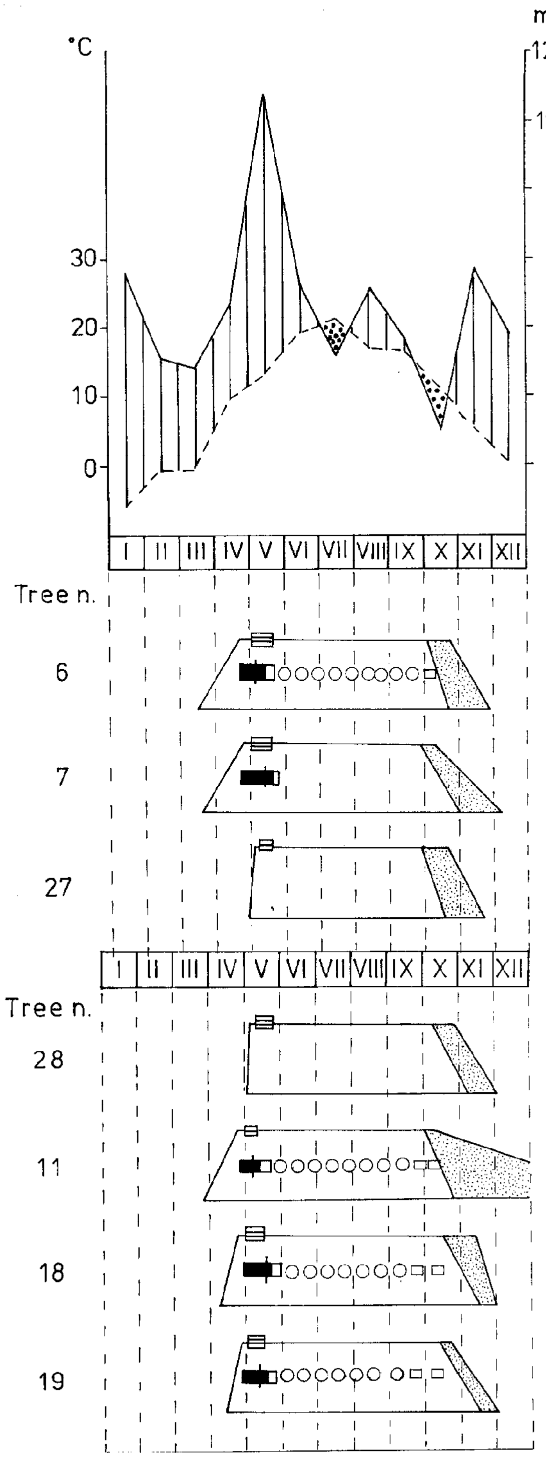


Fig. 5. Phenological data in 1987

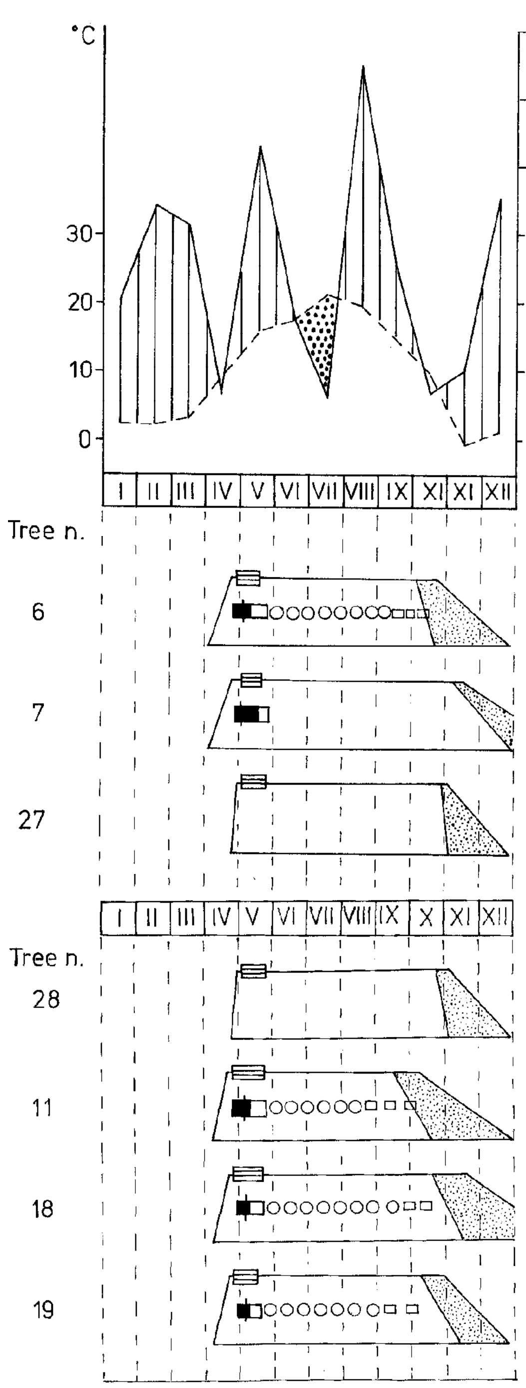


Fig. 6. Phenological data in 1988

course of bud-burst and full leaf unfolding were similar. The autumnal leaf yellowing began in *Q. phellos*, the fully coloured leaves were first observed in *Q. rubra*. The beginning of leaf fall was first in *Q. phellos*. The total leaf fall began with *Q. phellos*, ended with *Q. macranthera*. The catkins began to sprout simultaneously in *Q. rubra* and *Q. phellos*, pollen release simultaneously in *Q. rubra* and *Q. phellos*.

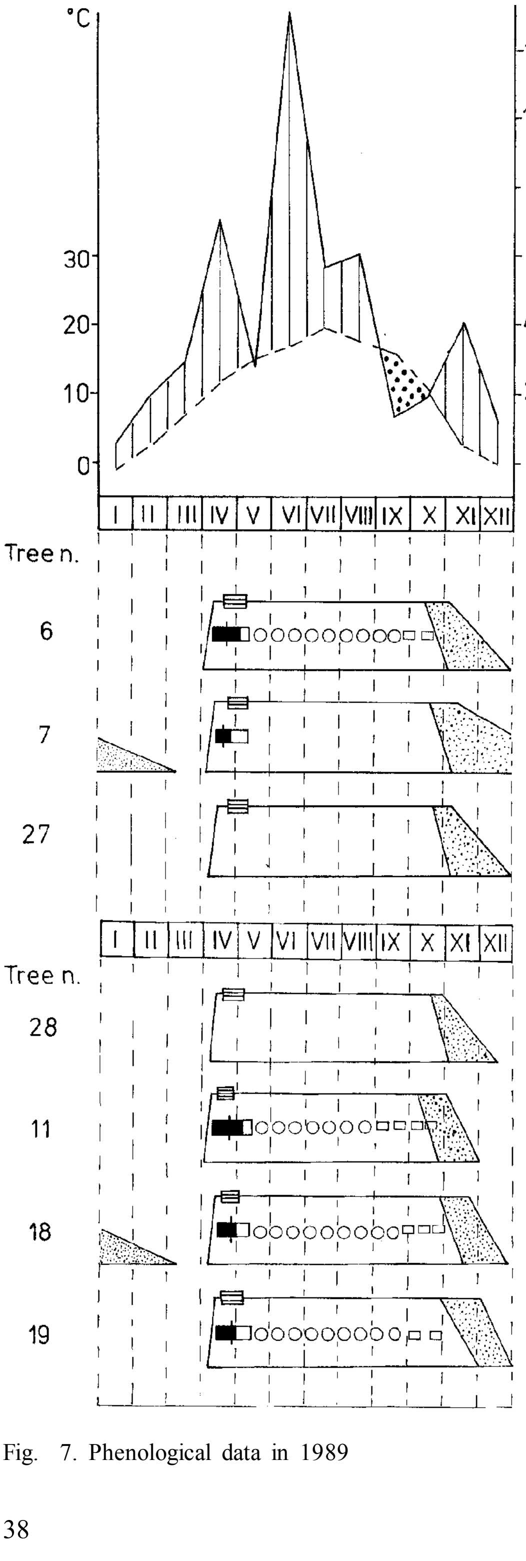


Fig. 7. Phenological data in 1989

The beginning of catkins fall was observed in *Q. phellos,* the full catkins fall in *Q. rubra*. The beginning of fruit development started in *Q. rubra* somewhat sooner than in *Q. phellos*. The fruits began to fall in *Q. macranthera* (the tree was fructifying for the first time), ended in *Q. phellos*, the complete fruit fall was observed as first in *Q. rubra*. All the mean values are precisely illustrated in Fig. 8.

It is necessary to point out different lengths of individual phenophases (1986–1989) for all the studied trees. According to duration, we classified the phenophases in three following categories: less than one month, 1–2 months, more than 2 months. The first category comprises:

4 – full leaf unfolding (min. A8–max. My8)
9 – beginning of sprouting of catkins (A2.5–A9)
10 – beginning of pollen release (A7–My5)
11 – beginning of catkins fall (My1–My9)
12 – total catkins fall (My3–My10)
13 – beginning of fruit development (My4–Jn1).

The second category consists of:

1 – beginning of bud swelling (M3–My1
2 – complete bud swelling (A2–My3)
3 – bud-burst (A3.5–My4)
5 – beginning of autumnal colouring (S6.5–M2)
14 – beginning of fruits fall (Ag7–S10)
15 – total fruits fall (S3–O9).

To the third category belong:

6 – total colouring of leaves (O3–D10)
7 – beginning of leaf fall (S9.5–N10)
8 – total leaf fall (N3–M3).

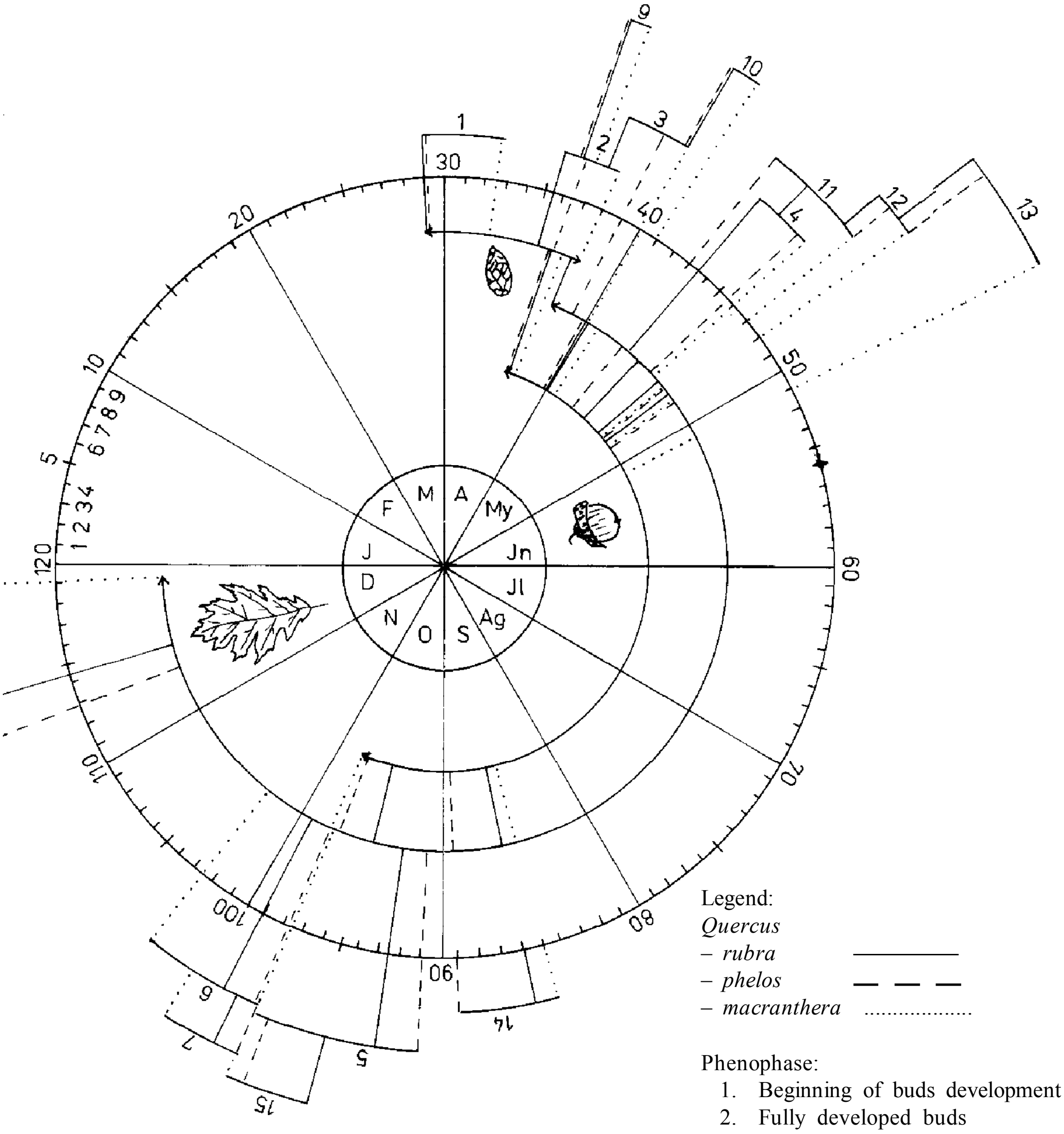
As recorded over the four-year study period, the shortest was the phenophase 9 – starting of catkins sprouting, the longest was phenophase 8 – end of leaf fall – this phase proceeded for 4 months.

All the measured values were processed using the Anova analysis. We sought to evaluate the impact of these factors: phenophase, species, year. The Table 2 (assimilatory organs) shows a statistically significant impact of phenophase (what is natural), species (significant differences between the species), and year. We can also suppose about an important influence of weather.

The generative organs were evaluated according to the methods described above in the relevant section. The dataset was subjected to the variance analysis (ANOVA) to find the effects of all examined factors: phenophase, species, year. The obtained results (Table 3) reveal evident statistically significant influences of all factors and their mutual interactions.

From the differences in phenophases connected with generative organs we only consider those statistically significant. In the phenophase 11 was found a significant difference between *Q. macranthera* and *Q. phellos.*

We close this section with a summary pronouncement that the analyses performed on datasets concerning assimilatory and generative organs finished with similar results. Statistically significant differences were only found in *Q. macranthera*. Statistically significant differences between the species in the frame of the individual phenophases were confirmed for the assimilatory organs 1.–5., for the generative organs 1.–2., 11.



Legend:
Quercus
– *rubra* ————
– *phelos* — — —
– *macranthera* ....

Phenophase:
1. Beginning of buds development
2. Fully developed buds
3. Bud burst
4. Fully developed leaves
5. Beginning of autumnal leaves yellowing
6. All the leaves turned to yellow
7. Beginning of defoliation
8. Total defoliation
9. The first catkins appearance
10. Pollen release
11. The first catkins falling
12. All catkins fallen
13. Beginning of fruits development
14. Beginning of fruits fall
15. The last fruits fallen

8. Graphical representation (average values) of the observed phenophases during the years 1986–1989

Table 1. Basic characteristics (in 1998) on observed trees

Species (number of tree)	Origin	Circumference of trunk (m)	Height of tree (m)	Width of crown (m)	Sociological status	Health condition (Požgaj, 1987)
Q. rubra	North America					
11		1.55	19	18	solitaire	1
18		1.10	18	6	2	1–
19		2.17	23	11	1	1–
Q. phellos	N. America					
6		2.23	22	18	1	2–
Q. macranthera	Caucasus					
7		0.62	17	5	3	4
27		0.43	10	4	3	3
28		–	–	–	–	–

Table 2. ANOVA – assimilatory organs

	Factors: 1 – phenophase, 2 – species, 3 – year					
Effect	df Effect	MS Effect	df Error	MS Error	F	p-level
1*	7	26835.58	128	18.02344	1488.927	0.0000
2*	2	289.8601	128	18.02344	16.0824	0.0000
3*	3	199.8922	128	18.02344	11.09068	0.0000
12	14	10.48427	128	18.02344	0.581702	0.8754
13*	21	54.6533	128	18.02344	3.032346	0.0001
23	6	14.86161	128	18.02344	0.824571	0.5529
123	42	19.61671	128	18.02344	1.0884	0.3518

Table 3. ANOVA – generative organs

	Factors: 1 – phenophase, 2 – species, 3 – year					
Effect	df Effect	MS Effect	df Error	MS Error	F	p-level
1*	5	730.1234	48	1.798611	405.9373	0.0000
2*	2	13.77361	48	1.798611	7.657915	0.0013
3*	3	60.63558	48	1.798611	33.71245	0.0000
12*	10	4.657778	48	1.798611	2.589653	0.0135
13*	15	11.36019	48	1.798611	6.316088	0.0000
23*	6	5.843981	48	1.798611	3.249163	0.0092
123	30	2.815926	48	1.798611	1.565611	0.0813

Discussion

Phenological observations on woody plants are important for correct timing in orchard management, botanical gardens, horticulture (Chitenden, 1965), management of parks, arboretums (Tomaško and Tomašková, 1992), and, naturally in forest management (Chroust, 1955) and general basic research. Formerly were only observed certain selected phenophases – for description purpose only – e.g. bud-burst, flowering, first ripe fruits, etc. (Linnaeaus, 1753 and others). Oak trees, primarily in natural forest stands are studied with focus on their fruits. The oak is not fruiting each year (Vyskot, 1958), the fruits are relatively rare, and consequently, it is important to provide prognostics about forthcoming mast years.

The first indicator for a correct prognosis is the timing of flowering. Flowering and pollen release are generally reported phenophases for common oak species. Aas and Riedmiller (1987) recorded the flowering in *Q. rubra* in May. According to our observations, the species was flowering in April (A7–A9) in the years 1986 and 1989, and in May (My1–My5) in the years 1987–1988. The above-mentioned authors report about fall of ripe acorns in October. In our conditions, the timing of this phase is shifted. According to our observations, the first fruit began to fall after the mid September, and the last fruits fell to the mid October. According to the individual years and trees, the fruits can already begin to fall by the end of August (tree No. 11, Ag7 – 1988), or even up to the end of September (tree 19, S10 – 1989), the total fall can be timed from the first half of September (tree No. 11, S3 – 1988) to the end of October (tree No. 19, O9 – 1989). According to Pagan and Randuška (1988), the fruits began to ripe in September or October of the second year, which almost corresponds to our observations. The fruits of this species (and also *Q. phellos*), always get ripe in the second year; consequently, it is possible to make estimations about the crop beginning with the flowering and proceeding through the following vegetation period, winter and in the second year, from the beginning of the vegetation period up to the full ripeness. Some authors report flowering in *Q. rubra* in May or June (Pagan and Randuška 1988), however, this fact does not correspond to our observations. In our conditions, flowering of *Q. rubra* in June is high disputable. *Q. phellos* and *Q. macranthera* are very rare in Slovakia, from which follows the lack of phenological data in the literature.

The comparisons of the course of phenophases between the studied introduced and Slovak autochtonous species (data for comparison are taken from Požgaj and Mercel, 1999) show evident that in the spring aspect is *Q. rubra* between the first species concerning the bud-burst, however, in the pollen release it belongs to the last third of the studied species (8 autochtonous). As for the total fruit fall, it belongs to the second half, in the total leaf fall to the leading oak species. In comparison with the data on *Q. pubescens* Willd. provided by Požgaj and Horváthová (1986), (we did not perform observations on this species), it is evident that the pollen release begins to the first days of May. *Q. rubra* has pollen release interval A7–My5, consequently, there is a considerable similarity.

All three *Q. rubra* trees were fructifying in all four years of the study. The fruits on these trees began to ripe more early than *Q. cerris* L., *Q. robur* L., *Q. virgiliana* Ten., *Q. frainetto* Ten., *Q. pedunculiflora* C. Koch, and namely in the same conditions and in a similar way as *Q. polycarpa* Schur, *Q. petraea* (Matt.) Liebl. and their cross-breeds (*Q. petraea* x *Q. dalechampii* Ten., *Q. polycarpa* x *Q. dalechampii*) (compare with Požgaj and Mercel, 1999).

In summary, *Q. rubra* is a species frequently studied in our forest research. In oak forest vegetation tiers in Slovakia, it is planted in many localities (Forest Enterprise Levice included). This species evidently finds here favourable ecological conditions for its viability vhat is documented by the excellent growth in young age and sound natural regeneration. The other two species are not used in Slovak forestry. We can meet them in parks (Benčať, 1982).

Conclusions

The work presents phenological data about three trees of *Q. rubra*, *Q. macranthera* and one *Q. phellos* growing in the Arboretum Mlyňany. The data were collected over 1986–1989.

For all the observed trees, it holds that their spring activity begins between M3 and My1. The flowering was recorded to the end of April and the beginning of May (range A7–My5), the ripening of fruits from the second half of September to the second half of October (S7–O8), the beginning of autumnal leaf colouring was first recorded in *Q. phellos* (O1), followed by *Q. rubra* (O2.5), the last was *Q. macranthera* (O7.5), the leaf fall from the second half of October to the second half of December (O7.5–D9). In several cases, some individuals maintained their leaves up to the following year (M2 *Q. rubra* – tree No. 7 in 1988).

Q. phellos was fruiting each year (however, typical mast year was not in each year), similar was the situation in all three studied *Q. rubra*, *Q. macranthera* was only fruiting once – tree No. 7 in 1986.

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Fenologické prejavy niektorých cudzokrajných dubov v Arboréte Mlyňany

Súhrn

Práca sa zaoberá dvomi druhmi duba zo Severnej Ameriky (*Quercus rubra* L. – dub červený, *Q. phellos* L. – dub grécky) a jedným z Kaukazu (*Q. macranthera* Fisch. et Mey. ex Honen. – dub veľkokvetý). Prinása fenologické údaje o troch jedincoch *Q. rubra*, troch *Q. macranthera* a jednom *Q. phellos*, rastúcich v Arboréte Mlyňany za roky 1986–1989. Informácie o taxačných a ďalších údajoch sledovaných jedincov prináša tabuľka 1. Jednotlivé sledované fenofázy prináša obraz 2. Na obr. 4 je zachytené fenologické spektrum všetkých sledovaných jedincov (rok 1986), na obr. 5 rok 1987, 6 – 1988, 7 – 1989. Za celé sledované obdobie priemerné hodnoty za druh prináša obr. 8. Z neho je zrejmé, že jarnú aktivitu najskôr začína (začiatok nalievania púčikov) *Q. rubra* a *Q. phellos* (M9 – vysvetlenie symbolov v metodike), úplné olistenie najskôr dosiahol *Q. rubra* (My3,5), jesenné prefarbovanie najskôr začal *Q. phellos* (O1), podobne ako prvý dosiahol aj úplný opad listov (D3), najneskôr *Q. macranthera* (D9). V prášení peľu dosiahli prím *Q. rubra* a *Q. phellos* (A10), úplný opad plodov najskôr dosiahol *Q. rubra* (O4,5). Údaj reprezentujúci *Q. macranthera* (S7,5) je iba za rok 1986, v ďalšom období ani jeden jedinec neplodil a ani nekvitol (rok pred začiatkom merania kvitli všetky). Dátumové rozpätie nástupu resp. ukončenia fenofáz za celé obdobie sledovania je v texte. Najväčšie rozpätie v rámci všetkých jedincov a sledovaných rokov bolo zaznamenané pri fenofáze 8 – úplný opad listov (metodika) a to od N3 po M3 v nasledujúcom roku, t. j. 4 mesiace, najmenšie pri 9 (A2,5–A9), 12 (My3–My10), 13 (My4–Jn1), 10 (A7–My5) a 11 (My1–My9).