EARTH CLIMATE SYSTEM EVOLUTION IN THE LAST 1 000 YEARS, WITH ACCENT TO THE LAST 100 YEARS

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Abstract: *Šťastný, P.: Earth climate evolution in the last 1 000 years, with accent to the last 100 years. In Folia oecologica. ISSN 1336-5266, 2003, vol. 30, no. 2, p. 13–23.*

Recognizing the problem of potential global climate change the scientific community takes heed of Earth climate system evolution more than 25 years. The results of the IPCC, as intergovernmental organization contributed to the UN Convention on Climate Change (1992) and to the adoption of the Kyoto Protocol to the UNFCCC in 1997. The last reports of the IPCC were presented the global warming as the result of forced greenhouse effect and it is not reasonable to explain it with variation of Earth climate system only. The climate system of Slovakia is the picture of Earth climate evolution in the middle latitudes of the Northern Hemisphere. The Slovak National Climate Program assumed the main potential impact and options of the climate, hydrological and ecological systems. In the article are presented the opinions, published in the IPCC reports with connection of recent studies results of the climate system of Slovakia and the scenarios of the climate system evolution in this century.

Key words: *climate change, global warming, hydrological regime, scenario*

Introduction

The focused attention is paid to the Earth climate system evolution in the connection of potential global climate change. In 1988 the World Meteorological Organization (WMO) and the United Nations Environmental Programme (UNEP) established the Intergovernmental Panel on Climate Change (IPCC). It is open to all members of the UN and WMO. The role of the IPCC is to assess on a comprehensive, objective and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impact and options for adaptation and mitigation. The IPCC does not carry out research nor does not monitor climate related data or other relevant parameters. It bases it assessment mainly on peer reviewed and published scientific/technical literature. A main activity of the IPCC is to provide in regular intervals an assessment of the state of knowledge on climate change. The First IPCC Assessment Report was completed in 1990. It's Second Assessment Report, Climate Change 1995, provided key input to the negotiations, which led to the adoption of the Kyoto Protocol to the UNFCCC in 1997. The Third Assessment Report (TAR), Climate Change 2001, was completed in 2001. The IPCC has decided to continue to prepare comprehensive assessment reports and agreed to complete its Fourth Assessment Report in 2007. The Slovak Republic issues in the frame of the UN Framework Convention on Climate Change (UNFCCC) the National Communications on Climate Change in which are presented the national conditions of climate change, its potential impact and options for adaptation and mitigation. The Slovak National Climate Program promotes the climate change research. The Third National Communication on Climate Change with results of National Climate Program was completed in 2001.

Earth climate system evolution

The Earth climate system is characteristic with its dynamic nature. The climate variation includes the time scale from decades, through thousands of years to the millions of years. The last sudden rise of temperature was in Holocene, approximately 11 500 years ago and was connected with end of glacial period.

The reason for climate changes could be divided to:

1. Natural
   - Astronomical (the change of Earth axis declination, change of Solar activity).
   - Volcanic activity.
   - Change of natural atmospheric aerosols.
2. Anthropogenic
   - Emission of greenhouse gases and aerosols caused with human activity.
   - Change of Earth surface utilization.
   - Urbanization.

The main reason for recent global warming is the forced greenhouse effect, caused by massive human-induced emission of greenhouse gases, especially CO_2 to the Earth atmosphere. This fact was based on many studies results. The other reason of climate change is change of Earth surface utilisation (deforestation, irrigation etc.)

In the period from 1750 up to now the CO_2 concentration rose from 280 ppmv to the level of 370 ppmv (rise about 32%) methane about 151%.

The level of CO_2 concentration is, based on paleoclimatological studies results, the highest in the last 420 000 years. The rate of concentration rise is about 50 times higher like during the "sudden" changes in the interglacials. The result of these processes is not only the chemical change of atmosphere composition, but also the change of the absorption of infrared terrestrial surface radiation.

The reaction of Earth climate system to the chemical composition of the atmosphere was the global warming, which was about 0.6 °C since 1861. Simultaneously, in the Northern Hemisphere the medium rise of precipitation was observed.

The rate and duration of warming in the 20th century is probably the biggest in the last 1000 years. The 1991–2000 decade is the warmest in the last millennium in the Northern Hemisphere (Fig. 1). The year 1998 was the warmest and 2002 the second warmest from the beginning of climatological observation. The paleoclimatological studies led to the reconstruction of temperature time series. The variation of temperature in the global scale was not significant, but in the European conditions could be found two singularities. The Little Climate Optimum in the period 900 AD-1300 AD was connected with warming. Crops flourished and production increased in this period. Little Ice Age was connected with harsher, colder weather, which brought on fierce storms, severe drought and crop failures. Western Europe experienced a general cooling of the climate between the years 1150 and 1460 and a very cold climate between 1560 and 1850 that brought dire consequences to its peoples.

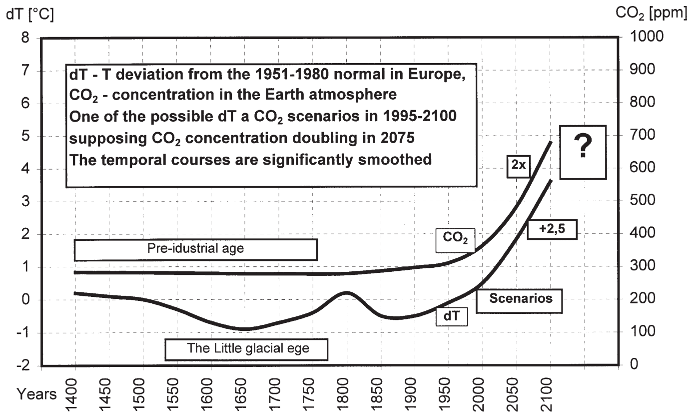


Fig. 1. Schematic air temperature (T) and carbon dioxide CO_2 concentration temporal course since 1400

Impacts from climate evolution analyse was used in hydrological cycle investigation Lapin et al. (2003), Szolgay et al. (2003), Majerčáková et al. (2004b). From the point of the surface water resources, the sensitivity and vulnerability of Slovakia territory on the possible climate change was made. The highest level of the water resources vulnerability was determined in the southern part of Slovakia except the Danube basin. The belt included the western, northern and northeastern parts of territory was determined as area with low level of sensitivity and vulnerability (Fig. 2).

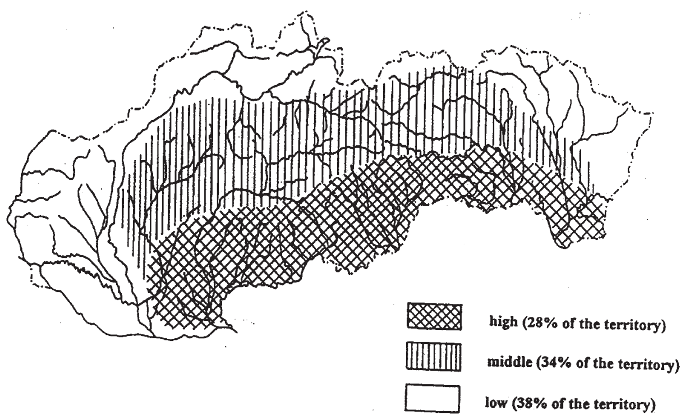
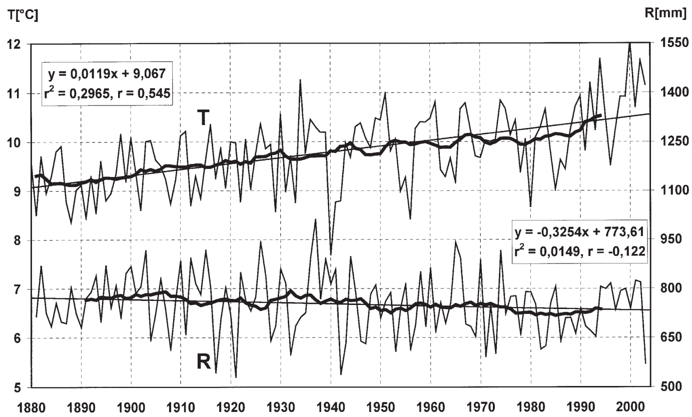


Fig. 2. Sensitivity and vulnerability of the territory on possible climate change (from the point of view of the surface water resources)

Climate evolution in Slovakia

The temperature trend in the Slovakia territory is analogous to the global trend. Since 1901 was the annual warming about 1.1 °C. The annual temperature time series from meteorological observatory Hurbanovo shows the gradual warming in the whole period 1881–2003, with unprecedented increase in the last decade of 20th century (Fig. 3). The trend of annual sums of precipitation was computed as areal average from 203 stations (Fig. 3). The average annual sum of precipitation was decreased in the period of last 100 years about 5.6 %, it made an amount about 32 mm in last 100 years. In the southern parts of Slovakia was the precipitation decrease more than 10 %, in the northern territory the trend was not significant.



Fig, 3. Annual temperature means (T) at Hurbanovo and annual areal precipitation sums (R) in Slovakia, 1881–2003. The T and R changes are presented with 20-years moving averages and linear trends of T and R.

The climate system variability has not changed. After transition change of some climatological characteristics variability in the period from 1965 to 1990, the variability was raised to the previous level Faško et al. (2000). The occurrence of days and events with high 24-hours precipitation sum is presented in Fig. 4. In the period 1965–1990, the decrease of those days and events was evident. High daily precipitation amounts were connected with heavy rain occurrence and sequent with flash floods.

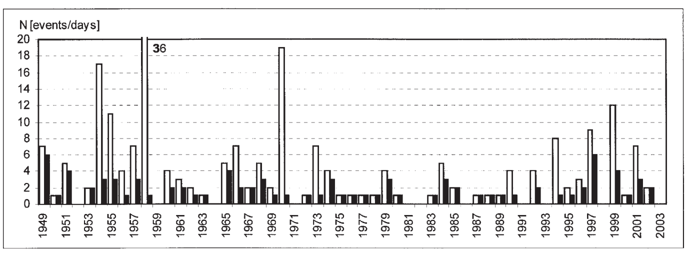


Fig. 4. Number of events (white) and days (black) with daily precipitation sum = 100 mm (in 700 stations in Slovakia in the period 1949–2003, 224 events, 88 days)

In the period 1989–2003 there were registered series of warm years (2000 was the warmest), 3 considerable droughts (1990–1993, 2000 a 2003), the drought 2003 was occurred in the most of territory of Slovakia. There were the considerable floods too (in the most events there were flash floods, but from snow melting too). In Fig. 5 are presented the warmest and coldest years from 1871 at Hurbanovo, from the top 12 of warmest years number of 7 was since 1991, the last cold year was recorded in 1980.

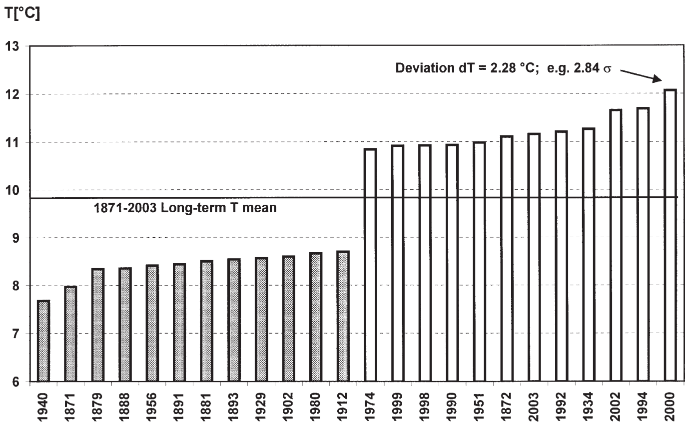


Fig. 5. 12 coldest and 12 warmest years in the longest observation period in Slovakia, at Hurbanovo, 1871–2003

The closer characteristics of the last 7 years were reviewed by MAJERČÁKOVÁ et al. (2004a):

1997

- Extraordinary floods in July in Morava, Myjava, Kysuca. Rajčianka and Danube rivers.

1998

- Extraordinary warm winter 1997/98.
- The spring floods on Uh and Bodrog rivers.
- July 20th – the flash floods in Malá Svinka, Dubovický potok, Žehriansky potok catchments. In the heavy rain centre was more than 100 mm per 1.5 hour, the assumed value of recurrence of the culminating discharge from stroked catchment was markedly less frequent like once per 1000 years (the specific discharge was about 7000 $l/s/km^2$). This hydrological phenomenon caused the death by drowning of 50 people in the swollen river.

1999

- The heavy snowfall in the eastern Slovakia in February.
- After the fast thaw occurrence of the flood in the Bodrog river in February.
- The floods caused by thaw and ice floods in the rivers Poprad, Hornád, Hnilec, Bodva, Torysa, Hron, Ipeľ, Štiavnica, Krupinica, Morava and Danube in March.
- The frequent thunderstorms and the series of heavy rains in the southern part of the central Slovakia in June.
- The series of heavy rains hit the small catchments in the basins of Morava, Váh, Hron and Ipeľ (July 13th culminating discharge was assumed less like once per 1000 years in Krupinica river).

2000

- Mean annual temperature was the highest from 1871 (+3 °C); from 1871 seasons – spring, autumn and vegetation period were the warmest, months – April was the warmest, June and August the second warmest, May, October and November the third warmest from 1871 (Fig. 6).
- Catastrophic drought was in the southern and south – western parts of Slovakia. The precipitation deficit was more 100 mm and the mean temperature 3 °C above normal.
- The beginning of drought in the south – western part was in the end of the flood on Bodrog river.

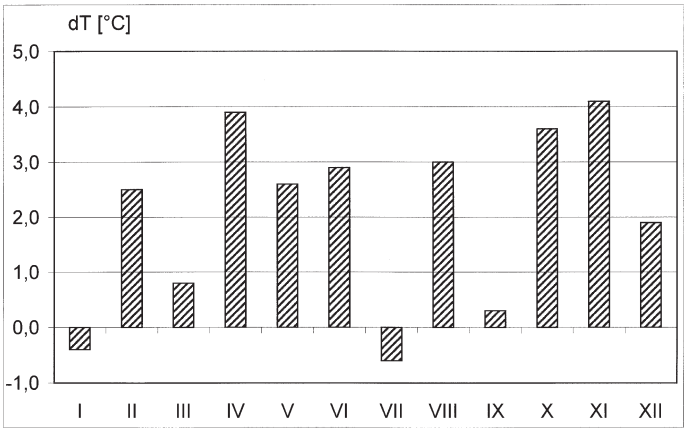


Fig. 6. Air temperature deviations from normal 1961–1990 for the monthly values in 2000, the warmest year at Hurbanovo since 1871

2001

- The next from the series of warm years, August (+2.8 °C), May (+2.5 °C) and October (+3.3 °C) were relatively warmest.
- July was the third wettest since 1881 (Zuberec 582 mm).
- This year was the first wet year since 1974.
- Combination of thaw and liquid precipitation caused floods in Bodrog river catchment in early spring.
- The series of flash floods in July hit Váh, Hron, Torysa, Poprad, Ondava and Topľa catchments. On July 24th at the south slopes of the High Tatras at Štrba village the extraordinary flood occurred. The evaluated specific runoff was 7–10 $m^3/s/\ km^2$ what was very close to extreme values in Slovakia. In the heavy rain centre was assumed 100–120 mm per 30 minutes. The highest daily precipitation total have been measured on July 16th at the precipitation station Hronec (142 mm).

2002

- The second or third warmest year since 1871, according Hurbanovo observation. The summer was the second warmest, only December was very cold.
- On January 29th the highest winter temperature in the history of instrumental observation in Slovakia was registered at Bratislava – Mlynská dolina station (20.3 °C).

- Year was wet, the 8th highest annual sum of precipitation since 1951was occurred; the highest monthly sums of this year were registered in July and August.
- On July 13th the daily precipitation amount 50 mm and more was occurred at 72 stations (about 10 percent of stations).
- From October 2001 to May 2002 was extraordinary dry in eastern part of Slovakia (about 40% from 8-months period normal).
- Floods were on Danube river in March (20 year discharge) and August (50 to 100 year discharge).
- Series of heavy rains and frontal precipitations caused floods in the Čierny Hron, Hron, Ipeľ and Slaná rivers catchments.

2003

- This year was the sixth warmest since 1871, especially in the south – western part of Slovakia; extraordinary warm was in period of May – August (Fig. 7 and 8). This temperature extreme was the most significant ever observed since 1851.
- Annual mean regional precipitation sum (573mm) was the second lowest since 1901 (except 1917) (SEKÁČOVÁ et al. 2004).
- The driest period was February – July with mean areal precipitation sum 324 mm (Fig. 9); the precipitation deficit with connection of extraordinary warm weather caused the most expressive drought since 1871 (FAŠKO et al. 2003).
- The first day of snow cover was extraordinary soon (October 24th) in the south – western part of Slovakia.
- Only two small series of flash floods were observed in the Trenčín territory and Ondava river catchment.
- Longest sunshine duration since 1901 was recorded at Hurbanovo.

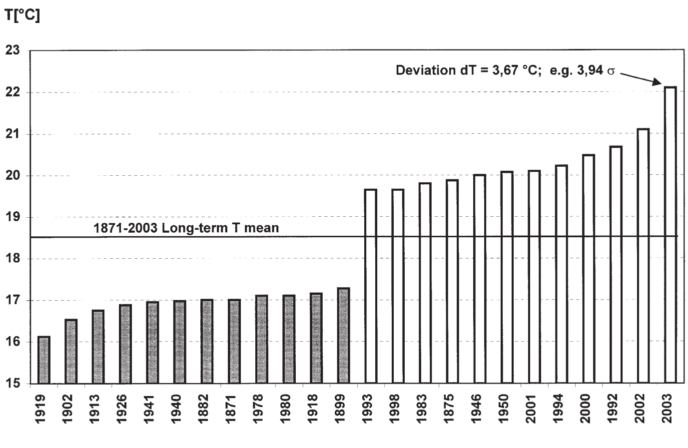


Fig. 7. 12 coldest and 12 warmest May – August seasons at Hurbanovo, 1871–2003

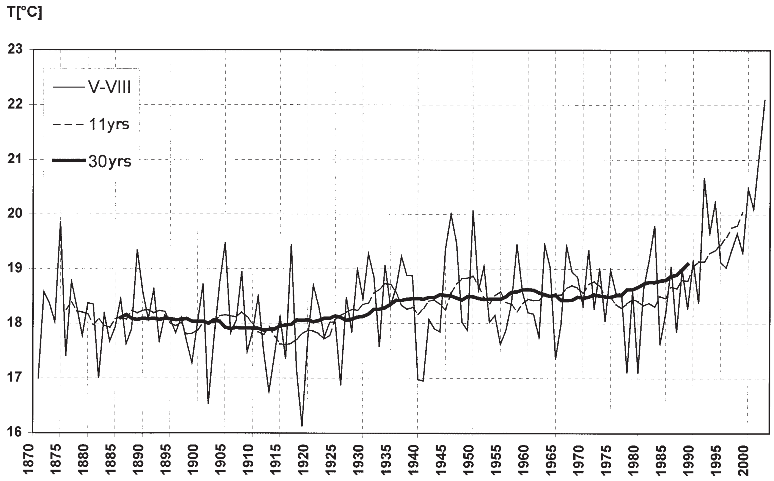


Fig. 8. Air temperature averages observed at Hurbanovo in the May – August seasons in 1871–2003. The trend is characterised by the 11- and 30-year moving averages

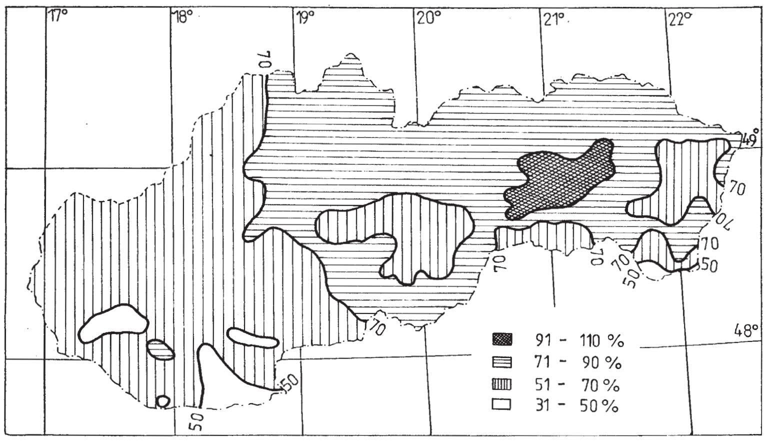


Fig. 9. Percentage of precipitation total in February – August 2003 season from the 1961–1990 normal in Slovakia

Assumed climate evolution in the future

In this century the nature with high probability would not be able to turn the chemical composition of the atmosphere. After some scenarios the warming and change of precipitation regime would be continued (Lapin et al. 2000). Another climatological elements would be affected with this regime.

For territory of Slovakia were prepared scenarios of basic climatological elements (Lapin et al. 2004), the temperature and precipitation for some time horizons. It is assumed the temperature growth of 2–4 °C till 2075 (Fig. 10), precipitation sum would not be changed essentially, but change of annual regime with growth in winter and decreasing in summer is achieved (Fig. 11). It is very probably, that periods of drought would be more frequent and longer too. The probability of more intensive rainfall would be increased. This temperature and precipitation regime could change the hydrological regime of rivers with shift of terms of maximum to the sooner month of the year and minima to the summer month.

The analyses for different sectors were made with connection to assumed climate change. The highest influence is achieved in hydrological regime change, with altering of drought and floods. The instability of ecosystems is important impact too.

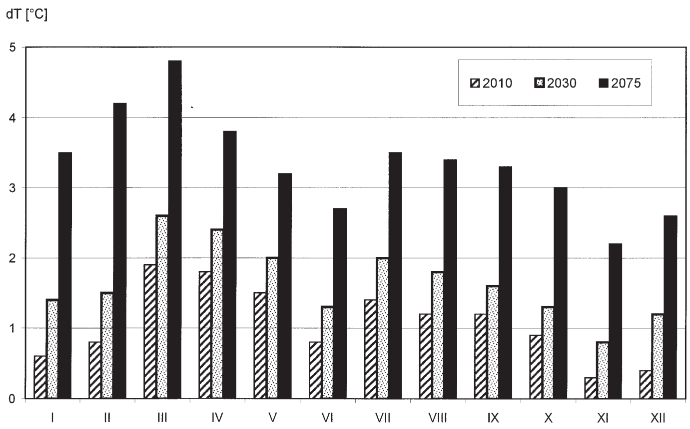


Fig. 10. Changes of long-term mean monthly air temperature in Slovakia in time horizons 2010, 2030 and 2075 – the CCCM 2000 scenario

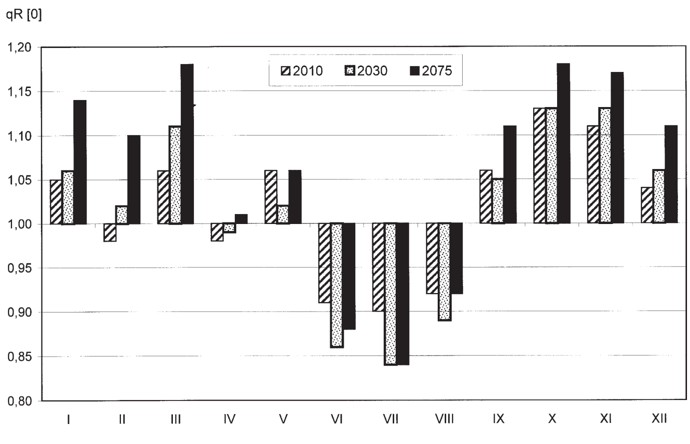


Fig. 11. Changes of long-term mean monthly sums of precipitation in the centre of Slovakia in time horizons 2010, 2030 and 2075 – the CCCM 2000 scenario

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VÝVOJ KLIMATICKÉHO SYSTÉMU ZEME ZA POSLEDNÝCH 1 000 ROKOV S DÔRAZOM NA POSLEDNÝCH 100 ROKOV

Súhrn

Problematike klimatickej zmeny sa venuje zvýšená pozornosť už vyše 25 rokov. Medzivládny panel o klimatickej zmene (IPCC), ktorý sa prezentovaním výsledkov skúmaní klimatickej zmeny zaoberá koordinovane prispel ku prijatiu Rámcovej zmluvy o klimatickej zmene (Rio de Janeiro 1992) ako aj ku Kjótskemu protokolu k tejto zmluve (1997). Posledné správy IPCC ukazujú, že globálne oteplenie je najmä výsledkom zosilneného skleníkového efektu atmosféry a toto oteplenie nie je možné vysvetliť len prirodzenou variabilitou klimatického systému. Vývoj klimatických pomerom na Slovensku je obrazom globálnej klimatickej zmeny. Výskumu klimatickej zmeny na Slovensku sa venoval Národný klimatický program SR, ktorý definoval hlavné dôsledky v klimatickom, hydrologickom ako aj ekologickom systéme. V práci sú predstavené názory, publikované v posledných správach IPCC spolu s výsledkami prác, zaoberajúcich sa vývojom klimatického systému Slovenska za posledných 100 rokov a predpokladaným vývojom v tomto storočí.

PRIORITIES FOR FOREST SCIENCE AND RESEARCH IN SLOVAKIA AT THE START OF THE 21ST CENTURY

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Abstract: *Konôpka, J., Voško, M.: Priorities for forest science and research in Slovakia at the start of the 21st century. In Folia oecologica. ISSN 1336-5266, 2003, vol. 30, no. 2, p. 25–32.*

This paper describes the current priorities of forest science and research in Slovakia. These priorities are grouped into seven interrelated foci: 1st: the effect of global atmospheric changes and anthropogenic activities on forest ecosystems. 2nd: preservation and reproduction of the forest gene pool, their species and ecosystem variety. 3rd: identification of the endangerment of forests by a complex of injurious agents and integrated forest protection. 4th: methods and procedures of sustainable forest management and their application in forestry. 5th: research on the effects of machinery on forest ecosystems; modelling of environmental technologies and the optimal use of forest resources. 6th: research on the methods and modelling economic evaluation of functions of services being provided by forests, principles of state forest policy for securing of their fulfilment. 7th: research on improvement of game environment and management.
Key words: *forest science and research, main directions and priorities*

1. Introduction and problems

In 2001, top representatives of the Ministry of Agriculture of the Slovak Republic (SR) discussed the document ”Main directions and priorities of agrarian science and research in Slovakia”. In accordance with this document, the global role of scientific research is to create and provide scientific and professional knowledge, recommendations and special advisory services for sustainable development of the agrarian sector. It is in fact participation in scientific research mainly in solving innovation activities of the land management, including the forestry sector, further, in actual problems and perspective issues in all branches of the sector, in supporting their both production and non-production roles. All these activities would be in accordance with main directions and priorities of the governmental and ministry concepts for development in the land management, including the processes of EU integration.

Sciences and subsequently also innovation processes in the sector of land management are increasingly being determined by the progress in basic scientific disciplines, mainly in biology and ecology, but also to a different extent in other fields. A modern and permanently efficient land management represents a multi-functional system, whose production takes place on in open landscape areas through the use of resources that constitute the main components of nature and environment. Therefore, sustainable development of all functions of the sector is possible only in an ecologically balanced country, having equilibrium human interventions. These systems require also secondary (fossil) energy to sustain their high production capacity. However, the dependence on fossil energy also causes instability in comparison with natural ecosystems, where the production of biomass occurs by self-regulating processes that use only solar energy. In modern land management the importance of ecological, landscape, environmental, as well as social functions has increased and thus the sector ranks among strategic interests of developed society.

In the forestry sector it is mainly securing sustainable development of the multifunctional character of forest communities. This as of most importance can be reached by:

- Conservation, revitalization, and improvement of effective use of forest ecosystems.
- Maintenance of development of landscape, agricultural and other socially important reproduction forest functions, including the improvement of the environment and game management.

Priorities for forest science and research have been formulated based on aspects of the multifunctional importance of forest ecosystems in the economic sphere and in the country as irreplaceable components of nature and environment.

The Department of Forestry at the Slovak Academy of Agricultural Sciences elaborated main directions and priorities in a way to be useful for future orientation of science and research. Employees of different sections of the Academy elaborated the document. Here we present the identified priorities, analyze current knowledge, and determine long-term research directions.

2. Priorities for forest science and research and their objectives

- *Effect of global atmospheric changes of the atmosphere and anthropogenic activities on forest ecosystems.* The aim is to obtain the most objective information on ecological conditions, their changes and development trends; to explain the effects of these changes on the state of forest ecosystems, contamination by air pollutants, health condition, vitality of forest tree species, and other. Research should clarify the interrelations in forest ecosystems and their changes, which will serve as a basis for the implementation of revitalization measures for degrading forest communities.
- *Preservation and reproduction of the gene pool of forests, their species and ecosystem variety.* The aim is to obtain and use new knowledge of species, biological and genetic variability of populations of forest tree species in order to influence positively particularly the preservation and reproduction of the autochthonous gene pool of forest tree species, thus increasing vitality, stability and functionality of forest ecosystems.
- *Identification of forests endangerment by a complex of harmful agents and their integrated protection.* The objective of this research is to specify decisive harmful agents (anthropogenic and natural), that are mutually combined into a complex causing destabilization and decline of forest communities. A second objective is to work out systematic measures of integrated forest protection against harmful agents according to the degree of forest endangerment with special regard to applying ecologically acceptable methods.
- *Methods and procedures of sustainable forest management.* The aim is to elaborate progressive procedures of forest management that would contribute to the sustainability of forest communities and sustained fulfilment of all forest functions (production and public-beneficial functions), including increased wood production and improved wood quality. A second objective is to work out proposals for better wood utilization, that are

currently implemented in the wood industry only to a small extent. Special attention should be paid to the elaboration of proposals for enhancement and better use of public-beneficial forest functions.

- *Research on the effects of machinery on forest ecosystems, modelling environmentally sound technologies and optimisation of the use of forest resources.* The aim is to work out a complex concept and programme of applying environmentally suitable machinery and technology for the management of forests in different growth phases and under different natural conditions. Secondly, to optimise its use with regard to obtaining the best possible economic parameters with the lowest possible damage to natural environment.
- *Research on methods and modelling of the economic evaluation of functions and services provided by forests, principles of forestry policy and tools for securing their fulfilment.* The aim is to work out systems of measures for increasing the economic effectiveness of forestry with respecting the multifunctional role of forests. It will be a proposal of applying economic tools, which support increasing effectiveness of wood production and its use. Then to make economic evaluation of public-beneficial functions of forest, possibly for reimbursement of losses for forest users due to additional cost in management maintaining public-beneficial tasks.
- *Research on the improvement of the environment for game management.* The aim is to work out a set of measures for improving the environment for game according to the carrying capacity of hunting grounds and the negative effects on game, including an optimisation of dividing the hunting area into hunting grounds, working out proposals for game management, that will guarantee game preservation, protection and improvement. It will be especially increasing of trophy quality of game, production of meat or other products.

International co-operation should be aimed mainly at integration of forest research into scientific-research programmes and projects of the EU. These should include sustainable development of forestry and rural areas, improvement of remote sensing methods and the complex utilization of forest biomass.

3. Specification of the priorities of forest science and research

3.1 The effects of global atmospheric changes and anthropogenic activities on forest ecosystems (Minďáš et al. 2003)

This issue is divided into 7 partial tasks as follows:

- Climatic changes, air and precipitation pollution.
- Objectifying information on changes and trends of the development of ecological conditions.
- Complex assessment of the effect of climatic changes and air pollution on the changes of site conditions.
- Carbon balance of forest ecosystems (including the commitments of Kyoto protocol).
- Growth processes of forest tree species and the effect of global changes.
- Climatic changes and activation of harmful agents.
- Revitalization, adaptation and mitigation measures in forestry.

This priority was ranked as first with a certain intention. We can suppose that global changes of the atmosphere and of anthropogenic activities will have the greatest effect on forest ecosystems. Therefore also other priorities of forest science and research are related with this one. They are mainly aimed at harmonizing of revitalization and adaptation measures with expected effect of climatic changes on forest communities, considering the knowledge on critical load and levels and their exceedance in implementation of revitalization measures, etc.

3.2 Preservation and reproduction of the gene pool of forests, their species and eco system variety (Longauer et al. 2003)

This is a serious issue, whose importance is stressed by the fact that there was preserved biodiversity in forests at the ecosystem, interspecific and intraspecific level within the territory of SR. From the analysis of the present state of adaptive capability of tree species, knowledge of their genetic variability, so far implemented measures and international commitments, concrete requirements to solve these tasks by forest science and research were identified:

- Analysis of the state of forest genetic sources and biodiversity of forest communities.
- Supporting measures to preserve domestic reproduction sources of forest tree species after fulfilment of the requirements of the Directive of EC Council 105/99 on the trade with reproduction material of forest tree species.
- Use of breeding methods and biotechnologies with renewal of stability, preservation of value production and fulfilment of ecological functions of forest stands.
- Introduction of systematic measures to preserve genetic sources of biodiversity of forest communities in accordance with Convention on Biodiversity, National strategy for biodiversity preservation, National Action Environmental Programme and Ministerial Conferences on Forest Protection in Europe.

3.3 Identification of forests endangerment by a complex of injurious agents and their integrated protection (Novotný et al. 2003)

This is based on the fact that forest protection at the world as well as at the European scale increasingly has to solve problems of synergic effect of several injurious agents, which attack forest ecosystems (parallel or consecutive). It requires a completely new approach to solving suitable methods of integrated forest protection because the measures must protect forest ecosystems against an entire complex of factors. A main approach is to enhance ecological aspects of defensive measures.

This issue was divided into the following components:

- Complex effects of the main abiotic injurious agents on forest ecosystems and the conceptual elimination or alleviation of these effects.
- Complex effects of the main anthropogenic injurious agents on forest ecosystems and conceptual restrictions or alleviation of these effects.
- Complex effects of the main biotic injurious agents influencing the vitality of forest stands and ecological methods for their regulation (insects, autotrophic plants, game and their effects on developmental stages of forest).

3.4 *Methods and procedures of sustainable management in forests and their application in forestry (Moravčík et al. 2003)*

This originates in the definition of sustainable management in forests as ”management and use of forests and forest land in a way and extent which will preserve their biodiversity, production potential, vitality and capability to fulfil at present as well as in future important ecological, economic and social functions on local, national and global level in a way not cause damage to forest ecosystems”.

It was proposed to solve the methods and procedures of sustainable management of forests within the following partial issues:

- Monitoring and assessment of the state and development of forests.
- Forest management planning of sustainable forest management.
- Forest regeneration (includes applying natural regeneration and revitalization of damaged and declining forests).
- Tending of stands (creating optimal age, species and area structure of forest stands, biological rationalization of the management in forests).

3.5 *Research on the effect of machinery on forest ecosystems, modelling environ mentally suitable technologies and the optimal use of forest resources (Ilavský et al. 2003)*

The technical level of silvicultural and logging practices does not reach the level in other developed states in the EU. This was caused partly by social and economic changes, which occurred after the year 1990. State forest organizations reduced their activities on a large area of forests belonging to non-state subjects. The process of privatization of machines and equipment has been going on in state forest organizations (the works will be secured mainly on contract). Machinery is mostly worn, frequently environmentally unsuitable and must be innovated. Also the access to forest stands is insufficient. In relation to the mentioned actual tasks, which must be solved in forest, science and research, there are also the following ones:

- Principles and procedures of ecologically suitable access to forests and its modelling by the use of Geographic Information Systems (GIS).
- Modelling of ecologically suitable technologies of works in forest with the use of the most modern machinery and equipment.
- Research on economic and ecological possibilities of the use of fully mechanized harvesting technologies in terrains with steeper slopes.
- Research on logistic methods and methods of GIS and Global Positioning Systems (GPS) in organizing logging-production works, reporting logged wood and wood trade.
- Research on environmental effects and limits to machinery works in forest environments.
- Research on the interaction of forest environment, machine and man.
- Research of higher degree on the use of raw wood material, including energy production as well as non-wood forest production, suitable machinery and technology.

3.6 Research on methods and modelling the economic evaluation of functions and services provided by forests; principles of state forestry policy and the tools for-securing their fulfilment (Ďurkovič et al. 2003)

The urgency of solving these issues originates mainly in the changes in the socio-economic conditions in the Slovak Republic, especially the transfer from directive control to market economy. After 1990, forests were returned back to their former owners and users (restitution laws), which means restitution of the private forest sector. In relation to this changes have occurred subsequently in state forest organizations, in state administration, forest management, forest research, etc. The Slovak Republic has to become EU member in a short time and therefore forest science and research should be aimed at solving following issues:

– Forestry and macroeconomics of Slovakia.
– Economics of wood-producing forest function.
– Economics of public-beneficial forest functions.
– Support to ecological aspects in forestry.
– Human factor in forestry.
– Tools of management in forestry.
– Principles of forestry policy.

3.7 Research on improvement of the environment for game and game management (Hell et al. 2003)

Game is an important renewable natural resource, which is being accepted also by the most important world conservation organizations as WWF and IUCN. In last decade the standardized stocks and quality of game have reduced in Slovakia. Therefore, measures with important participation of science and research must be implemented. Game management research has never been under uniform co-ordination in the SR. Therefore, it is proposed to promote an effective division of labour between institutions dealing with game management research. The main issues to be resolved:

– Management of ungulates.
– Management of field game.
– Management of water game.
– Protection and management of rare species and protected game.
– Care about the health of field.
– Game management economics.
– Game management legislation.

4. Discussion and conclusion

The main directions and priorities for forest science and research represent a set of topics and opinions, which followed from the analysis of present situation in forestry and the level of knowledge of science and research at home as well as abroad. The issues are open for discussion and complementation or adaptation. We think they can serve as a tool for further orientation of forest science and research in the Slovak Republic as well as for the formulation of concrete proposals of scientific-technical projects especially for the near future. The issues presented here are also given in the publication of Forestry Department of Slovak Academy of Agricultural Sciences "Main directions and priorities of forest science and research in Slovakia at entering the 21st century" (published by FRI Zvolen on the occasion of the 105th anniversary of the foundation of independent forest research in Banská Štiavnica). It is a joint work by top scientists from all scientific-research organizations and institutions in Slovakia including Lesoprojekt Zvolen and forest practice, which are members of the Forestry Department or its sections.

Because ecology plays a dominant role, the Institute for Forest Ecology of the SAS should be also very important. Interlinking of issues being solved at all forest scientific-research organizations and institutions should be supported to maximize the use of the obtained results in securing sustainable management of the forests in the Slovak Republic.

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HLAVNÉ SMERY A PRIORITY LESNÍCKEJ VEDY A VÝSKUMU NA SLOVENSKU PRI VSTUPE DO 21. STOROČIA

Súhrn

Charakterizujú sa hlavné smery a priority lesníckej vedy a výskumu. Ide o 7 na seba nadväzujúcich okruhov (vplyv globálnych zmien atmosféry a antropogénnych činností na lesné ekosystémy; zachovanie a reprodukcia genofondu lesov, ich druhovej a ekosystémovej rôznorodosti; identifikácia ohrozenia lesov komp

lexom škodlivých činiteľov a ich integrovaná ochrana; metódy a postupy trvalo udržateľného hospodárenia v lesoch a ich aplikácia v lesnom hospodárstve; výskum vplyvu techniky na lesné ekosystémy, modelovanie environmentálne vhodných technológií a optimalizácia využitia lesných zdrojov; výskum metód a modelovania ekonomického hodnotenia funkcií a služieb poskytovaných lesmi, zásad štátnej lesníckej politiky a nástrojov na zabezpečenie ich plnenia; výskum zlepšovania životného prostredia zveri a jej manažmentu).

THE IMPACT OF LAND-USE CHANGE ON SOIL MORPHOLOGY AND BIOGEOCHEMICAL CYCLING

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Abstract: *Farrell, E. P.: The impact of land-use change on soil morphology and biogeochemical cycling. In Folia oecologica. ISSN 1336-5266, 2003, vol. 30, no. 2, p. 33–39.*

Ireland has experienced two major periods of land-use change involving the forest. The first was the slow decline, over some thousands of years of the forest resource. This has been followed, in the past century, by a major afforestation programme. The paper will focuses on a study of the effects of deforestation on the morphology of a poor, acid soil and on an investigation of the influence of afforestation on biogeochemical cycling and its implications for ecosystem sustainability. The results demonstrate the complex nature of forest ecosystems in one region of Europe. They challenge both the concept and definitions of sustainable forest management
Key words*: Ireland, land-use, change, ecosystem, sustainability*

Introduction

The clearance of the forest for agriculture has been central to the viability of European civilisations (Perlin 1991). Deforestation resulting from incidental, uncontrolled exploitation of the resources of the forest has contributed to the degradation, if not the total destruction of both timber and soil resources and to the decline of civilisations. Mismanaged grazing has accelerated the destruction of the forest and to the suppression of its regeneration.

Ireland has experienced two major periods of landuse change involving the forest. The first was the slow decline, over some thousands of years of the forest resource, almost to the point of extinction. This has been followed, in the past century, by a major afforestation programme, which has gone a long way towards the restoration of the lost forest resource. This paper will focus on the influence of these major land use changes on soil morphology and biogeochemical cycling and their implications for ecosystem sustainability.

Deforestation

The natural forests of Ireland (*Quercus, Fraxinus, Alnus, Betula, Ulmus, Pinus*, spp.) were gradually depleted over several millennia until, by 1800, the forest cover represented only about 0.2% of the total land area. There were, within this period, several different phases of relatively intense exploitation. By the beginning of the 17th century, much of the remaining forest was confined to the less productive soils, in inaccessible, sparsely populated areas. The remnants of the natural forest, which survive today, are to be found in these regions. In our research group, we have studied the impact of deforestation at a number of these sites (Little et al. 1990; Little, Collins 1995; Farrell et al. 1996; Cunningham et al. 1999), which are located mainly in the west of Ireland.

The climate of western Ireland is dominated by the Atlantic Ocean and by the warming influence of the Gulf Stream. Annual precipitation is high (1200–2800 mm pa, almost all as rain) and the number of rain days is also high (>200 days per annum with more than 1mm of rain).

The soils of these regions are dominated by podzols and histosols. Over most of Europe, it is rare to find podzols in association with oak woodland. However, podzols occur commonly in upland regions of Ireland, on siliceous parent materials under high rainfall (Gardiner, Radford 1980). Morphologically, they are characterised by a peaty surface layer (O horizon), which tends to become darker towards its base, due to increased humification. Beneath it is a bleached, ash-grey mineral layer (E horizon), which in turn, is underlain by B horizons, which are yellowish-red in colour. The C horizon is usually extremely stony, originating as till, or weathered bedrock.

Podzolisation is the formation of an eluvial/illuvial horizon sequence due to the translocation of iron and aluminium with or without humus. A prerequisite seems to be the presence of a base-poor parent material. Podzolised soils have been generally associated with acid-generating flora, such as pine or heather. Their association with oak-dominated deciduous woodland is therefore of considerable interest.

Following a preliminary survey of a number of these acid oakwoods, which confirmed their widespread association with podzols (Little et al. 1990), attention focused on the impact of disturbance on soil morphology. This was examined by comparing wooded and currently non-wooded sites. At one site, Uragh, in County Kerry, south-west Ireland, the soils of an area known, from ^{14}C-dating to have been deforested about the year 1650, were compared with those in an adjacent, relatively undisturbed, intact woodland (Cunningham et al. 1999).

The soils at Uragh range from shallow lithomorphic soils on steeper ridges and rock outcrops to gley podzols in wet hollows and deep peats in troughs. Between these extremes, podzols and their variants predominate in the flatter positions (Cunningham et al. 1999). In general, surface accumulation of organic matter is greater in the non-wooded area. The non-wooded B horizons are firm or weakly indurated while their wooded counterparts are usually friable. Iron pans did not occur under the woodland canopy but were observed in profiles from the non-wooded site on water shedding, upper slope flank microsites (Table 1).

Table 1. Soil chemistry data for a representative profile from the wooded and non-wooded

Depth cm	Horizon	pH H_2O	pH $CaCl_2$	% L.O.I	% O.C	% Fe_d	% Fe_o	Fe_o:Fe_d
	Oi	4.0	3.1	79.1	51.2	0.2	0.1	0.3
	Eg	4.3	3.6	2.9	2.5	0.4	0.2	0.5
	Bh	4.5	4.1	14.5	6.5	3.9	2.3	0.7
	Bsh	4.8	4.3	12.3	4.6	3.3	2.7	0.8
	BC	4.9	4.4	2.9	2.3	1.4	1.0	0.7

Depth (cm): 0 10 20 30 40 50 60 70

Wooded - Humus iron podzol

Depth cm	Horizon	pH H_2O	pH $CaCl_2$	% L.O.I	% O.C	% Fe_d	% Fe_o	Fe_o:Fe_d
	Oi	4.3	3.5	82.3	43.3	0.2	0.2	1.0
	Oa	4.2	3.4	42.4	23.2	0.5	0.5	1.0
	Eagx	4.6	4.0	12.5	6.9	0.5	0.4	0.7
	Bm	-	-	-	6.5	14.8	14.5	1.0
	Bs	5.2	4.5	13.7	7.5	3.7	3.8	1.0
	C	5.3	4.5	1.7	0.8	0.7	0.3	0.4
	R							

Depth (cm): 0 10 20 30 40 50 60 70

Non-wooded - Peaty iron-pan podzol

Under the high rainfall/low-evapotranspiration conditions of the region, a moisture retentive surface organic layer accumulates, leading to reducing conditions, a deterioration in soil structure and the formation of a pan. The pan acts as a further barrier to water movement, oxidation is inhibited, organic matter accumulation increases, possibly resulting in peat formation.

Removal of a tree canopy disturbs the hydrologic balance, increasing the supply of groundwater by reducing the transpiration demand of the vegetation, and also by reducing the water interception of the canopy (GILLMOR 1977). In another semi-natural oakwood, of similar age and structure, in western Ireland, interception amounted to 12% of incoming precipitation (FARRELL et al. 1998). Responses of forest catchments to clearfelling have been described in detail from experimental work carried out at Hubbard Brook, New Hampshire, USA (BORMANN, LIKENS 1979; BORMANN et al. 1974). Following clearfelling, the amount of water passing through the ecosystem increases. Water uptake is drastically reduced as a result of the death of the tree root system.

Deforestation has resulted in the alteration of a susceptible ecosystem. It has led to significant soil degradation and ultimately, to diminished soil fertility. The end result of this land-use change is an ecosystem which is essentially unsustainable.

The question arises as to whether or not the pedogenic processes initiated or accelerated by deforestation are still active. In other words, did disturbance produce an effect, following which soil development returned to some sort of steady state condition, or is the soil still degrading as a result of an event that occurred 350 years ago? Iron fractionation studies at some of the sites suggest that, in some cases at least, translocation of iron is still occurring at a faster rate at the deforested sites than in the wooded sites, suggesting that the influence of forest clearance on pedogenic processes is still in progress, 350 years after the event.

Afforestation

Ireland has had an active State-sponsored afforestation programme for the past one hundred years. In the 1950s, the rate of afforestation was greatly increased. The 1990s saw another period of acceleration. As a result, the forest cover now represents 9.4% of the total land area. This period of expansion is projected to continue until 2030 (Anon. 1996).

The country's afforestation programme has relied very heavily on coniferous species; all of these are introduced, as Ireland has no native forest-tree conifers. The principal species planted is Sitka spruce [*Picea sitchensis* (Bong.) Carr.]; other important species include *Pinus contorta* var. *latifolia, Picea abies* L. and *Pseudotsuga menziesii* (Mirb.) Franco. Until the 1980s, plantations were confined, almost exclusively, to infertile acid soils, which were deemed unsuitable for agriculture. In the past twenty years, the limitations of this policy have become evident. While overall productivity has been very high, some of the plantations on poor sites have not been successful. In other cases, while the growth may have been satisfactory, environmental problems have been experienced and the potential consequences for ecosystem sustainability have given cause for concern.

The results of a study, at Roundwood, County Wicklow, in eastern Ireland, have been reported (Farrell et al. 2001). The objective of the study was to test the sustainability of the ecosystem against a number of chemical criteria. Input-output balances, proton budgets and critical loads were calculated, based on an eight-year monitoring period (1991–1998).

The Roundwood stand is part of an EU-wide network of forest health monitoring plots. It is a first-rotation plantation [Sitka spruce (*Picea sitchensis*)], established in 1955 on former extensively-managed, unenclosed hill land. The soil is a podzol, derived directly from weathered bedrock (schist and quartzite) or thin drift. Soil pH values, in H_2O, vary between 3.5 (O horizon) and 4.6 (C horizon), which is in the range of strongly acid soils characterised by aluminium buffering.

The site experienced significant atmospheric deposition. Total deposition of NH_4^+ and H^+ were estimated using the canopy budget model of Draaijers and Erisman (1995). Total deposition of H^+ was 123 $mmol_c\ m^{-2}\ yr^{-1}$ and of nitrogen ($NH_4^+ + NO_3^-$) 156 $mmol_c\ m^{-2}\ yr^{-1}$.

According to Van Breemen et al. (1984), most ecosystems with a ratio of external/internal H^+ sources greater than 0.5 show significant dissolution of soil Al^{3+} and SO_4^{2-} retention, resulting in export of free H^+ and Al^{3+} in drainage waters. At the study site, the ratio was in excess of 4. Other tests applied to the plantation forest ecosystem were exceedence of critical load of acidity, nitrogen saturation, based on nitrate leaching and pH of soil solution in B horizon (based on a critical pH value of 4.4, postulated by SVERDRUP, (1993). The site failed these tests of sustainability also.

The results of this type of analysis require careful interpretation. The forest stand is healthy; it is a productive stand, of considerable commercial potential. The normal rotation for such plantations in Ireland is in the range 40–50 years. Leaching losses of aluminium are high. Hydrochemical analysis of the stream draining this small catchment yielded toxic concentrations of inorganic aluminium (KELLY-QUINN et al. 1996)

It is possible that the results of this study reflect the impact of disturbance associated with the change in land-use from extensive grazing to plantation forestry. If this is the case, a new equilibrium might establish itself in due course. On the other hand, it is possible that this equilibrium situation will never be reached due to the regular, major disturbance episodes brought about by clearfelling.

Conclusions

For two hundred years, the scientific approach to the management of forests in Europe has been based upon the maintenance of a sustained yield of wood supply. Modern ideas of sustainability embrace all the goods and services of the forest and suggest that ”sustained yield” should be replaced by the broader concept of ”sustainable forest management” (WIERSUM 1995).

This broader definition of sustainable forest management requires that we better understand how forest ecosystems function. These two studies demonstrate the complex nature of forest ecosystems in one region of Europe. They challenge both the concept and definitions of sustainable forest management, which tend to ignore the fact that soil, climate and the ecosystems themselves are all dynamic. Many of the ecosystems that foresters are asked to manage in a sustainable manner are in fact, degrading, often as a result of previous mismanagement. In such cases, sustainable forest management may not be achievable.

Any objective assessment of sustainable management must have a known starting point against which the properties of the ecosystem can be compared in the future. The underlying assumption we make is that present is, in some sense, a steady state, a benchmark for future comparison. The reality is quite different. Scientists conduct their research and foresters their management in dynamic ecosystems, which are experiencing change, in directions which are unclear to us, not only from current environmental influences, acid deposition, climate change etc., but as a result of past events, previous land use, mismanagement, for example, of which we are often totally ignorant.

The commitment to sustainable forest management in Europe was developed in the Helsinki Process (ANON. 1993) and a subsequent Ministerial Conference in Lisbon. It identified criteria of sustainable forest management and for each criterion a series of indicators against which progress can be measured over time.

In developing criteria and indicators of sustainability, we should recognise that we operate under the influence of the general mindset of our time and that furthermore, within that, we are heavily biased towards the traditional scientific mindset. In other words, we believe that we can identify things to be measured (indicators), and through measuring aspects or components (parameters) of those things and comparing them with established standards (critical limits), we can determine whether or not a system (in our case, the forest) is being managed in a sustainable manner. We need to understand that not only will the appropriateness of the indicators, parameters and critical limits we have identified be challenged and modified in the future, but also the very mindset, which produced them will itself undergo change.

Bell and Morse (1999) describe the quest for sustainability as ”chasing a moving shadow”. In their words, ”The situation appears to be that, at the end of the 20th century, a word has been decided upon to conjure up the desirable outcome of social and political endeavours. Scientists and professionals have taken (or been given) the impossible task of achieving definitive measurement of this word. The impossible task was to measure what was never potentially measurable: the immeasurable ‘sustainability’.”

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ÚČINKY ZMIEN VO VYUŽÍVANÍ KRAJINY NA MORFOLÓGIU PÔD A BIOGEOCHEMICKÉ PROCESY PREBIEHAJÚCE V PÔDACH

Súhrn

Írsko prekonalo dve obdobia zásadných zmien vo využívaní krajiny, lesnú krajinu nevynímajúc. Prvým bol pomalý ale niekoľko tisícročí trvajúci úpadok lesného fondu vystriedaný začiatkom minulého storočia obsiahlym programom intenzívneho zalesňovania. Táto práca je zameraná na štúdium účinkov odlesňovania na morfológiu kyslých, na živiny chudobných pôd; na výskum vplyvu zalesňovania na priebeh bio-geo-chemických procesov ako aj na dôsledky, ktoré z toho vyplývajú pre stabilitu daných ekosystémov. Naše výsledky poukazujú na komplexnú povahu lesných ekosystémov v jednom z regiónov Európy. Apelujú rovnako na obsah ako aj na definície pojmu udržateľné obhospodarovanie lesa.

EFFECT OF SECONDARY SPRUCE FORESTS ON PHYTOENVIRONMENT IN THE SLOVENSKÉ RUDOHORIE MOUNTAINS

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Abstract: *Šomšák, L.: Effect of secondary spruce forests on phytoenvironment in the Slovenské rudohorie Mountains. In Folia oecologica. ISSN 1336-5266, 2003, vol. 30, no. 2, p. 41–59.*

This contribution is focused on changes in floristic composition of the herb layer, which is caused by secondary spruce forests. Evaluation of these changes is solved by way of phytocoenological table comparison. We found out that old spruce forests miss averagely 24 species of vascular plants compared to natural forest communities of Abieto-Fagetum, Poo chaixii-Fagetum and Circaeo alpini-Abietetum. The reasons of this decrease are evaluated using ecological analyses for demands of missing species to light, soil reaction and soil nitrogen. The effect of spruce needle litter, which causes acidification of rhizosphere, is considered to be the most important reason.

Key words: *secondary spruce forests, changes of the herb layer*

Introduction

Phytoenvironment, meaning the plant component of the forest ecosystem including all development stages of trees, grassy-like plants, herbs, mosses, lichens and fungi, represents integrated unit where its individual components affect each other. However it is an indisputable fact that all these components of phytosphere, except of epiphitic and epilithic species, draw the nutrients from soil. This drawing off is not primarily affected by the sum of nutrients in soil but by real demands of the concrete plant individual, by its metabolism respectively. Regardless to high amount of silica, aluminium and iron in soil, the plants prefer nitrogen, calcium, potassium and phosphorus. Šály (2000) calls this phenomenon as ”selective sorption”.

Why such wide and generally known introduction? Here are some reasons:

1. If we want to evaluate the effect of secondary spruce forests on global changes of phytoenvironment we must take into consideration not only effect of needle cover on radical changes in floristic composition of the herb layer. Although it is proved that needle cover causes changes in pH of litter and humus horizon of soil, it is also necessary to pay attention to the fact that majority of perennial species in spruce forest are rooted in upper part of B-horizon (*Vaccinium myrtillus*, *Luzula luzuloides*, *Calamagrostis arundinacea*, *Dryopterix filix-mas*, *Solidago virgaurea*, *Polygonatum verticillatum*).
2. Changes in the herb layer under secondary spruce forests occur also on soils with well developed buffering mechanisms, such as rendzinas. In such soils the pH values have changed only slightly in litter and humic horizons due to buffering effect of carbonic acid and carbonates.

3. Finally, changes in the herb layer composition accompany secondary colonisation of abandoned meadows and pastures with oligotrophic actual vegetation by spruce (acidophilous communities with *Nardus stricta* and *Calluna vulgaris*). This grassy vegetation disappears after the tree canopy is compact enough.

Foregoing reasons, but also some others, were a motivation for trying to explain the serious grounds for changes in the composition of the herb layer under secondary spruce forests compared to natural types of forests in the neighbourhood of village of Nálepkovo (Slovenské rudohorie Mts.).

Delimitation of the study area and its brief characteristics

The study area belongs to the Slovenské rudohorie mountains, more concretely to their unit Volovské vrchy mountains, and village of Nálepkovo is located just in the middle of this unit. The total are is 55.6 km^2 while forests cover approximately 3 251.56 ha. Altitude ranges between 550 and 1267 m above see level. The study area is divided into two individual parts by Hnilec river with its two major feeders: Tichá voda creek and Železný potok creek. The mountains are typical for long side ridges scattering from the main ridge to the north-east. They enclose deep valleys from which the valley along Hnilec river is the most important.

Geological structure has a pall character and it is formed by three tectonic units laying in superposition. As for soil genesis, gemericum unit is the most important one. This unit is built by quartz-seritic, seritic-quartz and quartz phylite rocks, metamorphous quartz wackes, coarse metaliparite tuffs and metaliparites (Bajaník et al. 1984). In the south-western part of mountains there occur also phylites, metamorphous sandstones, metabasalts, their tuffs and tuffits as well as green schist. There are also quarternary sandy gravels, loamy gravels, loams, clays and deluvial sediments.

Juráni (1997) describes Haplic Cambisols developed under fir-beech forest and Cambic Podzols under acidophilous beech forests and secondary spruce forests as the most frequent soil types. Stagnic soils accompany slightly sloped and long side foots.

An annual rainfall is averagely 796 mm, temperature 6.5 °C.

Methods

Methods used in this paper are based on phytocoenological characteristics of natural and original forest communities and monoculture phytocoenoses evaluated according to the Zurich-Montpellier geobotanical school (Braun-Blanquet 1964). We also used published papers by Šomšák (1973, 1979, and 1982), Šomšák and Balkovič (2002), Šomšák et al. (2003) and Šimurdová (2001a, b). Vascular plants are named according to Dostál et Červenka (1991, 1992), mosses according to Kubínska et Janovicová (1996). Information on relations of plant populations to some ecological factors (light, soil reaction, soil nitrogen) are adopted from Ellenberg (1974). Soil nomenclature is according to Collective (2000).

The method of phytocoenological table comparison was used to evaluate the effect of secondary spruce forests to the herb layer. Tables of natural forests were compared with tables of spruce monocultures while the attention was paid on selection of approximately similar site conditions in same localities.

Spruce forests of following communities were compared:

1. Abieto-Fagetum Klika (1936) 1949 – by Šomšák 1973,
2. Abieto-Fagetum Klika (1936) 1949 – by Šimurdová 2001a,
3. Poo chaixii–Fagetum Šomšák 1979 – by Šomšák 1979,
4. Poo chaixii-Fagetum Šomšák 1979 – by Šimurdová 2001a,
5. Circaeo alpini-Abietetum Šomšák 1982 – by Šomšák 1982,
6. Circaeo alpini-Abietetum Šomšák 1982 – by Šimurdová 2001a,
7. Avenello-Piceetum cult. Šimurdová 2001 – by Šimurdová 2001b,
8. Avenello-Piceetum cult. Šimurdová 2001 – by Šomšák 2003,
9. Calamagrostio arundinaceae-Piceetum cult. prov. – Šomšák msc.

Brief characteristics of compared communities

1. Natural forests

1.1. Association Abieto-Fagetum Klika (1936) 1949

Stands of this association spreads from 600 m above see levels up to 1000 m above see level in the study area. They colonise all aspects with slopes up to 30°. Soils belong to Haplic Cambisols, seldom to Cambic Podzols. Soil reaction of Ao horizon varies between 5.5 and 6.5 (Pelíšek 1955) in Haplic Cambisols and between 4.5 and 5.5 in Cambic Podzols (Juráni 1997). Humus content reaches approximately 3% in Ao horizon.

Mixed fir-beech stands have significant admixture of *Picea abies*. In the herb layer, there are dominants such as *Dentaria bulbifera*, *Galium odoratum*, *Mercurialis perennis*, *Senecio fuchsii*, *Calamagrostis arundinac*ea and ferns such as *Dryopteris filix-mas*, *D. carthusiana*, *Athyrium filix-femina* (for more detailed composition refer Table 1).

1.2. Association Poo chaixii-Fagetum Šomšák 1979

Beech forests which colonise plain relief of peneplain at the main ridge of the Slovenské rudohorie mountains. Their occurrence is concentrated to concave forms of relief where snow mantle remains about 2–3 weeks compared with other sites. Except of beech also *Acer pseudoplatanus*, less frequently also *Abies alba* and culturally conditioned *Picea abies*, are steadily present.

Soil conditions of this association create relatively various mosaics. Cambic Podzols together with Haplic Podzols vary in short spatial distances. Soil reaction of Ao horizon is however nearly uniform (pH between 3.7 and 4.6).

The herb layer is formed by two strong aspects. Geophytes such as *Scilla bifolia* subsp. *danubialis*, *Galanthus nivalis*, *Isopyrum thalictroides*, *Corydalis cava* and *Dentaria glandulosa* prevail in the spring aspect and species as *Vaccinium myrtillus*, *Poa chaixii*, *Soldanella hungarica*, *Calamagrostis arundinacea*, *Galeobdolon luteum* dominate in the summer aspect.

1.3. Circaeo alpini-Abietetum Šomšák 1982

These forest communities are typical for nearly absolute prevailing of *Abies alba* and only somewhere is admixed *Fagus sylvatica*. Similarly to other parts of the Slovenské rudohorie Mts. also here is high fraction of *Picea abies* present, mostly from old natural seeding. Forest stands usually occur at foots of north oriented sides and in valleys with ecological inversion.

Soils belong to Haplic Cambisols with pH between 5.5 and 6.5 (in water suspension) in Ao horizons.

Except of Slovenské rudohorie Mts. these forests are described from the Slovenské Beskydy mountains and Oravská Magura mountains (Šomšák 1983), Spišská Magura mountains (Šomšák 1986), Podtatranská kotlina basin (Šomšák et al. 1993, 1996). Floristic composition is shown in Table 1.

Table 1. Comparison of phytocoenological composition of the association Abieto-Fagetum and Avenello-Piceetum in the Slovenské rudohorie Mts.

Taxon		Abieto-Fagetum		Avenello-Piceetum	
		1	2	3	4
Tree species					
Fagus sylvatica	E3	V	V	I	I
	E2	IV	V	I	II
	E1	V	V	I	III
Abies alba	E3	IV	V	I	II
	E2	I	II	III	II
	E1	IV	V	IV	IV
Picea abies	E3	IV	V	V	V
	E2	I	II	V	II
	E1	II	III	V	V
Acer pseudoplatanus	E3	IV	I	.	.
	E2	I	.	.	.
	E1	IV	IV	.	.
Sorbus aucuparia	E2	.	.	IV	
	E1	III	I	V	V
Sambucus racemosa	E1	II	III	II	.
Daphne mezereum	E1	II	I	.	.
Lonicera xylosteum	E1	I	II	.	.
Fraxinus excelsior	E1	I	.	.	.
Ribes uva-crispa	E1	.	II	.	.
Betula pendula	E3	.	I	II	.
	E2	.	I	II	I
	E1	.	.	.	III
Tila cordata	E3	I	I	.	.
	E1	.	I	.	.
Larix deciduas	E3	.	I	.	.
Corylus avellana	E2	.	II	I	.
Pinus sylvestris	E3	.	.	II	I
Acer platanoides	E1	.	I	.	.
Common species					
Oxalis acetosella		V	IV	V	IV
Dryopteris carthusiana		V	V	V	V
Senecio fuchsia		V	V	V	III
Rubus idaeus		IV	IV	V	III
Calamagrostis arundinacea		V	V	V	III
Athyrium filix-femina		V	V	IV	III
Mycelis muralis		IV	IV	V	III
Maianthemum bifolium		III	IV	V	V
Gentiana asclepiadea		III	II	I	II
Polygonatum verticillatum		V	IV	.	II
Geranium robertianum		V	IV	II	.
Dryopteris filix-mas		V	V	.	II
Species with occurrence in the association Abieto-Fagetum					
Prenanthes purpurea		IV	IV	.	.
Galium odoratum		V	III	.	.

Continue Table 1.

Dentaria bulbifera		V	IV	.	.
Paris quadrifolia		IV	II	.	.
Mercurialis perennis		IV	II	.	.
Galeobdolon luteum		V	III	.	.
Asarum europaeum		III	II	.	.
Milium effusum		III	I	.	.
Scrophularia nodosa		III	I	.	.
Poa nemoralis		II	II	.	.
Sanicula europaea		II	I	.	.
Actea spicata		II	I	.	.
Aruncus sylvestris		II	I	.	.
Lilium martagon		II	I	.	.
Pulmonaria officinalis		II	I	.	.
Circaea alpine		II	I	.	.
Ajuga reptans		II	I	.	.
Viola reichenbachiana		I	II	.	.
Polygonatum multiflorum		I	II	.	.
Phegopteris connectilis		I	II	.	.
Dentaria glandulosa		I	II	.	.
Epilobium montanum		II	I	.	.
Urtica dioica		II	II	.	.
Cardamine impatiens		I	I	.	.
Galeopsis speciosa		I	I	.	.
Stellaria nemorum		I	I	.	.
Festuca gigantean		II	.	.	.
Adoxa moschatelina		II	.	.	.
Impatiens noli-tangere		II	.	.	.
Melica nutans		.	II	.	.
Species with occurrence in secondary spruce forests (Avenello-Piceetum)					
Frangula alnus	E2	.	.	I	I
	E1	.	.	IV	I
Chamerion angustifolium		.	.	II	I
Vaccinium vitis-idaea		.	.	I	I
Pleurozium schreberi		.	.	V	x
Dicranum scoparium		.	.	V	x
Polytrichum formosum		.	.	IV	x
Hylocomium splendens		.	.	II	x
Dicranella heteromala		.	.	II	x
Plagiothecium laetum		.	.	II	x
Species with higher quantitative values in secondary spruce forests (Avenello-Piceetum)					
Vaccinium myrtillus		I	III	V	V
Avenella flexuosa		.	II	V	V
Veronica officinalis		.	I	II	II
Rubus fruticosus agg.		II	I	IV	II
Other species					
Galeopsis tetrahit		I	I	I	.
Hypericum maculatum		I	I	I	.
Carex digitata		.	I	I	.

Continue Table 1.

Calamagrostis villosa	.	I	I	.
Rubus hirtus	.	II	.	IV
Fragaria vesca	I	II	II	.

Species with occurrence in only one association:

Column 1: *Acetosa alpestris, Angelica sylvestris, Carex sylvatica, Chrysosplenium alternifolium, Cystopteris fragilis, Digitalis grandiflora, Glechoma hederacea, Luzula sylvatica, Poa chaixii, Tithymalus amygdaloides, Lamium maculatum,*

Column 2: Alliaria petiolata, Brachypodium pinnatum, Campanula persicifolia, Dryopteris dilatata, Cruciata glabra, Galium aparine, Hedera helix, Viola collina, Viola odorata

Column 3: *Agrostis tenuis, Galium mollugo, Melampyrum sylvaticum, Sonchus arvensis*

Column 4: *Carex pilulifera, Holcus lanatus, Homogyne alpine, Soldanella hungarica*

References to literature used for individual columns:

Column 1: Šomšák (1973)

Column 2: Šimurdová (2001a)

Column 3: Šomšák (2003)

Column 4: Šimurdová (2001a)

2. Secondary spruce forests

2.1. Association Avenello flexuosae-Piceetum cult. Šimurdová 2001

This association includes secondary spruce forests, primarily those, which have remained at least for two generation at the same site. It is impossible to exclude the possibility that spruce trees were purposely planted in the past because spruce tree had excellently regenerated from seed already in the first generation. Tree canopy is affected by monodomination of spruce tree and the rests of tree composition of natural forests are only seldom. *Sorbus aucuparia* is admixed but, relatively constant species.

The herb layer of secondary spruce forest misses its own diagnostic vascular species; however, increased quantitative values of *Avenella flexuosa* are visible. Moreover, this association misses couple of plant populations typical for deciduous forests after comparison with fir-beech and montane beech forests (notice relevant phytocoenological tables). Remarkable feature is the presence of mosses while each species has high abundance.

2.2. Association Calamagrostio arundinaceae-Piceetum cult. ass. prov.

This association includes secondary spruce forests which are nowadays substituting the fir forests belonging to the association Circaeo alpini-Abietetum Šomšák 1982. Floristic composition is affected by the absence of species common for fir forests as *Circaea alpina*, *Prenanthes purpurea*, *Dentaria glandulosa*, *Viola reichenbachiana* and other 13–18 species. As for positive feature, only the massive abundance of *Calamagrostic arundinacea* could be mentioned.

Less significant is the difference in moss spectrum because the most of them accompany also natural fir phytocoenoses.

Results

Detailed herb layer comparison of mixed fir-beech and beech communities with phytocoenological structure of parallel existing secondary spruce forests showed similar results in all compared cases. They are as follows:

- absence of high amount of plant populations in secondary spruce forests,
- prominent quantitative dominance of one or two species in secondary spruce forests,
- growing of moss importance in the undergrowth of secondary spruce forests.

The number of missing species in secondary spruce forests, which exist in natural forest communities, varies between 20 and 30. Abieto-Fagetum is on the top with 30 missing species and it is followed by Poo chaixii-Fagetum (22 species) and finally by fir forests of Circaeo alpini-Abietetum with 20 missing species – notice Table 1, 2, 3.

Table 2. Comparison of phytocoenological composition of the association Poo chaixii-Fagetum and Avenello-Piceetum cult. in the Slovenské rudohorie Mts.

Taxon		Poo chaixii-Fagetum		Avenello-Piceetum
		1	2	3
Tree species				
Fagus sylvatica	E3	V	V	I
	E2	V	III	.
	E1	V	V	II
Abies alba	E3	III	I	I
	E2	I	I	.
	E1	III	II	II
Picea abies	E3	III	III	V
	E2	III	II	III
	E1	III	II	V
Acer pseudoplatanus	E3	III	IV	.
	E2	I	II	II
	E1	III	V	.
Sorbus aucuparia	E3	III	.	V
	E2	I	.	IV
	E1	IV	V	V
Daphne mezereum	E2	II	.	.
	E1	I	I	.
Lonicera xylosteum	E2	.	.	II
Betula pendula	E3	.	.	I
Ribes uva-crispa	E1	I	I	.
Common species				
Oxalis acetosella		V	V	V
Calamagrostis arundinacea		V	V	III
Dryopteris filix-mas		III	IV	II
Polygonatum verticillatum		V	IV	III
Dryopteris carthusiana		IV	III	V
Rubus idaeus		IV	V	III
Maianthemum bifolium		III	III	IV
Solidago virgaurea		V	III	V
Luzula luzuloides		IV	III	II
Gentiana asclepiadea		III	II	IV
Athyrium filix-femina		III	II	III
Hieratium murorum		III	I	III
Luzula sylvatica		III	I	III
Prenanthes purpurea		II	II	II
Geranium robertianum		I	I	IV
Avenella flexuosa		IV	IV	V
Vaccinium myrtillus		III	IV	V
Homogyne alpina		I	II	V
Epilobium montanum		I	I	I
Ajuga reptans		I	I	I
Stellaria nemorum		I	I	I
Soldanella hungarica		II	I	V
Veronica officinalis		I	I	I

Continue Table 2.

Species with occurrence in the association Poo chaixii-Fagetum			
Galeobdolon lutaeum	V	V	.
Senecio fuchsii	IV	IV	.
Galium odoratum	III	IV	.
Milium effusum	V	II	.
Poa chaixii	V	V	.
Dentaria glandulosa	V	II	.
Acetosa alpestris	III	III	.
Cicerbita alpina	I	II	.
Dryopteris phegopteris	I	I	.
Poa nemoralis	I	I	.
Lilium martagon	I	I	.
Asarum europaeum	II	I	.
Dentaria bulbifera	II	I	.
Mycelis muralis	I	I	.
Viola reichenbachiana	II	I	.
Phyteuma spicatum	II	II	.
Rubus hirtus	III	I	.
Silene dioica	I	I	.
Anemone nemorosa	II	II	.
Galanthus nivalis	IV	I	.
*Scilla *austriaca*	III	I	.
Isopyrum thalictroides	III	I	.
Aegopodium podagraria	I	I	.
Species with occurrence in the association Avenello-Piceetum			
Calamagrostis villosa	I	.	V
Veratrum lobelianum	.	I	III
Vaccinium vitis-idaea	.	.	II
Bryophyta	.	.	50%

Species with occurrence in only one association:
Column 1: *Actea spicata, Fragaria vesca, Mercurialis perennis, Ranunculus aconitifolius*
Column 2: *Chamerion angustifolium, Betula pendula, Carex digitata*
Column 3: *Cystopteris fragilis, Cardamine impatiens, Rubus fruticosus* agg.

References to literature used for individual columns:
Column 1: Šomšák (1979)
Column 2: Šimurdová (2001a)
Column 3: Šomšák (1973)

Table 3. Comparison of phytocoenological composition of the association Circaeo alpini-Abietetum and Calamagrostio arundinaceae-Piceetum cult. in the Slovenské rudohorie Mts.

Taxon		Circaeo alpini-Abietetum		Calamagrostio-Piceetum
		1	2	3
Tree species				
Fagus sylvatica	E3	III	.	II
	E2	II	.	.
	E1	IV	.	I
Abies alba	E3	V	V	.
	E2	III	I	.
	E1	IV	V	.
Picea abies	E3	IV	V	V
	E2	II	II	V
	E1	II	V	IV
Acer pseudoplatanus	E3	I	.	.
	E2	III	.	.
Sorbus aucuparia	E3	I	.	IV
	E2	IV	I	III
	E1	I	V	III
Sambucus racemosa	E2	I	.	.
	E1	III	III	.
Lonicera xylosteum	E1	I	IV	.
Tilia cordata	E3	.	I	.
	E1	I	.	.
Corylus avellana	E2	I	IV	.
	E1	I	III	.
Acer platanoides	E1	.	II	.
Lonicera nigra	E1	.	I	.
Ribes uva-crispa	E1	I	.	.
Common species				
Calamagrostis arundinacea		V	V	V
Rubus idaeus		V	V	IV
Maianthemum bifolium		IV	V	V
Avenella flexuosa		V	IV	V
Luzula luzuloides		V	III	V
Senecio fuchsii		V	V	III
Oxalis acetosella		V	V	V
Athyrium filix-femina		IV	V	I
Dryopteris carthusiana		V	V	I
Galeobdolon luteum		IV	V	II
Solidago virgaurea		II	IV	IV
Vaccinium myrtillus		II	II	V
Mycelis muralis		V	II	I
Polygonatum verticillatum		III	I	II
Gentiana asclepiadea		II	.	V
Vaccinium vitis-idaea		.	II	I
Soldanella hungarica		.	I	I
Stellaria nemorum		I	.	I

Continue Table 3.

Species with occurrence in the association Circaeo alpini-Abietetum			
Circaea alpina	V	V	.
Phegopteris connectilis	III	V	.
Calamagrostis villosa	II	V	.
Prenanthes purpurea	IV	IV	.
Galeopsis tetrahit	II	II	.
Fragaria vesca	III	II	.
Viola reichenbachiana	I	III	.
Dentaria glandulosa	I	III	.
Rubus hirtus	II	II	.
Carex digitata	I	II	.
Dryopteris dilatata	I	I	.
Geranium robertianum	I	II	.
Festuca gigantea	II	.	.
Epilobium montanum	II	.	.
Mercurialis perennis	II	.	.
Urtica dioica	III	I	.
Impatiens noli-tangere	II	.	.
Rubus fruticosus agg.	.	II	.
Moehringia trinervia	II	.	.
Cardamine impatiens	IV	.	.
Mnium punctatum	II	?	.
Atrichum undulatum	II	?	.
Eurhynchium zetterstedtii	I	?	.
Hypnum cupressiforme	I	?	.
Bryoflora common for both phytocoenoses			
Mnium affine	IV	?	III
Mnium undulatum	V	?	III
Dicranum scoparium	IV	?	V
Pleurozium schreberi	III	?	IV
Plagiothecium denticulatum	III	?	II
Polytrichum commune	III	?	IV
Hylocomium splendens	II	?	I
Plagiochilla asplenioides	I	?	IV
Polytrichum formosum	I	?	IV
Mnium cuspidatum	I	?	II
Tetraphis pellucida	I	?	I
Orthodicranum montanum	I	?	III
Plagiothecium curvifolium	I	?	II

Species with occurrence in only one association:

Column 1: *Actea spicata, Asarum europaeum, Cardamine flexuosa, Chamerion angustifolium, Chrysosplenium alternifolium, Cruciata glabra, Cystopteris fragilis, Galium schultesii, Galium odoratum, Glechoma hederacea, Isopyrum thalictroides, Melica nutans, Milium effusum, Poa nemoralis, Polypodium vulgare, Scrophularia nodosa, Stachys sylvatica*

Column 2: *Homogyne alpine, Salvia glutinosa*

Column 3: *Cicerbita alpina*

References to literature used for individual columns:
Column 1: Šomšák (1982)
Column 2: Šimurdová (2001a)
Column 3: Šomšák (msc. 17relevés)

Mutual comparison of missing species shows that 60% of these species is common (*Prenanthes purpurea*, *Dentaria bulbifera*, *D. glandulosa*, *Galium odoratum*, *Viola reichenbachiana*, *Galeobdolon luteum*, *Impatiens noli-tangere*, *Circaea alpina*, *Asarum europaeum, Lilium martagon, Cardamine impatiens and others*).

We tried to explain the absence of these populations by evaluating their affinity to three ecological factors: light, soil reaction, soil nitrogen.

1. Relations to light

This factor was chosen on the base of general knowledge that dense tree canopy of secondary spruce forest transmits less sunshine than mixed coniferous-deciduous forest. Moreover we take into consideration, that 20–30 years old stands of secondary spruce forest have absolutely depleted herb layer because of light deficiency. Results obtained in secondary spruce forests, which developed after individual communities, are collected in Table 4.

Table 4. Analysis of missing species according to light demands

Eco-logical number	light demands	Abieto-Fagetum		Poo-Fagetum		Circaeo-Abietetum	
		species number	%	species number	%	species number	%
2	extremely sciophilous - sciophilous	5	17	4	18	1	5
3	sciophilous	4	13.5	3	13.5	3	15
4	scio-semisciophilous	13	36	4	18	4	20
5	semisciophilous	5	17	5	23	4	20
6	semiscio-heliophilous	1	3	1	4.5	5	25
7	semiheliophilous	–	–	–	–	1	5
8	semiheliophilous-heliophilous	–	–	–	–	–	–
9	extremely heliophilous	–	–	–	–	–	–
X	indifferent	3	13.5	5	23	2	10

Regardless to expectations that especially heliophilous species should disappear from secondary spruce forests the results show direct contrast (Fig. 1). The highest percentage of missing species lies within categories from 2 to 5, it means within the spectrum of sciophilous species. The state according to individual associations is as follows:
– 89% of sciophilous species in secondary spruce forests after Abieto-Fagetum,
– 72% of sciophilous species in secondary spruce forests after Poo chaixii-Fagetum,
– 70% of sciophilous species in secondary spruce forest after Circaeo alpini-Abietetum.

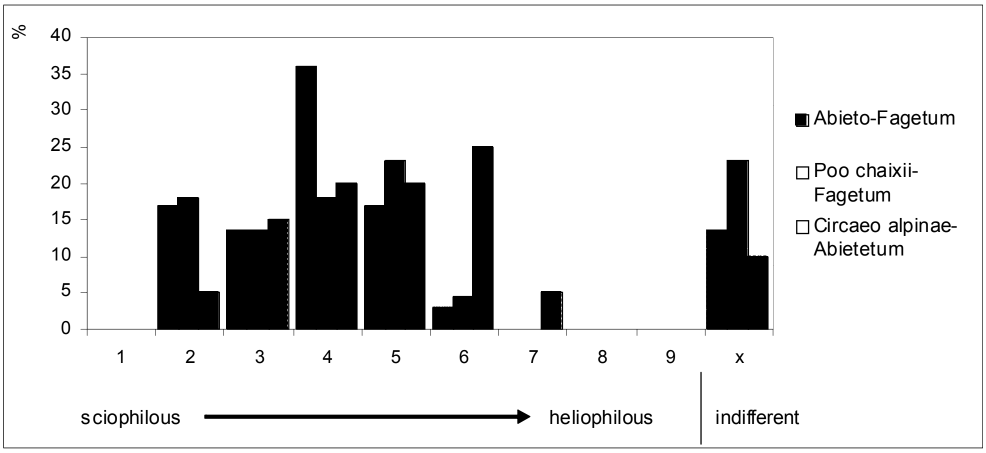

Fig. 1. Demands of missing species of secondary spruce forests to light

2. Relations to soil reaction

Evaluation of relations between plants of the herb layer and soil reaction was motivated by commonly interpreted opinions that needle litter causes acidification of soil horizons, especially Ao horizon. The results are summarised in Table 5.

Table 5. Analysis of missing species according to soil acidity demands

Eco-logical number	soil acidity demands	Abieto-Fagetum		Poo-Fagetum		Circaeo-Abietetum	
		species number	%	species number	%	species number	%
2	extremely acidophilous-acidophilous	–	–	–	–	2	10
3	acidophilous	–	–	1	4.5	2	10
4	acido- semiacidophilous	2	7	–	–	–	–
5	semiacidophilous	4	13	3	14	2	10
6	semiacidophilous-neutrophilous	3	10	1	4.5	2	10
7	neutrophilous	12	40	8	36	6	30
8	neutrophilous-basiphilous	3	10	1	4.5	–	–
9	basiphilous	–	–	–	–	–	–
X	indifferent	6	20	7	32	8	40

Analysis of dependence of missing species in secondary spruce forest on soil reaction proves already mild effect of spruce needle litter on acidification of topsoil horizons (rhyzosphere) (Fig. 2). The state according to individual associations is as follows:

– spruce forests after Abieto-Fagetum: form 30 missing species, 60% belongs to the group of neutrophilous plants (range from 6 category to 8 category) and only 20% to category of slightly acidophilous,
– spruce forests after Poo chaixii-Fagetum: from 22 missing species, 32% belongs to indifferent category, 55% to moderately acidophilous and neutrophilous and 13% acidophilous; ergo, prevailing missing species are from moderately acidophilous to acidophilous in this case,

– spruce forests after Circaeo alpini-Abietetum: from 20 missing species, 40% belongs to indifferent species against soil acidity, 50% belongs to neutrophilous and 10% to moderately acidophilous up to acidophilous species.

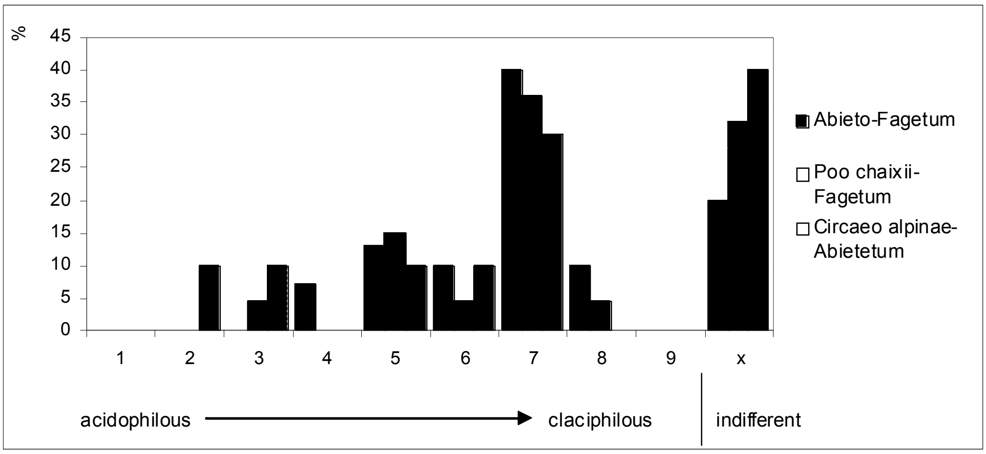

Fig. 2. Demands of missing species of secondary spruce forests to soil reaction

In addition, it is necessary to emphasize the entrance of mosses into secondary spruce forests. The evaluation of this phenomenon we managed only in case of spruce forests after Abieto-Fagetum and Circaeo alpinae-Abietetum. In case of spruce forests after fir-beech forests there are 6 species of mosses which are regularly repeating (*Pleurozium schreberi*, *Dicranum scoparium*, *Polytrichum formosum*, *Dicranella heteromala*, *Hylocomium splendens*, *Plagiothecium laetum*). It is problematic to specify exactly the reasons of this phenomenon because most of these species accompany all coniferous stands including those of secondary pine forests on sandy soils of Záhorská nížina lowland. Except of higher degree of acidification and inhibition of organic carbon mineralization this development of moss layer can be accelerated also by higher soil moisture under secondary spruce forests. Qualitative composition of moss layer in secondary spruce forests after Circaeo alpinae-Abietetum is only weak; nearly the same species as in natural fir forests.

3. Relations to soil nitrogen

It is very hypothetic to assess the degree of affinity to soil nitrogen because it is present mainly in organic components in soil, especially in proteins. These forms of nitrogen, as it is known, are inaccessible for majority of vascular plants (except of saprophytic species). However, based on long-time observations it looks like it should be possible to set some general idea as it is realised in Table 6.

Table 6. Analysis of missing species according to soil nitrogen demands

Eco-logical number	soil nitrogen demands	Abieto-Fagetum		Poo-Fagetum		Circaeo-Abietetum	
		species number	%	species number	%	species number	%
2	Extremely nitrophobic-nitrophobic	–	–	–	–	1	5
3	nitrophobic	2	7	2	9	1	5
4	nitrophobic - mezonitrophilous	1	3	–	–	–	–
5	mezonitrophilous	5	17	6	27	1	5
6	mezo- seminitrophilous	9	30	6	27	8	40
7	seminitrophilous	5	17	2	9	3	15
8	nitrophilous	5	17	4	18	3	15
9	basiphilous	–	–	–	–	–	–
X	indifferent	3	10	2	9	3	15

The situation within evaluated communities is as follows:

– spruce forests after Abieto-Fagetum: from 30 missing species, 80% belongs to contiguity of mezonitrophilous up to nitrophilous (ecological numbers 5–8), whereas only 10% belongs to nitrophobic category; 10% is indifferent,

– spruce forests after Poo chaixii-Fagetum: form 22 missing species, 81% belongs among moderate nitrophilous up to nitrophilous, 10% among nitrophobic and 9% among indifferent category,

– spruce forests after Circaeo alpini-Abietetum: from 20 missing species 75% are mezonitrophilous up to nitrophilous, 10% are nitrophobic and 15% indifferent.

Broad view on figure showing the relations between missing plants in secondary spruce forests and soil nitrogen (Fig. 3) cogently documents, that inhibition of microbial activity of soil organisms under effect of needle litter as well as moss biomass is an important factor. Approximately 78% of mezonitrophilous and nitrophilous vascular plants vanished in secondary spruce forests compared to whole scale of natural forest ecosystems.

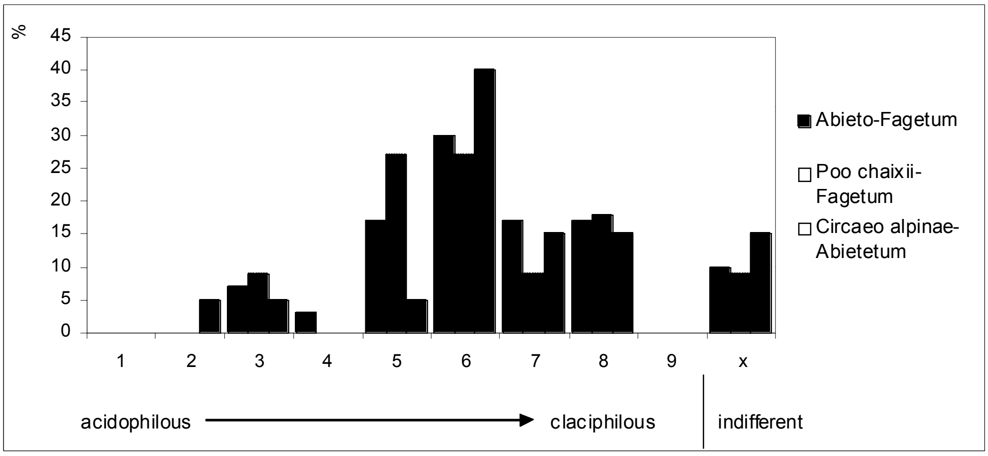

Fig. 3. Demands of missing species of secondary spruce forests to soil nitrogen

Stagnation in organic carbon mineralization under effect of inhibition of microbial activity, together with acidification of rhizosphere, is probably main reason why moss layer develops in secondary spruce forests.

Disscusion

The evaluation of changes in floristic composition of secondary spruce forests, which have developed at sites of former natural fir-beech forests (Abieto-Fagetum), ridge beech forests (Poo chaixii-Fagetum) and spruce-fir forests (Circaeo alpini-Abietetum) using methods of phytocoenological table comparison (Zurich-Montpellier methodology) and ecological analyses (to light, soil acidity and soil nitrogen) brought following results:

- The absence of significant amount of plant species in secondary spruce forests. It varies at approximately 20–30 populations (somewhere more). The highest number of missing species was found out in phytocoenoses after fir-beech forests (Abieto-Fagetum), it climbed up to 30 species. 22 species are missing in spruce forests after ridge beech forests (Poo chaixi-Fagetum) and 20 plant species in spruce forests replacing fir forests (Circaeo alpinae-Abietetum).
- Massive development of moss layer is typical in secondary spruce forests and it is according to preliminary opinion because of acidification of rhizosphere by needle litter. It also inhibits the decomposition of litter layer.
- High number of missing species in secondary spruce forests is not caused by changes in light inputs down to the stand. Analysis of species affinities to ecological value of light (Ellemberg 1974) showed just opposite results. In secondary spruce forests after Abieto-Fagetum, there are 83% of missing species belonging to sciophilous category. In case of spruce forests after Poo chaixii-Fagetum it is 72% and finally 65% in spruce forests after Circaeo alpini-Abietetum. The liquidation of the herb undergrowth was observed only in young dense stands of spruce.
- Ecological analyses of flora to other factors, such as soil reaction and soil nitrogen, brought conclusive proofs that these factors are the most important reasons of changes in floristic composition in secondary spruce forests. Eco-spectrum of missing species related to soil acidity shows that averagely 55% of them belong to neutrophilous species. The effect of spruce is even more significant in case of soil nitrogen because 75% of missing species belong to eco-spectrum of mezonitrophilous and nitrophilous species. However, these results must be verified by way of direct measuring of soil acidity as well as by way of microbial analysing of soil.

Acknowledgement

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VPLYV SEKUNDÁRNYCH SMREČÍN NA FYTOPROSTREDIE V SLOVENSKOM RUDOHORÍ

Súhrn

Príspevok prináša výsledky pokusu posúdenia zmien fytoprostredia sekundárnych smrečín existujúcich po prírodných ekosystémoch jedľových bučín zaradených do asociácie Abieto-Fagetum Klika (1936) 1949, vrcholových bučinách (Poo chaixii-Fagetum Šomšák 1979) a prírodných jedlín (Circaeo alpini-Abietetum Šomšák 1982). Floristické zmeny boli vyhodnocované vzájomným porovnávaním fytocenologických tabuliek spracovaných metódou zuryšsko-montpellierskej školy. Porovnaním sa zistilo, že v sekundárnych smrečinách po všetkých typoch prírodného lesa chýba značný počet cievnatých druhov (v priemere 24 druhov).

Príčiny tohto úbytku sa v príspevku riešia analýzou vzťahu chýbajúcich druhov podľa nárokov na svetlo, pôdnu reakciu a pôdny dusík (Ellenberg 1974). Posúdenie nárokov na svetlo dokázalo, že chýbajú tieňomilné druhy (až 76 %). Analýzy vzťahu rastlín k pôdnej reakcii naznačujú, že 55 % chýbajúcich druhov je neutrofilných. Rozbor ekospektra nárokov na pôdny dusík ukazuje, že až 75 % chýbajúcich druhov je mezonitráto- až nitrátofilných.

Autor príspevku sa prikláňa k názoru, že hlavnou príčinou týchto zmien je opad smrekového ihličia vyvolávajúci acidifikáciu rizosféry a útlm rozkladu organickej hmoty.

INSECT PESTS IN SLOVAK FORESTS

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Abstract*: Patočka, J.: Insect pests in Slovak forests. In Folia oecologica. ISSN 1336-5266, 2003, vol. 30, no. 2, p. 61–66.*

The paper deals with the most important insect pests in the Slovak Republic. It relates the period 1949–1990. The pests are listed according to the attacked woody plants in the land. We also present the damage to forests recorded over this period. The natural character of Slovak forests compared to the other Central European countries was reflected in a lower impact of insect pests on forests. The weather usually entailed insect outbreaks. The abiotic calamities were followed by gradations of bark and wood destroying beetles. Mass outbreaks of defoliating insects occurred usually after dry and warm weather in April or May. From long term factors providing for the insect outbreaks could be mentioned: unsuitable site-climatic factors and insufficient forest management, impact of industry, agriculture and traffic to environment. The result was a large-area decline of the forest health state and a complex decline in individual woody plants in Slovak forest stands.

Key words: *insect pests, forest woody plants, Slovakia, cause of damage*

Introduction

The forests in Slovakia are fairly different from the forests in the surrounding Central European countries by their natural conditions and by the history of human influence. This is evident, for example, on the species composition, forest management methods and situation at threatening by insect pests. The constitution, vulnerability and environmental resistance of forests are primarily controlled by underlying climate-site conditions and by the human impact influencing the forests in the past as well as at the present time. An insect calamity follows often after a windstorm, wet snow, rime and extreme dryness. These events disrupt forest stands, cause severe damage to them, weaken their resistance and, in such a way, promote insect outbreaks – especially of so called secondary pests such as bark and wood-destroying insects. On the other hand, also periodical occurrence of dry and warm weather in April or May could be favourable for defoliating pests because it lowers the woody plant resistance and pest mortality. The result is again an insect outbreak.

This paper presents an overview of occurrence of important forest woody pests in Slovakia in 1949–1990. The insect impact on the individual commercial woody plants is discussed according to their importance in Slovak forests.

Pests on beech

The beech is the most abundant woody species in the Slovak forests. However, in the given period it suffered only rarely from insect outbreaks. Only sporadic local occurrence of higher amounts of aphids (*Phyllapsis fagi* – Homoptera, Aphinidea) or moths (Lepidoptera), mainly from the families Geometridae and Lymanttriidae (*Calliteara pudibunda*) was noticed (Pfeffer 1954, Kulfan, Šušlík 1992, Šušlík, Kulfan 1993). The beech stands were especially threatened by complex diseases (beech decline caused by fungal and microbial infections – Mihál, Cicák 2001, 2003, Cicák, Mihál 2002), resulting at the first place from the human impact (e.g. air pollution).

Pests on spruce

The spruce is the second most abundant tree species in Slovakia. In spruce stands, the outbreaks of bark and wood-destroying insects were frequent as a result of abiotic calamities. Also heavy insect outbreaks occurred as a result of forest destroying during the World War II in 1940–1950's. The bark beetle *Ips typographus* was the most important in mature spruce stands (Pfeffer 1954, 1955), and most other scolytids associated with young spruce trees were less significant (Zach et al. 1997). On the other hand, the defoliating species, very important in the Czech Republic, Germany and Poland, played in Slovakia only an insignificant role (Kulfan 1994, 1998, Kulfan, Šušlík 1995, Úradník, Kulfan 2001). Some exceptions were recorded in 1949 – a limited outbreak of noon moth (*Lymantria monacha*) in the Žilina region, probably as a result of the dryness in 1947; small gradations of the webspinning sawfly *Cephalcia abietis* (Hymenoptera, Pamphilidae) in the region Kysuce and one outbreak of the leafroller moth *Zeiraphera griseana* (Lepidoptera, Tortricidae) in the Mountain massive Prašivá, Nízke Tatry Mts. (Čapek 1961).

Pests on oak

The oak species group occupies the third place by abundance in the Slovak forests. Periodical attacks by different moth larvae, in the past also by imagines of May beetles (*Melolontha* spp.– Coleoptera, Scarabeidae) were recorded (Patočka et al. 1999).

The oak stands growing on dry sites with higher presence of the Turkey oak (*Quercus cerris*) managed by the coppice method in the past, suffered from periodical attacks by their main pest – the gypsy month (*Lymantria dispar* – Lepidoptera, Lymantriidae) (Novotný 1989, Patočka et al. 1999). The coppice management method leads to a reduction in the root system – especially of the taproot. These oak stands were vulnerable to dryness in dry years. Therefore, their resistance against this pest was lowered.

The wet floodplain oak stands and also fairly moist stands in hilly lands and on foothills were frequently attacked by the Geometridae and leafroller (Tortricidae) moths (as the winter moth *Operophtera brumata,* great winter moth *Erannis defoliaria* or leafroller *Aleimma loeflingiana*) (Patočka et al. 1999).

The weather conditions were important for outbreaks of the relevant pests. The gradation of leafrollers and winter moths followed mostly dry and warm weather in the first and second thirds of April; for the Gypsy moth it was the end of April and beginning of May (Patočka et al. 1999).

Oak leafroller (*Tortrix viridana* – Lepidoptera, Tortricidae), the main pest on oak (e.g. Germany) is in Slovakia not very important, because it prefers the summer oaks (*Quercus robur* group), with a low abundance in this country (Patočka et al. 1962, Patočka et al. 1999).

In the 1980´s, an extensive oak decline was recorded (Čapek 1985). It had been preceded by a series of dry years, also owing to neglected sanitary measures in the stands and the girdling – a currently usual removal method of ill-formed oak trees. Thereafter, such trees were left in stands. Air pollutants together with weakening due to defoliating insects could also contribute to this phenomenon. However, the main and direct cause of the oak decline was the tracheomycotic disease connected with bark beetle (*Scolytus intricatus* – Coleoptera, Scolytidae) attacks. Oak trees, dying or severely weakened by tracheomycosis provided favourable conditions for the larvae of this bark beetle. Its maturation feeding inside of young shoots allowed the infection to spread to the still healthy trees. The transfer was also done by other insect species (Čapek 1985, Zach 1994, Patočka et al. 1999).

Pests on fir

In 1949, the fir belonged to high abundant (11%) woody species in Slovak forests. In the 19th century, extensive pure stands of this species penetrated into clearings resulted after cutting broadleaved stands in Central and Eastern Slovakia. The wood of these stands was burnt to obtain metallurgical charcoal before the black coal came to use. In spite of low altitude and rather warm climate (the 2nd and 3rd vegetation zones), the fir was intensively regenerated on clear-cut areas left after deciduous species. On the other hand, the site conditions were optimum for the primary pests – budworms (*Choristoneura murinana, Zeiraphera rufimitrana* – Lepidoptera, Tortricidae) (Patočka et al. 1960). In the 1950´s the fir trees in monocultures were mature and their flowers provided the optimum food for the vulnerable young larvae of the pests. The intensive and long term outbreak of these pests was promoted by this fact. Moreover, the fir trees were weakened by the dryness in 1947 when the weather was favourable for the development of the pests in its critical period – at the end of April and at the beginning of May. Such favourable conditions were thereafter repeated several times in the following years. The weakened trees were attacked with other pests (the bark beetles *Pityocteines* spp., *Cryphalus piceae* – Coleoptera, Scolytidae) and mycoses, e.g. *Armillariella mellea* (Patočka et al. 1960, Heško 1966). The consequence was a massive decline of the fir on extensive plots, which could not be hampered even with appropriate protective measures. The share of fir trees in Slovak forests has dropped – to the present merely 4% – as a consequence both of this calamity and high states of hoof game.

Pests on pine

The share of the pine in Slovak forests is lower compared to the other countries in Central Europe. The exception is only the area of sand dunes in the Záhorie region where outbreaks of the common pests on this species were frequent in the past – primarily defoliating moths (Lepidoptera), such as the pine beauty moth (*Pannolis flammea* – Noctuidae), pine looper moth (*Bupalus piniarius* – Geometridae), pine lappet (*Dendrolimus pini* – Lasiocampidae) and sawflies (*Diprion pini* – Hymenoptera, Diprionidae) (PFEFFER 1933, 1954, SCHIMITSCHEK 1941). However, over the discussed period, the outbreaks of these species occurred only temporarily and were less severe than in the 1930´s. On the other hand, groups of other pests endangered pine seedlings, cultures and young stands (primarily pine shoot moth, *Rhyacionia buoliana* – Lepidoptera, Tortricidae – PATOČKA 1994, and bark beetles belonging to the genus *Myelophilus* – Coleoptera, Scolytidae – PFEFFER 1955).

Pests on other woody plants

From the other woody plants, less frequent in Slovak forests, we mention here elm trees (*Ulmus* spp.), noticeably retreating owing to the mycosis – graphiosis transmitted by bark beetles of the genus *Scolytus* (Scoleoptera, Scolytidae) (PFEFFER 1954, 1955). Cultivated hybrid Euro-American poplars (*Populus* spp.) were planted as fast growing woody plants after the World War II – resulting in extensive artificial monocultures, with natural consequences to the forest protection. Nevertheless, the role of insects, e.g. the large poplar longhorn beetle (*Saperda carcharias* – Coleoptera, Cerambycidae) or moths (Lepidoptera) was very significant (CHARVÁT, ČAPEK 1954, PATOČKA 1954). However, the poplars were attacked by mycoses and microbial diseases (*Dotichisa populnea* and bacterial spotting) (LEONTOVYČ 1960, 1962, 1963). Some damage was also caused by the introduced American fall webworm *Hyphantria cunea* (Lepidoptera, Arctiidae). It was more pronounced on mulberries, maples, ashes and fruit trees (JASIČ 1964).

Conclusions

The natural character of the forest stands in Slovakia caused that the majority of forest insects occurred in latency in the study period. The bark beetle outbreaks usually followed after abiotic calamities. Defoliating insect populations increased mainly in consequence of favourable weather conditions for development of their young larvae in April or May.

Unfavourable site and climate conditions as well as unsuitable forest management are the most important long-term factors launching forest insect pest calamities. The main mistakes occurring in the forest management at the time were: establishment of unnatural coniferous monocultures, coppicing of broadleaved woody species, neglected prevention, and natural regeneration, not sufficient care about plantations as well as improper tending and stand sanitary measures, too high numbers of hoofed game, delayed removing of abiotic calamity timber. Moreover, year by year, the harmful influence of industrial air pollutants and excessive chemistry use in agriculture, forestry and traffic was increasing. The result was a large-area lowering in health state of forest stands.

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HMYZÍ ŠKODCOVIA V LESOCH SLOVENSKA

Súhrn

Práca uvádza významnejšie lesné škodce v lesoch na Slovensku v r. 1949–1990 na najvýznamnejších lesných drevinách. Hodnotí sa situácia v ochrane lesov v tomto období.

V dôsledku prirodzenejšieho charakteru lesov na Slovensku v porovnaní s inými európskymi krajinami sa škodcovia premnožovali zriedkavejšie, na menších plochách a s menšou intenzitou. Bezprostrednou príčinou vzplanutia hmyzích kalamít bolo hlavne počasie. Jeho výkyvy spôsobovali abiotické kalamity, ktoré mali za následok premnoženie podkôrneho a drevokazného hmyzu. Priaznivé počasie v apríli alebo v máji podmieňovalo aj gradácie listožravých škodcov. Z dlhodobých predpokladov hmyzích kalamít bola najdôležitejšia dispozícia porastov spôsobená stanovištno-klimatickými faktormi a vplyvom človeka. Išlo o nedostatky manažmentu lesného hospodárstva a narušenie životného prostredia industrializáciou a nadmernou chemizáciou vo viacerých oblastiach hospodárstva. Ich dôsledkom bolo veľkoplošné zhoršenie zdravotného stavu porastov a komplexné odumieranie drevín.

INVESTIGATIONS ON FOREST ECOLOGY IN BULGARIA – STATE AND PERSPECTIVES

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Abstract: *Raev, I., Tzakov, H.: Investigations on forest ecology in Bulgaria – state and perspectives. In Folia oecologica. ISSN 1336-5266, 2003, vol. 30, no. 2, p. 67–74.*

In this study is given an outline of principal phases of environmental research conducted by the Forest Research Institute of the Bulgarian Academy of Sciences. There are presented the most important results reached in the last decades and also several key-important subjects determining the effort in the forthcoming years. This work is not intended to give any complete description of the state, we have only focussed on certain selected facts, according to the program approved by the FRI BAS: biodiversity of forests in Bulgaria as a part of South-Eastern Europe; structure, functioning, development and adaptation of Bulgarian forests to climate changes; monitoring, preservation and regeneration of forest diversity in Bulgaria; basic concepts of social-economic and forestry management – close to nature management and multifunctional management of forests in Bulgaria.

Key words: *Bulgarian forests, ecological research, phases*

1. Introduction

Discussing the issue of ecological investigations in Bulgarian forests means covering an area, which extends over a major part of the investigations conducted by the Forest Research Institute with the Bulgarian Academy of Sciences (FRI-BAS) – the major research institution in Bulgaria dealing with forests.

In this study we shall try to systematize the principal phases of the environmental investigations conducted by the FRI-BAS, certain significant results obtained in the course of decades, as well as certain major prospective directions of efforts in the coming years. Naturally, this is a voluminous and hard task; therefore we shall try to mark solely the most significant elements of this development, without any claim to exhausting the subject.

2. Phases of the investigations related to forest ecology

Phase One (1928–1961) Is the time of the fixed-routing and ”point” investigations. This is the epoch of the great Bulgarian forest scientists, who have created the general image of the investigations of FRI-BAS. The first one among them was Academician Boris Stefa-nov, who used to prowl about Bulgarian forests and had made a profound analysis of their development, whereby he laid the focus on their ecological regularity (STEFANOV 1930; 1943 etc.). In a joint effort with another great Bulgarian scientist, Academician Nikolay Stoyanov, he compiled the first study on The Flora of Bulgaria (1966), which has served as the "Bible' for many generations of forest engineers and botanists and was in actual fact been the first attempt to write a book on the biological diversity of Bulgaria.

In all his publications Toma Zahariev, another great forest researcher, gives a marked preference to the link between "organism and the environment" and using a profoundly scientific approach he depicts the causes for dying out of coniferous monocultures in the areas around Sofia after the 1929 drought (Zahariev 1930).

On the basis of rich materials, collected in the forests of Rila, the Balkan mountain range and Strandga, Iliya Radkov has written several monographs, in which he has elaborated the foundations of his purely ecological approach, and has compiled the first ecological classification of the forests in Rila and some other Bulgarian mountains (Radkov 1961; 1970).

Phase Two (1961–1980). The need of investigation on the forest development processes through representative stations in the most important Bulgarian forests is gradually getting recognized. The beginning is laid at multi-annual stationary investigations of the ecological influences that have the greatest impact on forests. Dr. Vassil Serafimov from the FRI-BAS is the pioneer in this field. He drew on the experience of the Russian forest breeding school and founded the first forest hydrology stations – "Leeve" (1961) in representative forests of *Pinus sylvestris* L. along the southern slopes of Rila mountain and in 1963 he grounded the first four sites for the Govedartsi station along the northern slopes of Rila mountain for investigations into forests of *Picea abies* /L./ Karsten. (Serafimov 1974, 1978). In 1986, the scope of these studies was expanded to cover also forests of *Abies alba* Mill and *Pinus sylvestris* L., and as of 1988 also forests of *Pinus montana* (Raev 1989).

Since 1971, the Balkanets station has been set up in forests of *Fagus sylvatica* L. in the Central Balkan area, where work is underway on specific tree species and on experimental watersheds (Raev 1989).

The Devnya station was founded in 1976. It conducts investigations on the impact of polluted air on forests and the opportunities for survival of forest vegetation. Since 1979, investigations have been launched in the Parangalitsa biosphere reserve (Raev 1989), and since 1971–1973 two stations for investigation on the processes of erosion and erosion mitigation have been organized in Southwest and Central Bulgaria (Mandev 1979; Angelov 1958).

Being set up as specialized stations for study of the hydrological and soil-protection functions of forests, by mid-70's they turned to investigations of the multi-functional impact of forests in their capacity of ecosystems. Forest specialists, hydrologists, climatologists, soil specialists, as well as phylologists, geneticians, economists an other experts work on the issues of the same representative ecosystems. Solutions on important issues of Bulgarian forest engineering are formulated.

Phase Three (1981–2003). In the 80's of the past century, the ecological stations of the FRI-BAS became the primary sources of information for the needs of the system of monitoring of the state of forests in Bulgaria. The existence of acid rains in Bulgaria was proven as early as in 1980 and the stations were used to provide information about the resulting reaction of forest plants (Raev et al. 1985). Since 1986, they have been included in the system of monitoring of Bulgarian forests. These stations have collected unique information about the effect of the longest drought on record in Bulgaria during the period 1982–1994 (Raev et al. 2003).

3. Which are the major achievements of ecological investigations in Bulgaria in the recent decades?

3.1. In the field of forest hydrology and climatology

- The hypothesis about the supremacy of deciduous forests above coniferous forests from the point of view of hydrology in the conditions of Southeast Europe was developed.
- The ”zone of optimum” of coniferous forests and the gradient of the hydrological and climatic elements in Bulgarian mountains of the highest elevation have been defined.
- The norms of interception, the net precipitation levels and the water balance for the major coniferous forests have been determined.
- The regularity in the formation of the snow cover under the influence of coniferous forests in the zone from 1000 to 2000 m.a.s.l. has been identified.
- A model for determination of the river runoff in the watersheds depending on the elements of the climate has been elaborated.
- The hydrological efficiency of the different types of management of forest ecosystems has been defined.
- The causes of withering of coniferous forests in the low elevation zone etc. have been identified (Raev 1989; Nedyalkov, Raev 1988, etc.).

3.2. Mitigation of soil erosion

The climate-shaping role of riverbank forests in the watersheds of certain rivers in the Rhodopes has been proven (Angelov, Petkov 1958; 1960, etc.).

A precious contribution to the development of science and the practice are the results from the evaluation of the threat of erosion; the energy model of the loss of organic matter; the classification of soils according to their vulnerability to erosion (Mandev 1984; 1989; 1992 etc.).

Worth a similar recognition are the publications on the effect of forest species and grass areas as water regulating and soil protecting agents, as well as the loss of nutritive elements through the water runoff (Radkov 1979; Marinov 1987; Marinov 1990, etc.).

3.3. Forest soils science

Soil processes evolving under the impact of the tree species, air pollution etc. have been analyzed. In the most heavily polluted industrial areas in Bulgaria, the soils have been classified in categories according to their degree of unfitness for cultivation of forests (Zhelyazkov, Milanov 1981; Zhelyazkov, Peev 1984; Zhelyazkov et al. 1987, etc.).

In the zone of beech-tree forests, the investigations were focused on the ion composition of the lysimetric waters, water migration and the accumulation of substances. The results outline the better effect achieved by selective care for beech-tree forests (Zhelyazkov 1987).

In the biosphere reserves the content of clay minerals has been studied, the humus richness of these soils, the bioproductivity and energy performance of soils, the influence of acid rains on humus (Grozeva, Petrova 1984; Etropolski et al. 1984, etc.).

3.4. Biological productivity, taxation and forest management

Important results have been obtained about the forests of different age in Rila mountain; about the selected form of management of the ecosystems; about the organization of management of spruce forests (Nedyalkov 1965; 1967).

Investigations into the dynamics and structure of unique forests on the area of Parangalitsa Station have been conducted (Nedyalkov, Dimitrov 1981).

Results have been obtained about the structure and dynamics of the biomass in the beech-tree forests of the Balkan mountain range (Marinov et al. 1983). The structure and chemical composition of the biomass in the spruce forests in Rila mountain have been investigated (Grozeva et al., 1986).

3.5. Floristic composition of the ecosystems

Investigations on the flora and vegetation have been conducted in certain important ecosystems, as for instance the Parangalitsa Reserve, whereat 290 species of superior plants, 16 plant formations and 40 associations have been described (Bondev et al. 1981).

In the spruce forests in the Rila mountain, 48 species of superior plants, building the surface synusia of bushes, grass etc., have been described. The ecological characteristics of the species have been elaborated (Velchev, Indgeyan 1987).

3.6. Dendrochronology and history of forest ecosystems

The relationship between biomass growth and ecological factors has been depicted. Chronologies of the annual radial growth of *Picea abies, Pinus sylvestris, Quercus cerris, Fagus sylvatica* and others have been compiled. The factors limiting the growth of these forests have been defined (Raev et al. 1982; Raev, Georgiev 1985; Raev et al. 1993, etc.)

The history of the vegetation and ecological changes in the Rila mountain in the past 4000 years has been discovered. The evolution and trends in the development of the ecosystems during the last millennium have been outlined (Bozhilova 1981).

3.7. Pollution of the ecosystems. Ecomonitoring

Evidence about the existence of acid rains has been found out in the course of almost all the environmental studies in Bulgaria as early as in 1981. The main toxic substances in polluted air, mainly the result of transboundary pollution, have been defined (Arguirova et al. 1984; Raev 1988).

The study of the chemistry of river water, however, has proven that forest ecosystems in Bulgaria still possess a sufficient buffer capacity for filtering of clean water in the river systems (Gitsova et al. 1990; 1994).

The phyto indicators of pollution have been determined for the most endangered areas of the country (Gorunova 1979; 1988).

It is worth noting Bulgaria’s achievements with respect to the system of monitoring of forest ecosystems through 240 permanent test fields in this country, as well as through the network of five ecological stations. These data are collected since 1986 and are posted to the International Center in Hamburg (DONOV et al. 1988).

The FRI-BAS is a pioneer in other investigations related to ecology as well. The first efforts for re-cultivation of tracts damaged as a result of mining activities were made by Dr. Emil PROKOPIEV (1974; 1977). He is also the author of serious studies on the resistance to exhaust gases of the tree species in Bulgaria (PROKOPIEV 1959). This direction is currently enjoying notable advance, since innovative methods for recovery of tracts damaged by the uranium mining in Bulgaria have been developed (PETROVA 1991).

Serious work is underway also in the field of sustainable management of forest ecosystems with an emphasis on the natural recovery of forests, as well as on the introduction of selective forest management in Bulgaria (RAEV 1999; RAEV et al. 2000, etc.).

FRI-BAS ranks among the first institutes in our country which is working on the issues of climate change, the vulnerability of forests and the opportunities for their adaptation to climate change (RAEV et al. 1995).

4. Which issues will be in the focus of the investigations on forest ecology in Bulgaria in the coming years?

In 2002 the Forest Research Institute of the Bulgarian Academy of Sciences discussed and approved a program of the most important issues to be investigated in the coming years. Briefly speaking, they may be divided into the following four directions:

- Biodiversity of the forests in Bulgaria – a part of South-Eastern Europe;
- Structure, functioning, development and adaptation of Bulgarian forests to climate change;
- Monitoring, protection and regeneration of the forest diversity in Bulgaria;
- The basis of social-economic and forestry management, close-to-nature and multifunctional management of the forest resources in Bulgaria.

The FRI-BAS does its best to promote co-operation in its ecological investigations with other institutes of the BAS family, with universities and with research institutions from abroad. This is achieved via the European research programs (including the COST-25 Program: Long-term Forest Ecosystem and Landscape), Research projects of the European Forest Institute, collaboration with IUFRO, as well as co-operation on a bilateral basis with numerous institutes throughout Europe.

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ŠTÚDIUM ŽIVOTNÉHO PROSTREDIA V BULHARSKU – SÚČASNÝ STAV A PERSPEKTÍVY

Súhrn

V štúdii sú načrtnuté základné fázy výskumu v oblasti životného prostredia uskutočňovaného Lesníckym výskumným ústavom Bulharskej akadémie vied. Uvedené sú najvýznamnejšie výsledky dosiahnuté v priebehu posledných desaťročí ako aj niektoré z najdôležitejších cieľov, ku ktorým bude nasmerované úsilie v budúcich rokoch. Na vyčerpávajúci popis si táto práca nenárokuje, zameriame sa len na niektoré vybrané skutočnosti, podľa programu schváleného LVÚ BAV: biodiverzita v lesoch Bulharska ako časti juhovýchodnej Európy; štruktúra, fungovanie, rozvoj a adaptácia bulharských lesov na zmeny klímy; monitoring, ochrana a regenerácia diverzity lesov Bulharska; základy sociálno-ekonomického a lesníckeho manažmentu – prírode blízkeho obhospodarovania a multifunkčného obhospodarovania lesov v Bulharsku.

THE FACTS ABOUT THE REAL STATE OF SLOVAK FORESTS

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Abstract: *Greguš, C., Kellerová, D.: The facts about the real state of Slovak forests. In Folia oecologica. ISSN 1336-5266, 2003, vol. 30, no. 2, p. 75–81.*

The Slovak forest management is since 1920 continually put to thorough inventories performed after decades. The forest cover percentage of the land decreased from the 15th century up to 1920 when it reached a minimum of 33.4%. Thanks to the reforestation of devastated land performed in the following periods, at present we have reached a maximum value of 40.8%. In 1920 practically all the forests were production. The current state is 33.7% of protection forests and special-purposed forests (Fig. 1). In the 19th century, spruce and pine recorded remarkable increases (Fig. 2). To date we observe a favourable decrease in spruce, but, unfortunately, also in fir and a moderate increase in pine. In 1753 the stands in felling maturity were practically lacking, in 1920 most stands were young. In 2000 the current stands begin to enter the favourable state of the felling maturity (Fig. 3). Under a sustainable felling in the past, the allowable cuts were increasing (Fig. 4), on the other hand, rough interventions (exploitation) always entailed the reduction. The current favourable age structure will enable us, under a sustainable felling, to increase the allowable cuts in the next 30 years.

Key words: *forest, tree composition species, forest categories, age structure*

Introduction

In a forest management cycle, the final felling means an important event – harvesting; however, the harvesting alone. The final felling is performed in average after each 109 years, applying mostly the methods appropriate to the ecosystem management aimed to the forest natural regeneration. The primary commitment of the forest management encompasses the preceding 80–90 years when the forests are established, protected, cultivated and tended – using the full advantage of the professional knowledge, with the objective to secure both their important social benefits as well as the final wood procurement.

Material and methods

The outcomes in the forest management become to be of distinctive values with the variables summarised after the decades. Our forest management has been subjected to a continual monitoring since 1920 up to the present time. In this contribution we represent only the most realistic data and these only for the most significant decades. All the data are about all the Slovak forests, apart from their function. The exceptions are stocking and age structure related only to the production forests.

Results and discussion

Forest cover percentage

To the beginning of the 15th century, the percentage of forestland in Slovakia had already decreased to somewhat more than one half of the original state. The forest protection became to be an imperative – giving the birth to the profession of forester (the first nature protector) The decrease in the forest land cover continued, however, at a considerably lower rate up to 1920 when it reached a minimum of 33.4%. Then the forest management met the task of the landscape formation primarily through reforestation of devastate land until the percentage of the current forest cover 40.8% (year 2000) has been reached. This trend is supposed to persist also in the future.

Forest categories

In the up-to-present trend (Fig. 1) we point out the year 1920 when practically all the forests were commercial (production; only 0.4 % of protection forests), 1960 with origin of the term of a special purpose forest (water protection, spa, urban…) and the year 2000 as the final point.

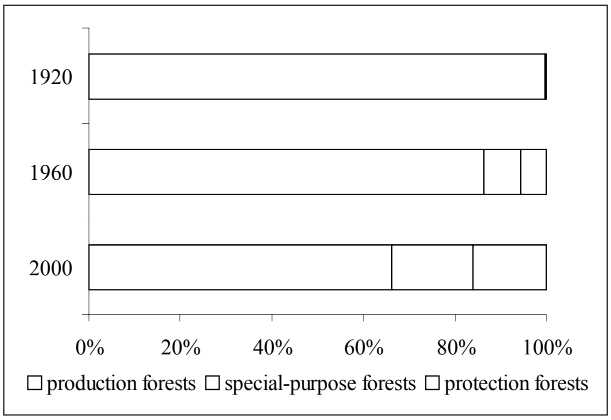

Fig. 1. Forest categories according to purpose

The rates of protection forests and special purpose forests continually increased, expressing in such a way the response of the Slovak forest management to the social and cultural development of the society. The World Conservation Union (IUCN) highly appreciates the Slovak Republic because its leading position in the area (33.7% from the total forest cover) of nature-protection-purposed forests among all the European countries (the developed included).

Tree species composition

The free market economy in the forest management (the middle of the 19th) entailed a considerable increase in the rate of commercial woody plants – spruce and pine (Fig. 2; compared are the original state and 1896). This trend continued up to the middle fifties when our forestry started to apply the methods appropriate to nature-near management. Up to this time a decrease has been reached in spruce and also, unfortunately, in fir (the tree is dying over all European countries). The presence of pine shows a moderate increase. The target objective is in further increase in broadleaved species forced by the global climate change.

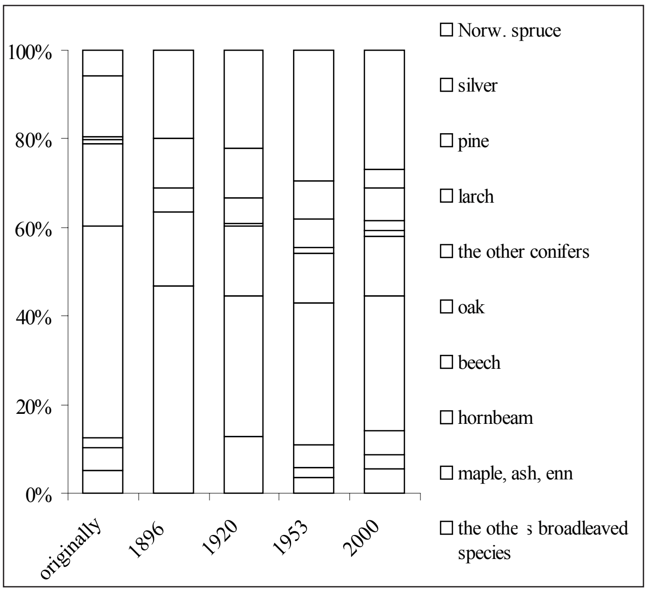

Fig. 2. Tree species composition

Stand density

Stand density (the area occupied by trees expressed here in % of the total stand area) is under a considerable impact of human, abiotic and biotic harmful agents. In the preceding 30 years, the Slovak forest management succeeded in keeping the stand density in Slovak forests with a continual gain (Table 1). The target objective (in average 0.83) is not far from to be reached; however, the current values in younger stands are higher than the forest protection requires and in the middle-aged stands they have been dropped, owing to harmful factors, to such an extent that the natural regeneration has been slowed-down.

Table 1. The trends in values of average stand density

Year	1946	1950	1970	1980	1993	2000
Average stand density	75	79	78	79	80	81

Forest silvicultural systems

A forest silvicultural system represents a basic idea in forest management. The simplest in terms of implementation but the least suitable for the forest ecosystems is the clear cutting. The most sophistic but also the most effective is the selection system. However, the implementation of this system is highly time consuming (it requires several decades to get together all the individual development phases on small plots arranged stepwise one above other). The most near-to-nature, ecologically correct and easy to implement is the shelterwood system (the new generation is created by natural regeneration under the shelter of the parent stand). This short contribution does not provide the space for the detailed description of the several centuries´ histories. In 1920 the shelterwood system represented 14.3% and clearcutting 85.7% of the currently applied methods. The forest management plans for the period 2000–2009 require 68.1% shelterwood, 29.1% clearcutting, 1.8% selection, 1.0% transfer and transformation. Two thirds of the total number of the planned management systems assigned to the shelter wood methods mean a remarkable step forward in Slovak forest management. The World Wildlife Foundation (WWF) a+ ranked the Slovak Republic with the third position in Europe (that means also in the world) thanks to the correct ecosystem management of the forests in the country.

Forest age structure

Having grown a high amount of stands entering the rotation maturity is the greatest success of our forest management overall the up-to-now documented development of the Slovak forests. This fact is inevitable to be pointed out here because the timber felling is the most important result of the management applied in a forest; and, simultaneously, it shows evident that we have succeeded in protection of forest stands against various harmful agents as well as in resisting economic and political calls for overfelling in the past. We present here three types of data about the forest age structure (Fig. 3). The year 1753 considers the state of forests in the Orava region, nevertheless, it can be taken as a sample representing the to-the-date situation in the whole land. We see that all the stands were very young and stands in felling maturity were lacking. In 1920, lower-aged stands continued to prevail by amount, on the other hand, also more mature stock had been accumulated. And, finally, the year 2000 announces the beginning of a favourable state when the lacks in more advanced age classes are step by step replaced by maturing stands reaching beyond the limits of the set objectives.

The continually improved age structure and appropriate tending have also positively influenced growing stock amount. It is evident on the data about the average growing stock per one hectare – with an increase from 169 mł. ha^{-1} in 1920 to 214 mł. ha^{-1} in 2000 (the target is an increase by 9.3%).

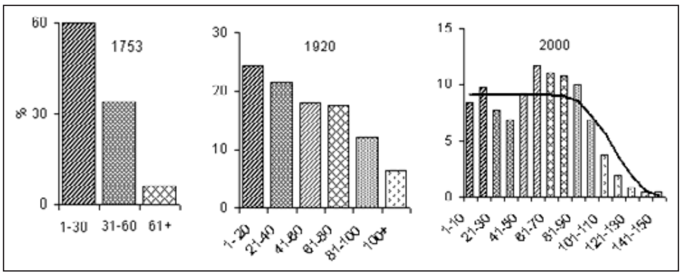

Fig. 3. Forested areas according to age degrees

Allowable cuts

An allowable cut (the amount of the sustainable cut per one year) is in terms of height, structure and distribution the most important directive in the forest management. It determines all the yields and expenditures, amounts of required labour, machinery, etc. It consists of two components-prescribed intermediate yield in young, tended immature stands (low in comparison) and the prescribed final yield in old mature stands (the source of the main income).

Under a sustainable felling in the past, both allowable cuts were increasing (Fig. 4), on the other hand, rough interventions (exploitation) always entailed a reduction. The low state in 1920 was the result of the First World War, and the drop-off in 1940 followed from the Second World War. The further decreasing (1950 and 1960) was caused by high overcuts required by the National Planning Commission. The overfelling was stopped in 1970, which entailed an increase in allowable cuts, with maximum values reached in 2000. The favourable age structure of the current stands will enable us, under the sustainable loading, to maintain the increase in allowable cuts over the next 30 years from which an increase by 750 000 m^3 per one year is supposed in the first decade. The only important thing is to provide the growing stock with sufficient time to reach the maturity.

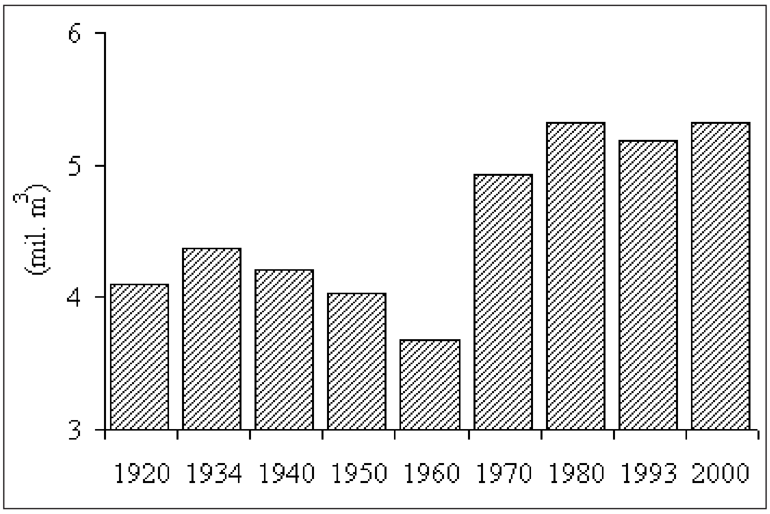

Fig. 4. Trends in allowable cuts

Conclusion

The well-focussed, positive trend in long term development of our forests is underlaid with an excellent trade-off between the forest management plans (230 years of here-to-for performance), state inspection and the management units guided by the executive forest managers. Several lacks were in some details; however, the positive general idea has been maintained. These positive facts connected with our forest management are in the evident contradiction to the far-from-objective negative evaluation of the Slovak forestry.

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FAKTY O STAVE SLOVENSKÝCH LESOV

Súhrn

Lesné hospodárstvo sa systematicky sleduje od roku 1920 po desaťročiach**.** Lesnatosť klesala od 15. stor. do roku 1920, keď sa dosiahlo minimum 33,4 %. Zalesňovaním nelesných pôd sa dosiahla výška súčasného maxima lesnatosti 40,8 %. V roku 1920 boli prakticky všetky lesy hospodárske, dnes zaznamenali ochranné lesy a lesy osobitného určenia nárast na 33,7 % (obr. 1). V 19. stor. značne narástlo zastúpenie drevín smreka a borovice (obr. 2) a do súčasnosti sa úspešne znížil podiel smreka, žiaľ i jedle a mierne stúpla účasť borovice. V roku 1753 porasty zrelé na ťažbu chýbali, v roku 1920 prevažovali mladšie porasty a rok 2000 uvádza nastupujúci priaznivý stav zrelých zásob (obr. 3). Etáty pri dodržaní únosnej ťažby v minulosti vždy stúpali (obr. 4), ale pri násilných zásahoch (nadťažbách) klesali. Priaznivá veková štruktúra umožní pri rešpektovaní únosných ťažieb ďalší rast etátov v najbližších 30 rokoch.

CHANGES IN THE FOREST LANDSCAPE COVERING IN THE WEST PART OF THE STAROHORSKÉ MOUNTAINS IN THE YEARS 1800–2000

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Abstract: *Gajdoš, A.: Changes in the forest landscape covering in the West part of the Starohorské Mountains in the years 1800–2000. In Folia oecologica. ISSN 1336-5266, 2003, vol. 30, no. 2, p. 83–90.*

Different places have different types of forest landscape. In the historical development, human intervention in the forest landscape was more and more significant. Contemporary situation in the Starohorské Mountains is the result of a long-term influence of natural and anthropogenic factors. Changes in the forest covering are explained and documented on grazing and its influence on landscape. The utilisation of landscape is documented by publications comprising maps of the area published in the 18th and 19th centuries. Reforestation of the area has a long tradition in the Starohorské Mountains. Forest management plans of particular forest management units (FMU) provided us with valuable information as well.

Key words: *forest landscape covering, reforestation, soil erosion*

Introduction

More detailed development of the Starohorské Mountains forest vegetation can only be revealed and explained by the use of historical written documents which provide us with valuable information regarding e. g. settlements, description of particular possessions, borders, accounts, plans, economic activities like mining, wood-cropping, sheep dairy-farming, etc. From the end of the 18th century, the development of forest vegetation in the area can be revealed from maps.

Material and methods

Based on the historical maps (Mikovíny 1st half of the 18th century, Martinez 1810, Balas 1837) and data of phenomenalistic-historical character (e. g. Alberty 1989), we tried to reveal and explain the utilisation of the landscape in the 1st half of the 19th century in the west part of the Starohorské Mountains, which used to be the territory of municipal forests belonging to the area of Banská Bystrica.

Results and discussion

Undistinguished forests, clear-felled areas and wood-extracted areas with isolated trees occupied the largest area. The map of Balas (Balas 1837) indicates broad-leaved trees, coniferous trees and scrub and uses various signs to recognise them. He distinguishes the size of woody plants and by use of different colours he distinguishes proprietary relations to forests (municipal forests, chamber forests). In fact, this map represents and ”ideal view” of the map processing. According to quantity and distribution of particular signs denoting woody plants in the whole territory of the Starohorské Mountains we can conclude that broad-leaved trees prevailed over coniferous trees. Scrub was mainly situated in the southern part of the area, young trees were situated in the east part of the area. In the west part, broad-leaved trees prevailed. According to BALAS (1837), the area of the Kordícka Furrow was the least forested part. According to more detailed maps worked out by MARTINEZ (1810), the area of the Kordícka Furrow was reforested particularly in the west part (on the base of the Kremnické Mountains) and in the Lučivnianske Mountains (particularly in the northern part). Reforestation was not continuous, there were large areas of glades and clear-felled areas. Insufficient reforestation was recorded in the north-east slopes of the Japeň Mountain situated above the Starohorská a Turecká Valleys, as well as the left-side part of the Starohorská Valley. The maps show that in these localities, there are continuous territories of undistinguished forest, clear-felled areas as well as wood-extracted areas.

Continuous forest areas were situated in higher and steep positions, in the ends of valleys and in steep rocky slopes. In other places, there were small areas of thinned-out forests. In mountainous area management zones (smelting works, mines etc.) and strains (Špania dolina water line) there were mostly glades and clear-felled areas. Due to the shortage of information and data we are not able to exactly determine and calculate size of the area in the west part of the Starohorské Mountains (i. e. the area of municipal forests belonging to Banská Bystrica). In the east part of the Starohorské Mountains, on the southern foot, there were clear-felled areas and glades converted into pastures (from the Nemčianska Valley to Podkonice and Hiadeľ). On the map made by MIKOVINY, we clearly distinguish and identify areas with plough soil situated in this part of the area.

The second largest area was represented by forest woods and pastures (in higher positions, there were also mowable meadows), then forest woods with mosaics of mowable meadows and areas with prevailing pastures and mosaics of forest vegetation (see Table 1).

Table 1. Utilisation of the landscape in the West part of the area at the beginning of the 19th century (worked-out by A. Gajdoš)

Utilisation of the Area	Area in %
1. building zone, gardens near houses	1.03
2. fields, meadows (mowable meadows), fruit trees, set-aside land	6.07
3. devastated areas (badlands)	0.36
4. plough soil, adjoining land	0.73
5. areas with forest woods and pastures (situated in higher locations mowable meadows)	13.64
6. areas with forest woods and mosaics of mowable meadows	9.84
7. prevailing pastures with mosaics of forest vegetation	12.32
8. valleys with plough soil, gardens and mowable meadows	0.91
9. undistinguished forests, clear-felled areas, wood-extracted areas with isolated trees	54.67
10. piles from mines	0.42

Larger areas of these territories were situated near lower located villages (e. g. Jakub, Uľanka, Kordíky, Riečka and Turecká) or highly located villages (Jelenec, Jergaly, Donovaly). Other villages (Staré Hory, Špania Dolina, Piesky) occupied smaller area. Another typical feature was their location on the sunny slopes of the south and south-west expositions (above Turecká, above Harmanec), as well as mild slopes of the valley and leveled areas.

Pastures in the east part of the Starohorské Mountains covered topmost areas, meadows were situated near villages (Podkonice, Hiadeľ). Areas with forest vegetation were spread everywhere, they created natural borders between owners of the land or cadastral areas.

Areas with plough soil (fields), set-aside land, meadows and fruit trees covered areas near villages (Jakub, Tajov, Riečka). Larger continuous areas of plough soil were situated between the Laskomerská Valley and Jakub, and near the Sásovská Valley. In lower positions, there were situated fields on alluvial plains and terraces. Above the Laskomerská and the Sásovská Valleys, there could be found mainly soils of hilly countries situated on the slopes in the south exposition. The surroundings of Králiky was famous for fruit farming (growing of plums for the nobility from Radvaň).

Built-up areas were mainly in the Starohorská Valley and in the southern part of the Kordícka Furrow. Valley positions on the alluvial plains were utilised as plough soil, mowable meadows or gardes (growing of vegetable). Fields in the wider surroundings of the Starohorská Valley were utilised mostly in this way.

After the year 1900, the reforestation by spruce (*Picea*) prevailed. The reforestation by fir (*Abies)* was not so significant. Large areas were reforested at that time. Sowing material of an unknown origin or material imported from warmer climate areas was very common.

The events caused by the First World War in the years 1914–1918 have great impact on the forest covering. Wood-cutting of all woods spread out mainly in the surroundings of villages. In the wider surroundings, young trees were cut-off as well. In many places of the Kordícka Furrow, there remained only adult clear pine-fir trees without their lower floors. Coppices had a very low stability against wind and snow. In the surroundings of the Tajovský Brook, there arose areas destroyed by erosion which can be found there even today.

There was no reforestation in the years 1918–1923. After this period, reforestation of badlands with pine (*Pinus*) started and pine spread out independently further on the territory of the Starohorské Mountains. However, deforestration counitued as well. The main purpose was to obtain new pastures. The last big loss arose in the period of the land reform in the years 1925–1927. Pastures were preferred to forest areas and in the years 1900–1938, approximately 2000 hectares of forest were cut-off and converted into pastures in the Starohorské Mountains. Deforestation was even realised on the steep slopes of the mountains.

In the state forests of the former administration zone of Staré Hory (in the years 1920 – 1925), fir (*Abies* 39.9%) prevailed, the second position belonged to spruce (*Picea* 29.2%) and beech (*Fagus* 19.4%). The percentage of other tree species was the following: pine (*Pinus* 2.2%), maple (*Acer* 1.7%), elm (*Ulmus*) with maple (1.1%), ash (*Fraxinus* 0. 14%) and larch (*Larix* 1%). In the official statistics (Barták 1929), birch (*Betula*), hornbeam (*Carpinus*) or alder (*Alnus*) were not mentioned at all. However, the statistics included forest nurseries (0.01%), clear-felled areas (1.1%) and open stands (4 %), where birch (*Betula*), oak (*Quercus*) and hornbeam (*Carpinus*) could occur. Alder (*Alnus*) must have occurred on the banks of the brooks and in the valleys. In the text part of the book, there is a mention regarding rare occurrence of comon yew (*Taxus*).

In the years 1920–1925, in the municipal forests of Banská Bystrica*,* broad-leaved trees prevailed (60%), beech (*Fagus* 40%) used to be the most common tree. As far as coniferous trees is concerned, fir (*Abies* 25%) prevailed. Other very common coniferous trees were spruce (*Picea*) and pine (*Pinus*). Common yew (*Taxus*), maple (*Acer*), elm (*Ulmus*) and ash (*Fraxinus*) reported lower occurence. Birch (*Betula*), larch (*Larix*), goat willow (*Salix caprea*) and whitebeam (*Sorbus aria*) reported rare occurrence. Very rare species were willow (*Salix*) and alder (*Alnus*). Common yew (*Taxus*) occurred mainly near Harmanec, althouth it grew also in the area of the Starohorské Mountains. In the years 1930–1936, there was a significant deforestation of 200-year old larch (*Larix*), particularly in the surroundings of Staré Hory.

In nineteen thirties and nineteen forties, pastures were expanded further. The expansion took place particularly on the edges of the area (the Sásovská Valley, the Kordícka Furrow, Javorie above Podkonice etc.). In the saddles and mild slopes of the top areas, there were mowable meadows. On the steep slopes, in the surroundings of villages (e. g. Sásová) there were mowable meadows, similarly in the Kordícka Furrow. After the contruction of the power station receivers on the Starohorský Brook and after the construcion of rail system in the bottom part of the Starohorská Valley, the mosaic of landscape covering changed.

War events in the years 1944–1945 accelerated dynamism of changes in the Starohorské Mountains forest covering. They were also reflected in the quality of the forest woods. Increased anthropic influence in hardly accessible areas violated and changed the landscape covering. Trees destroyed by explosion were infected by fungal diseases which lasted until nineteen sixties. In the years 1941, 1944 and 1945 there were strong wind calamities which caused significant damage on trees in eastern part of the area. In the year 1947, there was an extreme draught which caused several forest fires.

After the construcion of the new road in 1961 (which meets European standards) through the Donovalské Saddle, a new phase of all-year utilisation of the west part of the area started. After the construction of new forest roads, woodcropping became even more intense. On the dikes of roads and rails, silver birch (*Betula verrucosa*) and elder (*Sambucus nigra*) occured.

In the coming years, forest exploitation continued in other areas. In the Kordícka Furrow it was most significant. Forest reproduction was realised through suckers and the restoration of coppice forest. Large young coppices of copse (particularly hornbeam beech woodland) occurred in this area even in the nineteen sixties and their fragments have been preserved until now. The edges of forests were utilised for grazing of cattle. Fir beech woodland with spruce have been preserved in the west edge of the Kordícka Furrow (on volcanic soil of the Kremnické Mountains). Typical landscape scenery of the Kordícka Furrow was represented by mosaics of areas with wood plants of scrub character, like dogwood (*Swida*), cornelian cherry (*Cornus*), guelder rose (*Sorbus*), juniper tree (*Juniperus*), hawthorn (*Crateagus*), hazel (*Corylus*), (*Berberis*) and blackthorn (*Prunus*).

In nineteen fifties and sixties, grazing was still a significant factor in the dynamism of changes in forest covering. Furthermore, cattle and sheep breeding spread in the areas of large gale-disasters as well. Every year shepherds peeled spruce bark in order to cover the roofs on their homes. New access lines for cattle and sheep were created on the gale-disaster areas. In addition, weeding spread out continuously which prevented self-sowing woody plants from growing.

Conclusions

Since 1948 wood-cropping was partly realised by a hewing way which means that in some places forest exploitation was introduced in the areas of 120–200 metres wide in the form of stripes or wedges. Clearing in large areas continued and as a consequence in many forest stands heliophyte woody plants started to prevail (e. g. maple, ash). In 1960 the representation of coniferous and broad-leaved woody plants was nearly the same (50.7% : 49.3%) in the west part of the area the percentage of occurrence of trees was the following: 1. beech (*Fagus*, 33.6%), 2. fir (*Abies*, 22.4%), 3. spruce (*Picea*, 20.2%), 4. pine (*Pinus,* 6.6 %), 5. maple (*Acer,* 4.8%), 6. oak (*Quercus,* 4.3%), 7. hornbeam (*Carpinus*, 2.9%), 8. ash (*Fraxinus*, 2.5%), 9. elm (*Ulmus*, 0.9%), 10. larch (*Larix*, 0.7%), 11. birch (*Betula*, 0.4%), 12. aspen, willow (*Populus*, *Salix* 0.3%), 13. locust tree (*Robinia*, 0.15%) and others (*Tilia*, *Alnus*).

Strong wind calamity in 1961 affected spruce monocultures in the Starohorská Valley. Snow calamities in the years 1963–1967 seriously affected this area as well. In nineteen sixties (1963–1976) fir (*Abies*) started to languish under the influence of several factors: dry years 1957, 1963 and 1967; as a consequence mistletoe, under-bark insect and mycelium under stems started to spread, particularly on fir (*Abies*) and spruce (*Picea*). Since nineteen fifties fir crust has begun to spread. Spruce (*Picea*) and ash (*Fraxinus*) were affected by root rot and stem rot under the influence of peeling and gnawing of bark by deer and by grazing of sheep and cattle. Grazing of cattle and sheep damaged forest stands mainly in the Kordícka furrow. In the years 1959–1968 harmful effects of grazing could be seen on 31% of the forest stands area. Damaged coniferous and broad-leaved trees were in nineteen seventies affected by rotting.

Because of significant languishing of fir (*Abies*), small-scale and large scale clear-cutting of affected woody plants was ordered in the second half of nineteen seventies. Reforestation by spruce (*Picea*) was realised on the above mentioned areas. Clear-felled areas spread, e. g. FMU Staré Hory (total land area of 6 528.2 hectares). The land area of clear-felled areas increased from nearly 2 hectares (the year 1965) to more than 60 hectares as a consequence of totally insufficient reforestation of old and new clear-felled areas.

On the slopes of south-east, north and north-east exposition, natural rejuvenation of fir (*Abies*) was successful and was further accompanied by a natural restoration of spruce (*Picea*) in higher positions. In the Jelenská Valley, in the surroundings of Turecká and in the surroundings of Stará Píla near Andrášová, beech (*Fagus*) started to prevail over other coniferous woody plants. Maple (*Acer*) was naturally rejuvenated together with beech. Appropriate channeling of woody plants structure (clear cutting of beech forest) caused that in these localities, coniferous trees prevailed with the dominating representation of spruce (*Picea*) as so called economic woody plant. In the year 1970, FMU Staré Hory had the following percentage of woody plants: 60.6% coniferous trees and 39.4% broad-leaved trees. Beech (*Fagus)* had the highest percentage (31.5%). Highly represented forest vegetation stage was beech and widely spread group of forest types were limestone beech forests (19.4% of land area).

Table 2. Selected localities of landscape covering in the West part of the area in 1989

Soil utilised for agricultural purposes in hectares (ha) and %					Land area in hectares (ha) and %		
Plough soil	Gardens	Meadows	Pastures	*Total*	Forests	Other grounds	Total land area
0.39 ha	1.11 ha	84.96 ha	21.26 ha	107.72ha	5 980.88 ha	98.29 ha	6 186.89 ha
0.006 %	0.02 %	1.3 %	0.3 %	1.7 %	95 %	1.6 %	100 %

Source: FMU Staré Hory (1989)

Natural rejuvenation by beech (*Fagus*) is realised in the surroundings of Staré Hory (115 ha), Zlatý Brook (12.5 ha) and Richtárová (12.5 ha). Rejuvenation by pine (*Pinus*) is realised by one hudred percent. Artifitial reforestation by larch (*Larix*) is realised in the surroundings of Staré Hory (24.8 ha) and in the Haliar Valley (6.3 ha). Intensity of reforestation by spruce (*Picea*) and fir (*Abies*) is high due to intensive woodcutting (economic woody plants).

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ZMENY V LESNEJ KRAJINNEJ POKRÝVKE V ZÁPADNEJ ČASTI STAROHORSKÝCH VRCHOV ZA OBDOBIE ROKOV 1800–2000

Súhrn

Lesná pokrývka je na rôznych miestach rozličná. V historickom vývoji do nej čoraz častejšie zasahoval človek. Súčasný stav lesov Starohorských vrchov je výsledkom dlhodobého vplyvu prírodných a antropogénnych činiteľov. Zmeny lesnej pokrývky sú zdokumentované na príklade pasenia a jeho vplyvu na krajinu. Využitie krajiny je zdokumentované na základe mapových diel z 18. a 19. storočia. Zalesňovanie územia má v Starohorských vrchoch dlhú tradíciu. V prvej polovici 19. storočia v západnej časti Starohorských vrchov, vtedajšieho územia banskobystrických mestských lesov, najväčšiu plochu zaberali nerozlíšené lesy, holiny a vyrúbané plochy so solitérmi stromov. Balasova mapa (BALAS 1837) značkami na plochách znázorňuje aj listnaté, ihličnaté stromy a kroviny. Rozpoznáva výšku drevín a farebne odlišuje vlastnícke vzťahy k lesom (mestské, komorské lesy). Je to vlastne „ideálny pohľad“ mapového spracovania. Podľa zastúpenia jednotlivých značiek lesných drevín v celom území Starohorských vrchov prevládali listnaté dreviny nad ihličnatými. Kroviny sa vyskytovali väčšinou na južnom okraji územia, mladé stromy vo východnej časti územia. V západnej časti územia mali prevahu listnaté dreviny. Najmenej zalesnenou časťou (podľa BALAS 1837) bolo územie Kordíckej brázdy. Na podrobnejších Martinezových mapách (MARTINEZ 1810) bolo územie Kordíckej brázdy zalesnené najmä v západnej časti (na úpätí Kremnických vrchov) a v Lučivnianskych vrchoch (najmä v severnej časti). Zalesnenosť však nebola súvislá, boli tu veľké plochy rúbanísk a holín. Nízku zalesnenosť mali severovýchodné svahy Japeňa nad Starohorskou a Tureckou dolinou, ako aj ľavostranná časť Starohorskej doliny. Na mapách sú v týchto lokalitách súvislé územia nerozlíšeného lesa, holín a vyrúbaných plôch. V štátnych lesoch bývalej správy Starých Hôr v rokoch 1920–1925 mala najväčšie zastúpenie jedľa (*Abies* 39, 9 %), potom smrek (*Picea* 29, 2 %) a buk (*Fagus* 19, 4 %). ďalej to boli borovica (*Pinus* 2, 2 %), javor (*Acer* 1, 7 %), brest (*Ulmus*) s javorom (1, 1 %), jaseň (*Fraxinus* 0, 14 %) a smrekovec (*Larix* 1 %). V oficiálnej štatistike (BARTÁK 1929) sa vôbec neuvádzalo zastúpenie brezy (*Betula*), hrabu (*Carpinus*) alebo jelše

(*Alnus*). Boli sem však zahrnuté lesné škôlky (0, 01%), holiny (1, 1%) a riediny (4 %), kde mohli mať breza (*Betula*), dub (*Quercus*) a hrab (*Carpinus*) svoje zastúpenie. Jelša (*Alnus*) sa musela vyskytovať na brehoch potokov v dolinách. O nepatrnom výskyte tisu (*Taxus*) je zmienka len v textovej časti. Na základe silného chradnutia jedle (*Abies*) bola v druhej polovici sedemdesiatych rokov nariadená maloplošná aj veľkoplošná holorubná ťažba postihnutých porastov. Na vyrúbaných miestach bolo zalesňovanie sadenicami smreka (*Picea*). Rozšírili sa holiny, napr. v LHC Staré Hory (celkový výmer 6 528, 2 ha) v tomto období vzrástla plocha holín z necelých 2 ha (rok 1965) na vyše 60 ha v dôsledku nezalesňovania starých aj nových holín. V súčasnosti sa prirodzeným zmladením najviac zalesňuje buk (*Fagus*) v okolí Starých Hôr (115 ha), Zlatého potoka (12, 5 ha) a Richtárovej (12, 5 ha). Zmladenie borovicou (*Pinus*) je stopercentné. Smrekovcom (*Larix*) sa najviac umelo zalesňuje v okolí Starých Hôr (24, 8 ha) a v doline Haliar (6, 3 ha). Intenzita zalesňovania smrekom (*Picea*) a jedľou (*Abies*) je veľmi vysoká z dôvodu intenzívnej ťažby (ekonomické dreviny).

DIAMETER STRUCTURE OF A BEECH PARENT STAND AT SHELTERWOOD CUT PHASES

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Abstract: *Barna, M., Marušák, R.: Diameter structure of a beech parent stand at shelterwood cut phases. In Folia oecologica. ISSN 1336-5266, 2003, vol. 30, no. 2, p. 91–98.*

The work deals with development of diameter distribution at diameter classes at a beech parent stand on four plots. In February 1989, shelterwood cuts of various intensities were applied at partial plots. Particular intensities correspond to particular phases of shelterwood cut. Data from 1989, 1996 and 2001 were used for dynamics of trees diameter investigation. The highest increase of trees number in 1996 was obtained in diameter class 42 cm on all partial plots (PP) with cut. On the PP H (high cutting intensity) an increase in diameter class 46 cm was also recorded. That means a shift by two diameter classes was only recorded on PP H. A marked increase of trees number on this plot in 2001 was in diameter class 50 cm (increase from 1.8% to 14.3%). On the other plots the increase was lower. On the PP M (medium cutting intensity) the increase was from 3.7% to 6.4% and on the PP L (low cutting intensity) from 1.7% to 1.8%. An influence of cutting on shift of trees to a higher diameter class on this plot was marked only during the first period (7 years). Average stand diameter was increasing with cutting intensity, but standard deviation and coefficient of variation were decreasing.

Key words*: diameter structure, shelterwood cut, Fagus sylvatica*

Introduction

The diameter structure of the forest stand is determined by the trees number distribution in diameter classes. Its theoretical and practical meaning results from the fact, that the tree dimensions directly influence the utility value of produced wood.

In the even-aged pure stands a unimodal distribution of diameters frequency is characteristic. Their shape is not simple and is influenced by various factors (tree species, way of stand establishment and stand tending, site conditions, age and area). Within a period when the crown canopy is full, the diameter distribution is generally symmetrical. In this period, the influence of factors retentive and retaining trees growth is being mutually balanced. Later a certain degree of asymmetry is created. It is influenced by the trees competition and tending (Šmelko et. al. 1992). The tree species influence on the diameter structure is expressed by different biological properties of the species. The main difference is between groups of light-demanding and shade-loving species. In consideration of large plasticity of the shade-loving species (beech, fir) when suppressed trees are being kept alive for a long time, the diameter range is large and the diameter curve is relatively flat (Halaj 1957). For light-demanding species (oak, pine) it is different. An improvement of yield class and age increasing influences the diameter distribution in such a way, that the range is larger and the tapering is smaller (Wenk et. al. 1979). Stand area has also similar influence.

Mentioned factors make possible to estimate actual and future tree distribution in the diameter classes in the forest stand. Their imperfection is, that they do not receive enough development changes which influence the diameter structure during the stand life. A very actual task of present research is searching of the dynamics regularity of the diameter distribution and their mathematical quantification (Šmelko et al. 1992). Dynamics during 12-years period as reaction on changed growth conditions after shelterwood cut phases in a beech stand is solved in the paper. Obtained results can be used at cutting control of forests managed by shelterwood system (Žíhlavník, 2000, 2001; Majoroš, 1999, 2001; Marušák 2001).

Material and methods

The research was conducted in a beech stand at the Ecological Experimental Station (EES) the Western Carpathians Slovakia (48° 38' N, 19° 04' E). The beech stand in the EES is 100 years old and is situated on a 12-20° western slope at 470 m above sea level. The mean annual temperature (1978-1997) was 8.2 °C (during the vegetation period 14.9 °C), and the mean annual precipitation was 664 mm (370 during the vegetation period). In terms of forest typology, EES belongs to 3rd altitudinal zone, fertile site B, forest type group *Fagetum pauper-inferiora* – forest type 3312 (Kukla 1997).

When the EES was establishing, the forest stand was composed of mixed 85 (78–90) years bole stage with composition of beech 62%, fir 22%, oak 7%, hornbeam 6%, lime 3% and uneven stocking 0.8–0.9. In February 1989 the shelterwood cut of various intensities took place so that particular plots correspond to particular shelterwood cut phases. The target was to regulate the tree species composition and stocking on particular plots. The original stand stocking changed to: **0.3 – PP H** (high cutting intensity), **0.5 – PP M** (medium cutting intensity), **0.7 – PP L** (low cutting intensity). One partial plot remained without cut and with original stocking **0.9** (**PP C** – control). The intention was mainly to remove dying, ill and low-quality trees to make beech as dominant (Voško et al 1986). After the cutting, diameters of all remaining trees were measured. Other measurements were made after 7 vegetation periods (spring 1996 – first investigation period) and then after the next 5 vegetation periods (spring 2001– second investigation period). All trees were sorted into diameter classes (range of 4 cm) according to their diameter. Further information are mentioned by Barna (2000), Kellerová at al. (1997), Kodrík (2002), Kováčová and Schieber (2003).

Results and discussion

A curve of diameter frequency of shade-loving trees is generally less peak and has a higher variation range than the curve of light-demanding trees. These facts are visible on all searched plots (Fig. 1) because the shade-loving trees predominate.

Light-demanding trees in representation of oak (*Quercus dalechampii* Ten.) range from 5.3% to 1.1% of total trees frequency (Table 1).

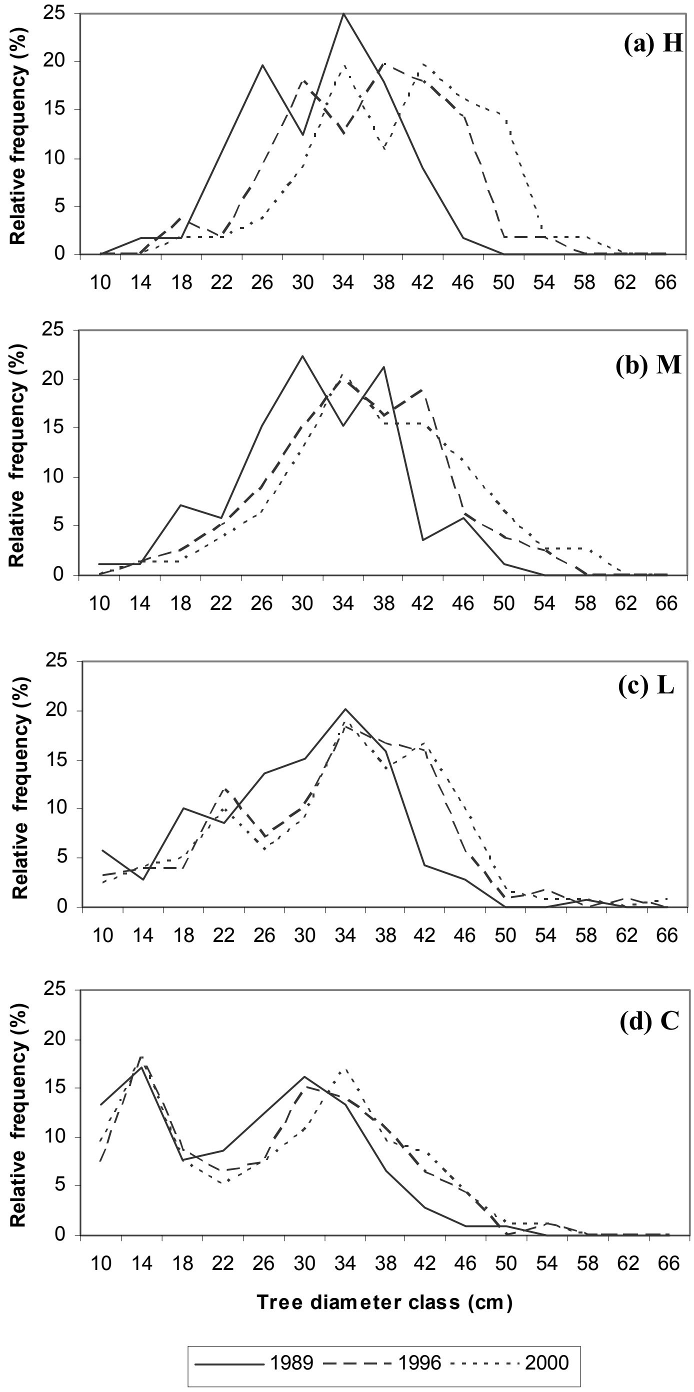

Fig. 1. Diameter distribution of particular permanent plots (H – high cutting intensity, M – medium cutting intensity, L – low cutting intensity, C – control plot)

Table 1. Development of relative tree species composition in 1989, 1996, 2001 (in %) (H – high cutting intensity, M – medium cutting intensity, L – low cutting intensity, C – control plot)

Tree species	Permanent plot / Year											
	H			M			L			C		
	1989	1996	2001	1989	1996	2001	1989	1996	2001	1989	1996	2001
Fagus sylvatica L.	92.9	92.9	92.9	87.1	90.0	91.0	76.3	81.7	84.3	89.5	94.7	94.7
Quercus dalechampii Ten.	5.3	5.3	5.3	3.5	3.8	3.8	3.6	2.4	2.5	1.9	1.1	1.1
Carpinus betulus L.	1.8	1.8	1.8	2.3	2.5	2.6	0.7	0.8	0.8	2.9	2.1	2.1
Abies alba Mill.	0.0	0.0	0.0	7.1	3.7	2.6	19.4	15.1	12.4	5.7	2.1	2.1

Halaj (1957) found out that particular trees, with equivalent height position in mixed forest stands, had the same diameter distribution as pure stands. Decreasing mean stand diameter, mostly influenced by age and site class, frequency curves are moved in the axis *x* to higher values and their tapering is less (they are more flat) and variation higher. In our case mean stand diameter increased with higher cut intensity and frequency curves had higher tapering and less variation (Table 2).

Table 2. Statistic characteristics of diameter distribution in partial plots

Characteristic	Permanent plot / Year											
	H			M			L			C		
	1989	1996	2001	1989	1996	2001	1989	1996	2001	1989	1996	2001
Mean value (cm)	32.02	36.76	40.08	31.64	35.53	37.37	29.37	32.62	33.78	24.13	26.47	27.07
Error of mean value	0.96	1.03	1.11	0.83	0.91	0.98	0.78	0.89	0.97	1.01	1.15	1.21
Standard deviation (cm)	7.20	7.73	8.28	7.61	8.18	8.65	9.20	10.04	10.70	10.35	11.23	11.82
Variance (%)	51.8	59.8	68.6	58.0	66.9	74.8	84.6	100.7	114.5	107.2	126.1	139.6
Coefficient of variation (%)	22.58	21.03	20.67	24.06	23.02	23.15	31.31	30.76	31.68	42.90	42.43	43.65
Difference min-max (cm)	34.70	35.70	37.80	36.60	40.33	42.50	51.30	52.43	56.55	42.80	46.99	48.00
Minimum (cm)	13.30	17.00	18.25	11.70	13.97	14.65	6.70	9.33	9.35	6.20	6.80	7.30
Maximum (cm)	48.00	52.70	56.05	48.30	54.30	57.15	58.00	61.75	65.90	49.00	53.79	55.30
Curtoses	–0.22	–0.33	–0.31	–0.08	0.07	0.02	0.03	–0.09	–0.02	–1.03	–1.00	–1.06
Skewness	–0.26	–0.33	–0.43	–0.19	–0.15	–0.11	–0.23	–0.27	–0.23	0.08	0.06	0.07

H, M, L, C – see Table 1

The frequency curve of control plot has two peaks. The first is in diameter class 14 cm and the second during the research moved from diameter class 30 to 34 cm. The same diameter distributions before cutting were also on the other PPs in 1988 (Štefančík 1994). According to Šmelko (1992), it can be caused by the silvicultural methods performed on the plots before the research.

The frequency curve on all plots with the shelterwood cut decreased the most steeply in the diameter class of 42 cm (Fig. 1). The biggest shift of the frequency curve on the axis

x to the right was recorded on the plot *H* at the left side (growing side of distribution) by 2 diameter classes, by one in each study period, and at the right side (decreasing) by 3 diameter classes. A similar development was also recorded on the plots *M* and *L*, but in a smaller extent, adequate to the cut intensity. In 1996 we saw a double increase of the tree number on the plot *H* in the diameter class of 42 cm, on the plot *M* it was 5.4 times and on the plot *L* 3.7 times increase. In the diameter class of 46 cm it was as follows: *H* – 5.1 but on the plot *M* there was no increase and on the plot *L* only 1.9. It means a shift by two diameter classes only on the plot *H* (Fig. 2b). In the year 2001 (Fig. 2c) there was an increase of the number of trees in the diameter class of 50 cm on the following plots: *H* from 1.8% to 14.3%, *M* from 3.7% to 6.4% and *L* from 1.7% to 1.8%. It means a significant shift on the plot *H*, smaller one on the plot *M* and practically no shift on the plot *L*. The shift on the plot *L* in the second period of observation is identical to the control plot, i. e. the influence of the shelterwood cut on the tree shifting to higher diameter classes lasted only during the first period of observation (7 years).

The division of the number of trees n_j by the diameter classes d_j can be numerically expressed by a whole range of statistical characteristics. According to Šmelko (2000) the most important ones for practical needs are the following: arithmetic mean, standard deviation and coefficient of variation.

The arithmetic mean ($\bar{d}$) characterizes the average diameter (the diameter maturity) of the stand and it indicates a position of the diameter distribution on the axis x in the graph. We can see from the Table 2 that the largest mean diameter was recorded on the plot *H* with the strongest cut and the smallest one was recorded on the control plot *C* without any cut during all periods of observation. If we compare the relative increments (Table 3) between the individual periods of observation or for the overall period there was a decreasing tendency from the plot *H* to the plot *C*. It was caused by the methodology of the shelterwood cut application, the intention of which is explained in the chapter Material and Methods. Relatively thicker and healthier trees, which had a better position in the stand and therefore they had bigger increments, remained on the plots with a stronger cut.

The standard deviation (s_d) characterizes variability of values of the diameter d_j around the diameter $\bar{d}$ in such a way that it indicates the limits $\bar{d} + s_d$ (in cm), in which a certain number of all values d_j occurs. Almost all values of the tree diameter in the stand are included within the $6.s_d$ (Šmelko 2000). This rule of 6-multiple of s_d is valid according to Prodan (1965) also for the case of completely asymmetric distribution. The bigger the value s_d is, the more various are the diameters of trees in the stand and vice versa. The values of the standard deviation for the stands of experimental plots were increasing with the stand age and density (Table 2). The explanation of this dependency comes out from the same principle as for the diameter; the differences come out from the methodology of the shelterwood cut application.

The coefficient of variation ($s_d\%$) is the relative rate of the diameter variability. It expresses the standard deviation in percentages from the arithmetic mean and in this way it allows a mutual comparison of the diameter diversity also of such stands, which have different average diameter (e. g. young and old stands). We can see from the Table 2 that the coefficient of variation goes drops with increasing cutting intensity. The highest one of 43.65% is on the control plot, and the lowest one of 20.67% is on the plot *H*. From the viewpoint of time a decline of the values of coefficient of variation occurred only on the plot *H*, the time dependency was not found out on other plots. Halaj (1957) derived the empiric tables indicating a relative division of the tree number and stock on the basis of two arguments: mean stand diameter and three degrees of the diameter dispersion. They resulted in very important information about the coefficients of variation of the tree diameters, which for the beech are in the range of 24–46%. We can see from the Table 2 that values for the plots *C* and *L* belong to this range, values for the stand *M* with medium intense cutting are marginal and values for the plot *H* with intense cutting are 3.33% under the observed range. It demonstrates that the stand structure becomes the most effective, with low diameter variability after the seed cutting and light felling in the shelterwood regeneration.

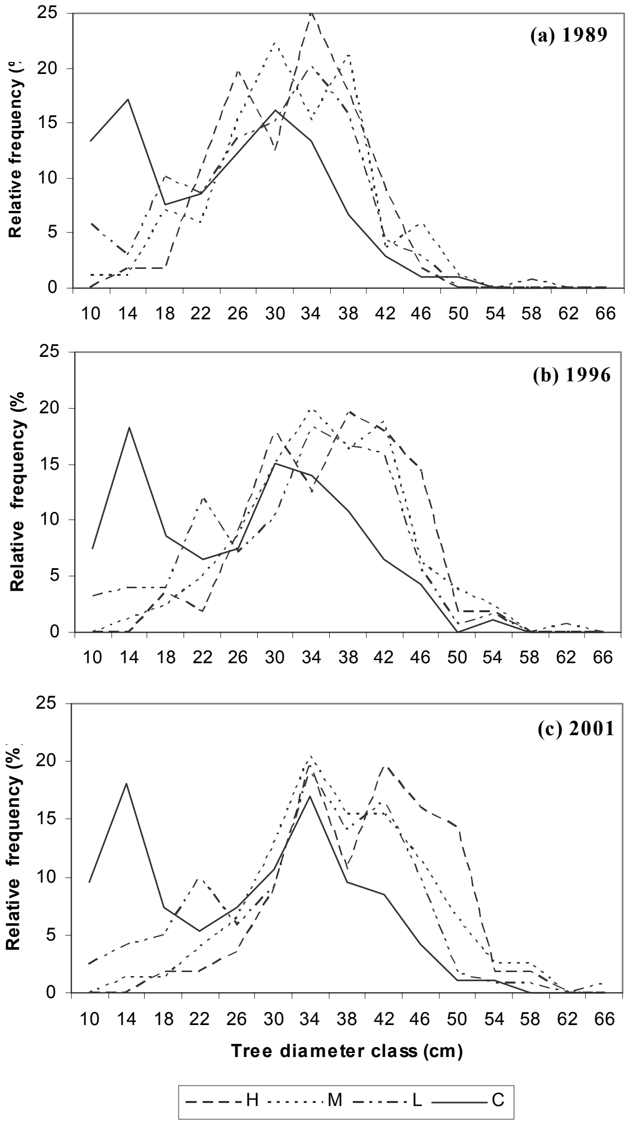

Fig. 2. Diameter distribution in particular periods (H – high cutting intensity, M – medium cutting intensity, L – low cutting intensity, C – control plot)

Table 3. Relative increments of mean diameter between periods 1989–1996, 1996–2001 (a) and 1989–2001 (b)

Permanent plot		H			M			L			C		
Year		1989	1996	2001	1989	1996	2001	1989	1996	2001	1989	1996	2001
Increment (%)	a	14.8	9.0		12.3	5.2		11.1	3.6		9.7	2.3	
	b	25.2			18.1			15.0			12.2		

H, M, L, C – see Table 1

Conclusions

The distribution of the number of trees at diameter classes changes in the course of the stand life. The changes are of two kinds: mechanical – they are caused by the thinning and shelterwood cuttings, by which the situation suddenly changes and dynamic – caused by the diameter increase in consequence of the tree growth. They are taking place continuously and they are the function of all factors influencing this growth. We can see according to the values of statistical characteristics of the tree diameter distribution on observed plots (Table 2) that the dynamic changes of stands are the more quick the more intensive cutting was applied (Fig. 1). By above-mentioned statistics we independently described the individual properties of the diameter distribution. At modeling of the diameter structure it is possible to use its mathematical formulation by means of the frequency functions (in particular: Charlier A-function, Beta-function, Gamma-function, Weibull function and others). The actual tendency leads to the models that allow estimating the diameter structure of the stand not only to a certain instant of time, but also predicting its future development from the known initial state.

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HRÚBKOVÁ ŠTRUKTÚRA BUKOVÉHO MATERSKÉHO PORASTU V OBNOVNÝCH FÁZACH CLONNÉHO RUBU

Súhrn

V práci skúmame vývoj rozdelenia počtu stromov po hrúbkových stupňoch v bukovom materskom poraste na štyroch plochách. Vo februári 1989 na skúmaných plochách bol aplikovaný ťažbový zásah rôznej sily, ktorá zodpovedala jednotlivým fázam clonného rubu. Dynamiku rozdelenia hrúbok stromov sme skúmali a matematicky kvantifikovali z údajov v rokoch 1989, 1996 a 2001. Na všetkých plochách s ťažbovým zásahom najväčší nárast počtu stromov v roku 1996 nastal v hrúbkovej triede 42 cm a na ploche H s najsilnejším zásahom aj v hrúbkovej triede 46 cm. To znamená, že posun o dva hrúbkové stupne bol iba na ploche H. V roku 2001 najvýraznejšie zvýšenie počtu stromov na tejto ploche bolo v hrúbkovej triede 50 cm – z 1,8 % na 14,3 %, na ploche so stredným zásahom (S) z 3,7 % na 6,4 % a na ploche M s miernym zásahom z 1,7 % na 1,8 %. Vplyv ťažbového zásahu na presun stromov do vyšších hrúbkových tried trval na tejto ploche len počas prvého skúmaného obdobia (7 rokov). Priemerná hrúbka porastu rástla so silou zásahu, ale smerodajná odchýlka a variačný koeficient sa znižovali.

GROWTH, PRODUCTION AND QUALITY OF 35-YEAR-OLD SEED PROGENIES OF EUROPEAN CHESTNUT (*CASTANEA SATIVA* MILL.)

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Abstract: *Tokár, F.: Growth, production and quality of 35-year-old seed progenies of European chestnut (Castanea sativa MILL.). In Folia oecologica. ISSN 1336-5266, 2003, vol. 30, no. 2, p. 99–105.*

The experimental chestnut plantation at Horné Lefantovce was established in 1966-1967 with one-year-old seedlings (seed progenies) from 86 selective chestnut (Castanea sativa MILL.) trees coming from 12 Slovak habitats, in the form of pure stand and under uniform conditions. The work evaluates growth, production, stem and crown quality of seed progenies after 35 years. The best results were observed in seed progenies (SP) Jelenec 2, Horné Lefantovce A, Tlstý Vrch 1, 2, 2′, 3, 4, 9, Duchonka 2, 3, 5, 6, 10, 12, Bratislava 4, the worst in SP Stredné Plachtince 5, Krná 3, Modrý Kameň 7.

Key words: *growth, production, quality, seed progenies, Castanea sativa MILL.*

Introduction

Slovakia lies on the northernmost border of the edible chestnut (*Castanea sativa* MILL.) cultural area (BENČAŤ 1960). On 12 sites were selected 123 selective trees the seeds of which were collected to produce seedlings for the experimental chestnut plantation in Horné Lefantovce (BENČAŤ, TOKÁR 1971). A detailed ecological-production (BENČAŤ, TOKÁR 1978, 1979, 1980, 1984, TOKÁR 1980, 1985, 1990, 1992, 1996, 1998, TOKÁR, BOLVANSKÝ 2002) and conservation (JUHÁSOVÁ 1992) research were carried there.

The work evaluates thickness, height, and volume growth, volume production (stock and overall production), stem and crown quality of 86 seeds progenies established in the form of pure stands (permanent research plots- PRP) of European chestnut 35 years ago on the experimental chestnut plantation in Horné Lefantovce.

Material and methods

The work evaluates quantitative and qualitative characters on 35-yr seed progenies of chestnut coming from 86 selective trees from 12 sites of Slovakia: Jelenec (J) – 11 selective trees, Horné Lefantovce (HL) – 16, Tlstý Vrch (TV) – 11, Duchonka (D) – 13, Radošina (R) – 5, Bratislava (BA) – 5, Častá (Č) – 2, Stredné Plachtince (SP) – 4, Rovňany (RO) – 6, Dolné Príbelce (DP) – 3, Krná (K) – 4, Modrý Kameň (MK) – 6.

Permanent research plots (PRP) of progenies were established in Horné Lefantovce within a chestnut plantation in spring of 1966 and 1967 (Fig. 1) with 1-year old seedlings in a triangular design 2 x 1 m (the distance between rows 2 m, the distance of seedlings in a row 1 m) on 30 x 20 m area large. The plantation has been established on a brown farm land at an elevation of 250 m (local name Ferdinandka) in a warm climatic zone about 20 km north of Nitra.

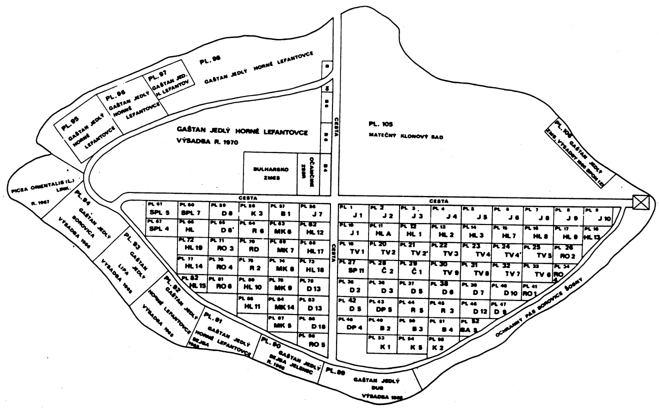


Fig. 1. Experimental plot of *Castanea sativa* in Horné Lefantovce
1 : 1000

At present the PRP-s belong phytocenologically to the oak forest vegetation stage into the group of forest types Carpineto-Quercetum. At the end of the vegetation period of 1976, 1981, 1986, 1991, 1996 and 2001 tree class, stem and crown quality were evaluated on each of PRP-s according to the criteria as shown in Table 1. Breast-height diameter (dbh) was measured in all live trees on the PRP-s with a metal calliper with an accuracy of 1 mm, heights were measured in 30 trees along a transect of the PRP-s (four rows of trees) using a Blume-Leisse height gauge with an accuracy of 0.5 m. In calculating the volume of chestnut trees, volume tables for oak (Halaj 1963) were used.

Table 1. Tree class, stem and crown quality evaluation

Scale	Tree class	Stem quality	Crown quality		
			size	density	shape
1	codominant trees	high quality	average	average	regular
2	dominant trees	average quality	long	very dense	forky
3	intermediate trees	low-quality	small	thin	bouqet-like
4	supressed trees				irregular (deformed)

Mean values of thicknesses $d_{1,3}$, heights, main stem volume, volume stock, total volume production, total mean increments, stem quality, crown quality and overall evaluation of the seed progeny were, in dependence on a site and selective tree, divided into 6 rating groups (categories) whose width was determined by means of the value of standard deviation calculated from the whole collection of 86 seeds progenies (according to Šmelko and Wolf 1977) in this way: 1 – excellent, 2 – very good, 3 – good, 4 – bad, 5 – very bad and 6 – inconvenient. The results obtained are given in graphic depiction.

Results

Growth and production

The greatest mean thickness $d_{1,3}$ has been measured in trees from the progeny, the smallest from TV 9 (24.7 cm) the progeny MK 7 (8.4 cm). On the basis of the mean thicknesses $d_{1,3}$ we may say that the plantation of chestnut at the age of 35 years belongs to the growth phase of small pole forest even thin stem forest. The majority of PRP-s (43.02 %) belongs to the category of good. The variability is 14.15%.

The range of mean heights on PRP-s is from 9.5 m (K 3) to 20.2 m (R 3). The majority of PRP-s belongs to the category of bad (39.54%). The height variability is 15.32%.

The best results in volume growth of mean stem were observed in progeny from HL A (0.454 m^3), the worst in seed progeny from MK 7 (0.032 m^3). The majority of PRP-s belongs to the categories of good (29.08%) and bad (34.88%). At the age of 35 years seed progenies reach volume stock from 2.67 $m^3.ha^{-1}$ (MK 7) to 410.00 $m^3.ha^{-1}$ (D 2) (Fig. 2, Fig. 3) and in the majority of cases the PRS-s are ranked among bad (34.88%) and the smallest number among the category of excellent (2.32%). In the total volume production the progenies reach from 40.37 $m^3.ha^{-1}$ (K 3) to 877.49 $m^3.ha^{-1}$ (D 12). The majority of PRP-s belongs to the category of bad (45.36%), the least number to the category of excellent (9.30%). The total mean increment is from 1.15 $m^3.ha^{-1}.year^{-1}$ (K 3) to 25.07 $m^3.ha^{-1}.year^{-1}$ (D 12).

Fig. 2. View of 35-years old seed, progeny D2

Fig. 3. High quality stem of 35-years old chestnut tree from seed progeny D2

Stem and crown quality

The best mean stem quality (1.15) was recorded in individuals from the progeny on R 2, the worst individuals were from MK 7 (2.40). The majority of seed progenies belonged to the category of good (46.51%). Coefficient variation is 18.19%.

In crown quality its size, density and type were evaluated. The best mean value in crown size (1.11) was observed in RO 1 progenies. In density the best mean value (1.03) was observed in the progeny of TV 2. The best crown type (1.00) was observed in J 1 progeny.

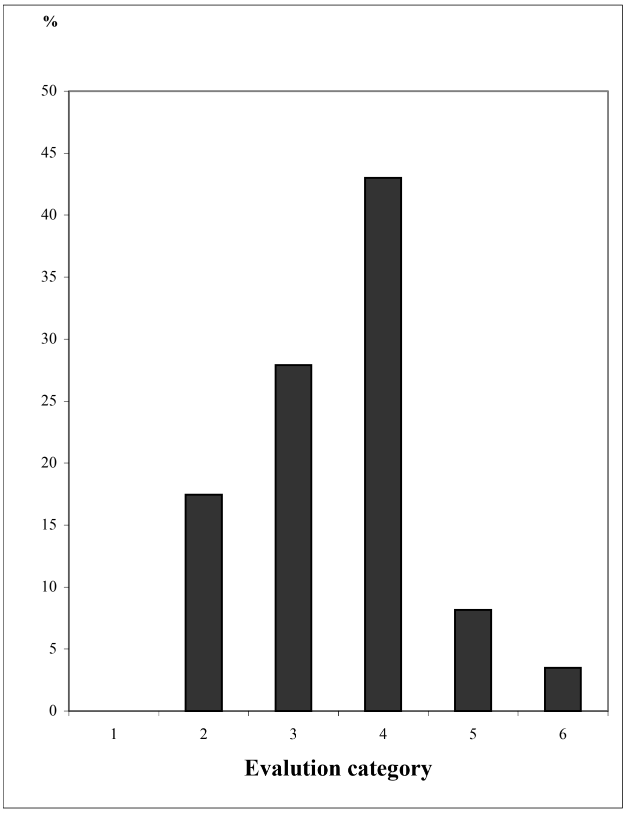
Summary evaluation

On the basis of the overall evaluation of seed progenies when the mean value of all evaluation categories of all evaluating quantitative and qualitative characters (thickness $d_{1,3}$, tree heights, mean stem volume, volume stock per ha, total volume production, quality stem and crown was calculated the seed progenies were classed into the following resulting categories:

very good: J 2, HL A, TV 1, TV 2, TV 2´, TV 3, TV 4, TV 9, D 2, D 3, D 5, D 6, D 10, D 12, BA 4,

good: J 1, J 5, J 11, HL 3, HL 10, HL 17, HL 18, TV 4´, TV 5, TV 6, TV 7, TV 8, D 7, D 9, D 13, R 3, R 5, RD, BA 2, BA 3, BA 5, SP 11, RO 4´, MK 9
bad: J 3, J 4, J 6, J 8, J 9, J 10, HL 1, HL 2, HL 7, HL 8, HL 9, HL 11, HL 12, HL 13, HL 14, HL 15, HL 19, D 8´, D 13´, D 18, R 2, R 6, BA 1, Č 1, Č 2, RO 1, RO 3, RO 4, RO 6, DP 4, DP 5, DP 5´, K 2, MK 5, MK 6, MK 8, MK 14
very bad: J 7, D 8, SP 4, SP 7, RO 2, K 1, K 5
incovenient: SP 5, K 3, MK 7

As shown by the survey the majority of seed progenies (43.02%) belonged to the category of bad, the smallest number (3.49%) to the category of inconvenient (Fig. 4). Stands from the selective trees whose progenies belong to categories of bad, very bad and inconvenient ought not to be established.



Explanations: 1 – excellent, 2 – very good, 3 – good, 4 – bad, 5 – very bad, 6 – inconvenient

Fig. 4. Summary evaluation of the 35-years old seed progenies (SP) of European chestnut into categories on the experimental chrestnut plantation in Horné Lefantovce

Discussion

The growth and production of chestnut in our country and in its natural area are evaluated by Holubčík (1968) and Issinskij (1968). They come from different ecological conditions and therefore their results cannot be compared with ours. It suggests that growth and wood production of young forest stands are affected besides ecological conditions in good deal also by genetic disposition of individuals from which the progeny originated.

The results point to the fact that within the cultural area of chestnut in Slovakia there are valuable parent trees whose seed progeny excels in good growth, production and stem quality and therefore they can be a suitable material for further breeding work in our country.

Growth and production of young forest stands is affected to a great deal, besides ecological conditions, also by genetic disposition of individuals from which the progeny originated. Many seed progenies keep their high qualitative and quantitative parameters during the whole period of their development. Evaluations of the experiment (Benčať, Tokár 1980, 1984, Benčať, Golha 1990, Tokár 1993, 1996, 1998, Tokár, Bolvanský 2002) have revealed the fact that very good and good results were produced by some selective trees from the sites of Horné Lefantovce, Tlstý Vrch, Duchonka, Radošina which are orchard cultures. After 30 years they can be completed by some selective trees from the site of Jelenec and that is a typical forest culture.

Conclusion

The experimental chestnut plantation at Horné Lefantovce, 35 years since its establishment, represents a rich gene-pool collection of European chestnut (*Castanea sativa* MILL.) in Slovak Republic.

The best results in the growth, production, stem and crown quality have been observed in seed progenies Jelenec 2, Horné Lefantovce A, Tlstý Vrch 1, 2, 2′, 3, 4, 9, Duchonka 2, 3, 5, 6, 10, 12, Bratislava 4, the worst seed progenies Stredné Plachtince 5, Krná 3, Modrý Kameň 7.

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RAST, PRODUKCIA A KVALITA 35 ROČNÝCH SEMENNÝCH POTOMSTIEV GAŠTANA JEDLÉHO (*CASTANEA SATIVA* MILL.)

Súhrn

Kastanetárium v Horných Lefantovciach bolo založené v r. 1966–1967 jednoročnými sadenicami (ako semenné potomstvá) z 86 výberových stromov gaštana jedlého (*Castanea sativa* MILL.) z 12 lokalít Slovenska vo forme nezmiešaných porastov v rovnakých ekologických podmienkach.

Predložená práca zhodnocuje rast, produkciu (zásobu, celkovú objemovú produkciu), kvalitu kmeňa a koruny 86 semenných potomstiev pri veku 35 rokov.

Najlepšie výsledky dosiahli semenné potomstvá Jelenec 2, Horné Lefantovce A, Tlstý Vrch 1, 2, 2´, 3, 4, 9, Duchonka 2, 3, 5, 6, 10, 12, Bratislava 4, najhoršie semenné potomstvá Stredné Plachtince 5, Krná 3, Modrý Kameň 7.

Kastanetárium v Horných Lefantovciach predstavuje aj pri veku 35 rokov bohatý zdroj genofondu gaštana jedlého na Slovensku.

GROWTH, STRUCTURE AND PRODUCTION IN MONOCULTURES AND MIXED STANDS OF THE EUROPEAN CHESTNUT *(CASTANEA SATIVA* MILL.)

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Abstract: *Krekulová, E.: Growth, structure and production in monocultures and mixed stands of the European chestnut (Castanea sativa MILL.). In Folia oecologica. ISSN 1336-5266, 2003, vol. 30, no. 2, p. 107–114.*

European chestnut belongs to the longest-established introduced tree species in our land. The chestnut monocultures and mixed stands on permanent experimental plots in Horné Lefantovce near Nitra have been since 1976 under a continual study on the growth, structure and production of aboveground biomass in both fresh and dry forms. The obtained results show that mixing of the European chestnut with indigenous woody plants can have favourable effects on production, coupled with amelioration and protection of the environment.

Key words*: production, European chestnut, growth*

Introduction

In the past, the production and species composition of indigenous forests in Slovakia were improved not only by improving silvicultural measures but also by introduction of exotic woody plants (HOLUBČÍK 1968). According to BENČAŤ (1982), the implementation of these exotic species met with a considerable success, thanks to favourable climatic and ecological conditions in the country.

The research on the introduced woody plants focussed on their potential implementation in the forest management has a considerable history in the Slovak Republic. The influence of moderate positive thinning from above on growth and production of monocultures and mixed stands of European chestnut (*Castanea sativa* MILL.) is studied on a series of permanent experimental plots in Horné Lefantovce.

According to TOKÁR (1987), the European chestnut is a very viable woody plant for use in the forest management – thanks to its biological and production assets: high growth rate in the first years, low nutrient demands, the quality of stem and fruits, considerable esthetical value.

In this contribution we compare between two permanent experimental plots tented by means of positive moderate thinning from above: PEP II chestnut monoculture and PEP VIII chestnut stand with a 40 % admixture of small-leaved linden. We evaluate the structure of the stands and the production of the aboveground biomass.

Material and methods

In various types of chestnut stands on the PEP in Horné Lefantovce, the study was focussed on growth and production in this exotic woody plant as well as on the influence of admixture of other woody plants of the growth and production of chestnut trees. The selection of sample trees on both permanent plots was performed according to mean diameter for each tree class and according to the tree species. The trees on both plots were classified to the following tree classes: 1 – dominant, 2 – co-dominant, 3 – intermediate, 4 – suppressed; and their d.b.h. diameters were measured. Tree height was determined in each species and each plot on 30 trees. The biomass of sample trees was sorted into the individual components (stem, branches, annual shoots and leaves) in field, immediately after the cutting. We measured stem length with a measuring tape, took samples for dry weight determination from all the biomass components, and cut, after each 1 m of stem length, disks for dendrochronological analyses. The biomass samples were dried at a temperature of 80 °C, and their dry weights were determined. We also determined leaf area index (LAI – total leaf area related to unit ground area) for each tree species on the relevant experimental plots. This variable was determined using a photo-planimeter EIJKELKAMP on sample trees (by 100 leaves) representing the studied species on the studied plots. Both fresh and dry total weights of above-ground biomass in each tree class and tree species were obtained by direct multiplication of the values determined on the corresponding sample trees by the tree number in the class on the whole PEP and per one hectare. The data were supplemented with other mensurational characteristics: basal area, aboveground biomass expressed per volume unit, ($m^3.ha^{-1}$), dry weight ($t.ha^{-1}$) volume, leaf area index ($ha.ha^{-1}$).

Results

From the measured dendrometrical variables we could conclude that both the stands were in the growth phase of pole-timber. The most abundant diameter class in the chestnut monoculture was 18, in the stand mixed with the small-leaved linden it was 22 for both the species.

The basic statistical characteristics of the d.b.h. diameter in the chestnut monoculture on PEP II were: arithmetical mean – 16.96 cm, standard deviation – 4.01 cm and variation coefficient 25.46%. In the chestnut stand mixed with the small-leaved linden PEP VIII were the corresponding values for the main species: 19.2 cm, 4.59 cm, and 23.91%, for the small-leaved linden 18.47 cm, 7.93 cm and 42.93%.

The basic statistical characteristics of the tree height in the chestnut monoculture on PEP II were: arithmetical mean – 18.17 m, standard deviation – 0,62 m and variation coefficient 3.4%. In the chestnut stand mixed with the small-leaved linden PEP VIII were the corresponding values for the main species: 19.57 m, 1.38 m, and 7.5%, for the small-leaved linden 17.56 m, 4.68 m and 26.65%.

The total aboveground biomass production in fresh state on PEP II consisted of: stems – 89.7%, branches – 6.5%, leaves and annual shoots – 3.8%.

The total aboveground biomass production in fresh state on PEP VIII consisted of: stems – 86.1%, branches – 11.1%, leaves and annual shoots – 2.8% in the chestnut, and of stems – 76.8%, branches – 18.6%, leaves and annual shoots – 4.6% in the small-leaved linden.

The total leaf area per unit ground area, leaf area index (LAI), expressing, according to Benčať (1996) relative capacity of the plant photosynthetic apparatus through the ratio between the leaf area and the soil area, was lower in the chestnut monoculture on the PEP II, with a value of 7,232 ha.ha^{-1} (Table 1). In the mixed stand with the small linden was its value in total 7.496 ha.ha^{-1}, from which 5.032 ha.ha^{-1} was to the chestnut (67.2%) and 2.464 ha.ha^{-1} (32.8%) to the small linden (Fig. 1).

Table 1. Basic variables in the chestnut monoculture on PEP II and in the stand of chestnut mixed with small-leaved linden on PEP VIII

	PLOT II	PLOT VIII	PLOT VIII	PLOT VIII SUM
TREE SPECIES	CHESTNUT	CHESTNUT	LINDEN	SUM
AGE OF TREE	38	38	39	–
NUMBER OF STEMS	1501	861	457	1318
%	100	65.4	34.6	100
BASAL AREA $m^2.ha^{-1}$	34.49	26.43	11.77	38.20
%	100	69.2	30.8	100
VOLUME $m^3 . ha^{-1}$	383.08	327.00	134.10	461.10
%	100	70.9	29.1	100
ABOVERGROUND BIOMASS- FRESH $t.ha^{-1}$	244.07	211.10	99.90	311.00
%	100	67.9	32.1	100
ABOVERGROUND BIOMASS – DRY $t.ha^{-1}$	154.12	123.86	54.73	178.59
%	100	69.4	30.6	100
LAI $ha.ha^{-1}$	7.32	5.04	2.46	7.50
%	100	67.2	32.8	100

Table 2. Mensurational variables of chestnut trees on PEP II according to tree classes

TREE CLASS	1	2	3	4	**SUM**
NUMBER OF TREES ON PLOT II	4	210	28	5	**247**
NUMBER OF TREES PER ONE HECTARE	26	1275	170	30	**1501**
BASAL AREA OF AVERAGE STEM	0.047	0.024	0.013	0.003	–
BASAL AREA $M^2.HA^{-1}$	1.22	30.60	2.22	0.45	**34.47**
VOLUME OF AVERAGE STEM	0.516	0.272	0.126	0.013	–
VOLUME $M^3.HA^{-1}$	13.42	347.82	21.44	0.41	**383.08**
FRESH ABOVEGROUND BIOMASS OF AVERAGE STEM IN KG	398.45	174.45	64.4	11.4	–
FRESH ABOVEGROUND BIOMASS IN $T.HA^{-1}$	10.36	222.42	10.95	0.342	**244. 07**
DRY ABOVEGROUND BIOMASS OF AVERAGE STEM IN KG	243.49	109.71	45.09	7.73	–
DRY ABOVEGROUND BIOMASS IN $T.HA^{-1}$	6.33	139.88	7.66	0.231	**154. 10**

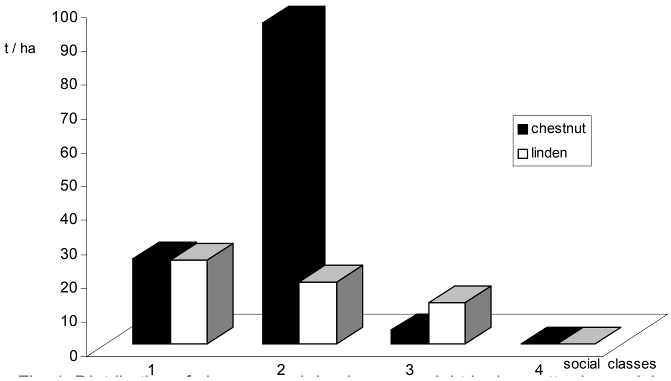

Fig. 1 Distribution of aboveground dendromass weight in dry matter by social classes on PEP VIII

The weight of the aboveground biomass in the fresh state in the monoculture on the PEP II was 244.07 t. ha^{-1}. In the mixed stand on PEP VIII it was in total 311 $t.ha^{-1}$, from which 211.10 $t.ha^{-1}$ (68%) was to the chestnut and 99.90 t. ha^{-1} (32%) for the small-leaved linden (Table 3).

The weight of the dry aboveground biomass in the monoculture on the PEP II was 154.12 t. ha^{-1}. In the mixed stand on PEP VIII it was in total 178.6 $t.ha^{-1}$ (Fig. 2), from which 123.86 $t.ha^{-1}$ (69%) was to the chestnut and 54.73 t. ha^{-1} (31%) for the small-leaved linden (Table 3).

We can see that better results in tending chestnut trees by means of moderate thinning from above were obtained on plot 8 in the chestnut stand mixed with the small leaved linden.

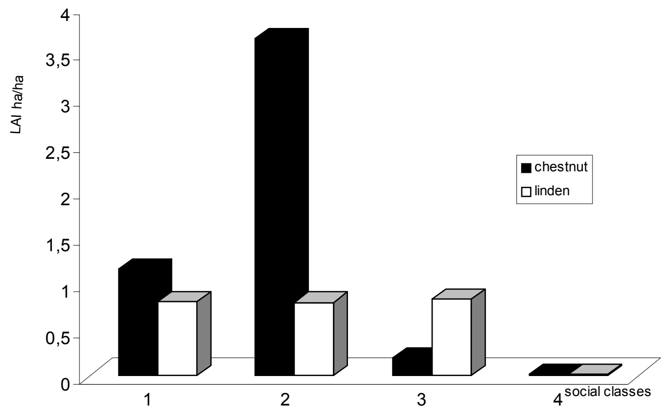

Fig. 2 Distribution leaf area index (LAI) by social classes on PEP VIII

Table 3. Mensurational variables of chestnut and small-leaved linden on PEP VIII according to tree classes

TREE CLASS	1	2	3	4	**SUM** CHESTNUT	1	2	3	4	**SUM** LINDEN
NUMBER OF TREES ON PLOT 2	19	80	13	1	**113**	16	17	23	4	**60**
NUMBER OF TREES PER ONE HECTARE	145	609	99	8	**861**	122	129	175	31	**457**
BASAL AREA OF AVERAGE STEM	0.042	0.031	0.015	0.004	–	0.0401	0.033	0.0145	0.0015	–
BASAL AREA $M^2.HA^{-1}$	6.09	18.87	1.44	0.033	**26.433**	4.892	4.296	2.540	0.045	**11.77**
VOLUME OF AVERAGE STEM	0.463	0.399	0.163	0.018	–	0.5173	0.3541	0.144	0.0034	–
VOLUME $M^3.HA^{-1}$	67.193	243.54	16.13	0.144	**327.00**	63.11	45.68	25.20	0.11	**134.1**
FRESH ABOVEGR. BIOMASS OF AVERAGE STEM IN KG	339.55	252.5	79.95	18.75	–	347.35	283.20	119.49	3.79	–
FRESH ABOVEGR. BIOMASS IN $T.HA^{-1}$	49.23	153.77	7.91	0,150	**211.07**	42,76	36,53	20,91	0,117	**100.32**
DRY ABOVEGR. BIOMASS OF AVERAGE STEM IN KG	173.84	155.33	40.10	11.32	**–**	202.16	139.66	68.38	2.66	–
DRY ABOVEGR. BIOMASS IN $KG.HA^{-1}$	25.21	94.59	3.96	0.091	**123.851**	24.66	18.02	11.97	0.082	**54.732**

Discussion

According to Tokár (1987), the choice of the species composition has a key importance also at cultivation of induced woody plants. The proportion of admixtures controls to a considerable extent the volume production of the final stand. We have confirmed this fact with the results obtained on both studied permanent plots: in the chestnut monoculture growing on PEP II and in the chestnut – linden stand on PEP VIII.

The average stem volume of chestnut trees on PEP II was 0.255 m^3. In the mixed stand on PEP VIII we obtained 0.379 m^3 for chestnut and 0.293 m^3 for small-leaved linden.

As we can see in Table 2 illustrating the situation on PEP II and in Table 3 for PEP VIII, the major part of the aboveground biomass is represented by dominant and codominant trees. Our observations were consistent with Šmelko (1982), according to whom the differences between the tree classes are reflected not only in the relevant tree volume but also in their diameter. The author means that the differentiation in the diameter growth begins to be evident already at an stand age of 30 years and then is maintained continual and permanent. In the height growth, the differences between the tree classes are less pronounced. Our results well correspond to the results of other authors, e.g. Tokár (1987, 1998), considering the tree age, species and tending procedure.

Oszlányi (1986) recorded for the total biomass of a 53-year old pine stand the following values: fresh 360.90 $t.ha^{-1}$, dry 175.53 $t.ha^{-1}$ (total biomass – aboveground plus belowground).

Tokár and Krekulová (2003) and also the results obtained by a 25-year comparative study of tending of various chestnut stands on PEP Horné Lefantovce clearly show that the aboveground biomass production on the studied PEP was always higher in chestnut stands containing admixtures of other woody plants.

The goal has been set to present the all hitherto obtained knowledge about growth and production of the European chestnut within a broader interdisciplinary context. and to arrange also a linking with dendro-chronological evaluation of the examined species. It is reasonable to consider the European chestnut as a promising species for the recuperation of the environment in localities fulfilling the ecological demands of this tree species (hedgerows. windscreen hedges. orchards. bio-corridors…). The positive results obtained with favourable influence of the small linden mixed to chestnut trees can be with advantage used to improve the environment and to reach higher aesthetic value of the landscape in the relevant regions. In the conditions of the threatening global warming it is necessary to put in connection the results obtained in complex study on both indigenous and exotic woody plants (abiotic and biotic harmful agents), in the frame of their limiting factors, as well as to seek their simultaneous application in mixed stands.

Conclusions

The production properties of stands of the European chestnut (*Castanea sativa* MILL.), an introduced woody plant to Slovakia, and the influence of admixture of some native tree species (small-leaved linden, forest pine) have been put under a long term research on the PEP series in Horné Lefantovce. In this paper we compare between the production parameters and mensurational variables of the chestnut monoculture on PEP II and of the stand mixed with the small-leaved linden on PEP VIII. Since 1976, both stands have been tended by light thinning from above performed at 5-year intervals (TOKÁR 1987). At present, they are at the thick pole growth stage.

Our results show a positive influence of mixing the chestnut with the small-leaved linden reflected in growth and production of chestnut trees. TOKÁR (1987) means that this could be a result of favourite ecological conditions formed by gradual decomposition of the litter of both tree species.

The present aboveground biomass amount of the 38-year old chestnut monoculture on PEP II is 154.12 t. ha^{-1} in the dry state, from which 90.8% is represented by trees belonging to the main stand level.

The value of the dry aboveground biomass of chestnut trees in the equally aged mixed stand on PEP VIII is 123.9 t.ha^{-1}, from which are 76.4% the proportion of the codominant and 20.3% the proportion of the dominant trees. The total dry aboveground biomass value in the small leaved linden is this stand is 54.73 t. ha^{-1} from which 32.9% belong to the codominant and 45.1% to dominant trees. The sum of the aboveground biomass (in dry state) of the both species is 178.63 t. ha^{-1}.

RAST, ŠTRUKTÚRA A PRODUKCIA ROVNORODÉHO A ZMIEŠANÉHO PORASTU GAŠTANA JEDLÉHO (*CASTANEA SATIVA* MILL.)

Súhrn

Vedie sa dlhodobý výskum rastu, produkcie cudzokrajnej dreviny gaštana jedlého (*Castanea sativa* MILL.) a vplyv zmiešania s našimi domácimi drevinami (lipa malolistá, borovica lesná) na TVP v Horných Lefantovciach. V uvedenom príspevku je porovnanie produkcie a dendrometrických veličín rovnorodého porastu gaštana jedlého na TVP č. II a zmiešaného porastu gaštana jedlého s lipou malolistou na TVP č. VIII. Oba porasty boli vychovávané miernou úrovňovou prebierkou od roku 1976 s intervalom návratu 5 rokov (TOKÁR 1987), nachádzajú v rastovej fáze žrďoviny.

Z výsledkov vyplýva pozitívny vplyv zmiešania lipy malolistej na rast a produkciu gaštana jedlého, čo môže byť podľa TOKÁRA (1987) spôsobené aj priaznivými pedologickými pomermi, ktoré sa vytvárajú postupným rozkladom opadu oboch drevín.

Vo veku 38 rokov má nezmiešaný porast gaštana jedlého na TVP č. II 154,12 t. ha^{-1} hmotnosť nadzemnej dendromasy v sušine, z čoho 90,8 % tvoria práve úrovňové stromy.

V tom istom veku na TVP č. VIII má gaštan jedlý 123,9 t.ha^{-1} hmotnosť nadzemnej dendromasy v sušine, z čoho tvoria úrovňové stromy 76,4 % a nadúrovňové 20,3 %. U lipy malolistej na tejto ploche – TVP č. VIII 54,73 t. ha^{-1}, z čoho tvoria úrovňové stromy 32,9 % a nadúrovňové 45,1 %, pre obe dreviny spolu činí hmotnosť nadzemnej dendromasy v sušine 178,63 t. ha^{-1}.

Priemerná hrúbka $d_{1,3}$ pre gaštan jedlý na TVP č. II. je 16,96 cm, na TVP č. VIII. má táto drevina priemernú hrúbku $d_{1,3}$ 19,2 cm, pre lipu malolistú na TVP č. VIII. činí priemerná hrúbka $d_{1,3}$ 18,47 cm.

Celková kruhová základňa na ha na TVP č. VIII. činí 38,2 m^2 , z toho pre gaštan jedlý 26,43 m^2 (69,2 %) a pre lipu malolistú 11,77 m^2 (30,8 %). Na TVP č. II. ja celková kruhová základňa 34,47 m^2.

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BELOW-GROUND BIOMASS IN A HORNBEAM-OAK FOREST STAND

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Abstract: *Kodrík, M.: Below-ground biomass in a hornbeam-oak forests stand. In Folia oecologica. ISSN 1336-5266, 2003, vol. 30, no. 2, p, 115–119.*

With regard to the absence of data about below-ground biomass in mixed forest stands we have established (in area of the School Forest Enterprise of Technical University Zvolen) a monitoring plot consisting of European hornbeam (Carpinus betulus L.) and oak (Quercus robur L.). Total below-ground biomass of European oak (Quercus robur L.) was 38.07 t.ha^{-1} which was 71% from the whole below-ground biomass of the trees on the forest stand. Total belowground biomass of European hornbeam (Carpinus betulus L.) was 15.62 t.ha^{-1} and presented 29% from the total amount. Species composition of the stand is 65% (oak) and 35% (hornbeam). It shows ratio of roots on the forest stand differ from its species composition.

Key words: *below-ground biomass, European oak, Quercus robur, European hornbeam, Carpinus betulus*

Introduction

In spite of technical problems with obtaining data on below-ground biomass we can find several results of investigation on forest stands created by one species. In our geographic conditions such knowledge and data concerning below-ground biomass production were gained by Oszlányi (1980), Kodrík (1992a), Kuděla (1992), Čaňová (1996, 1997) for beech (*Fagus sylvatica* L.) forest stands; by Oszlányi (1980, 1986) and Kodrík (1992b,c, 1994) for spruce (*Picea abies* L. Karst); by Kodrík, J. and Kodrík, M. (1996) for fir (Abies alba Mill.) and by Oszlányi (1979, 1981) for pine (*Pinus sylvestris* L.). Data about fir-beech forest stand below-ground biomass production were gained by Kodrík (1993). In introduced tree species similar observations were carried out by Benčať (1988a, b, 1989a, 1992a, b, 1993, 1995, 1996) for Black locust and by Soják (1991) for Douglas fir. Benčať (1985, 1986, 1988c, 1989b, 1991) also paid an attention to some other introduced tree species.

There are a lot of data missing what concerns the below-ground biomass production analysis of older mixed forest stands. Therefore the task of our paper is investigation on below-ground biomass production of mixed forest consisting of hornbeam and oak.

Material and methods

The research was carried out in the beech forest stand at the School forest enterprise of Technical University Zvolen. It is situated on a south-east 35% slope. It represents 85 year old hornbeam-oak forest stand with an average stocking of 0.8.

We have gained all data on below-ground biomass by destructive sampling of trees. To get a complete picture of the position of the individual trees, repeated stock-takings of trees assorted each tree according to Kraft's classification scale (Vyskot et al. 1971). This scale takes into account the relative altitudinal position of the tree and formation of the crown. Kraft (Vyskot et al. 1971) distinguishes the following classes: Dominant, codominant, partially codominant, undertopping and fully shaded trees. The selection resulted from the calculated mensurational tree variables, separately for each Kraft class (Oszlányi 1975).

We processed by four sample trees out of the first three classes in each species. The tree root system was excavated by means of the archeological method (Kodrík 1994), combined with washing of the system with water. Furthermore, a tractor with a winch and a power saw were used. The fresh weight was determined in the field using scales with an accuracy of 0.05 kg. The research method is in details described in Kodrík (1994) and Barna and Kodrík (2002).

Results

The sample trees were selected based on the actual mensurational data on the stand. Above ground forest stand characteristics according to the first three tree classes are shown in Table 1.

Table 1. Mensurational data

Species	Species composition	Height [m]	DBH [1] [cm]	Volume [m^3]	Density [stems.ha^{-1}]	Stock [m^3 .ha^{-1}]
Oak	65 %	23	27	0.52	212	110
Hornbeam	35 %	20	19	0.25	224	56

1 diameter at breast height

Research results concerning the below-ground biomass production in the examined hornbeam-oak forest stand are presented in Table 2. The analysis is based on eight sample trees. Their total below – ground biomass production was 53.59 t.ha^{-1} where the share of stumps were 43% and the share of roots with diameter more than 10 cm reached 25% of the total below-ground biomass production. Next three diameter classes were presented by percentage shares from 7% to10%. Roots with diameter 0.6-2.0 cm represented almost 5%. Fine roots and thin roots up to diameter 0.5 cm represented the smallest part of below-ground biomass (1.6%). Total below-ground biomass of oak was 38.07 t.ha^{-1} which were 71% from the whole below-ground biomass of the trees in the forest stand. Total belowground biomass of hornbeam was 15.62 t.ha^{-1} and presented 29% from the whole. Species composition is 65% (oak) and 35% (hornbeam). Therefore, the proportion of tree roots in the forest stand differs from its species composition.

Table 2. Weight distribution of belowground biomass of pedunculate oak *(Quercus robur* L*).* and European hornbeam *(Carpinus betulus* L.) according to diameter classes expressed in dry weight [t.ha^{-1}]

Tree	Belowground biomass according to diameter classes [cm]							Total	%
Class	≤ 0.5	0.6–2.0	2.1–5.0	5.1–7.0	7.1–10.0	>10,0	Stump		
Oak	0.530	1.552	3.647	2.631	2.884	10.411	16.367	38.072	71
Hornbeam	0.320	0.918	1.662	1.248	1.646	3.015	6.760	15.619	29
Σ	0.850	2.470	5.309	3.879	4.530	13.426	23.127	53.591	
%	1.6	4.6	9.9	7.2	8.4	25.1	43.2	100.0	

Discussion and conclusions

The belowground biomass of beech trees in sub-mountainous mixed forests is lower compared to the belowground biomass of oak trees growing in this vegetation tier. The total belowground biomass in beech was 25.2 t.ha (Kodrík 1999) compared to 38.1 t.ha^{-1} determined in oak. The percentage distributions according to the diameter fractions were also different. The most remarkable differences were recorded in the two largest diameter categories (roots with diameter exceeding 10 cm and stumps).

The belowground biomass of beech trees was also determined in a monoculture. Here we obtained a value of 27.0 t.ha^{-1} (Kodrík 1998) for the roots. Also this value is lower compared to the corresponding value in oak. On the other hand, in the pure stand, the percentage distribution of the beech belowground biomass according to the diameter fractions was more similar to oak than in the case of the mixed stand.

Thus we can see that the belowground biomass in oak is substantially higher compared to beech trees. It would be meaningful to compare between several oak stands. The values of oak belowground biomass presented in this paper represent the first results of a pioneer work in this area. The author has not found references on such sort of data in the worldwide literature.

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PODZEMNÁ BIOMASA HRABO-DUBOVÉHO PORASTU

Súhrn

V práci sú uvedené výsledky výskumu podzemnej biomasy v dúbrave s prímesou hrabu. Výskumná plocha bola založená na území Vysokoškolského lesníckeho podniku Technickej univerzity vo Zvolene. Vek porastu bol 85 rokov a zakmenenie 0,8. Celková podzemná biomasa duba (*Quercus robur* L.) bola 38,07 $t.ha^{-1}$, čo predstavovalo 71 % celkovej podzemnej biomasy drevín porastu. Celková podzemná biomasa hrabu (*Carpinus betulus* L.) bola 15,62 $t.ha^{-1}$, čo predstavovalo 29 % z celej podzemnej biomasy drevín porastu. Zastúpenie drevín bolo pre dub 65 % a pre hrab 35 %. Výskumom sme okrem celkovej produkcii koreňov a podzemnej produkcii v jednotlivých hrúbkových triedach zistili, že zastúpeniu drevín neodpovedá ich percentuálny pomer podzemnej biomasy.

THE ANALYSIS OF PLANT SPECIES COMPOSITION OF FOREST FRAGMENTS IN BRATISLAVA

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Abstract: *Reháčková, T., Ružičková, J.: The analysis of plant species composition of forest fragments in Bratislava. In Folia oecologica. ISSN 1336-5266, 2003, vol. 30, no. 2, p. 121–130.*

In the central part of the city Bratislava remained the fragments of natural Carpathian oak-hornbeam forest. They are represented by woods "Horský Park" (22.4 ha), "Kalvária" (4.25 ha), the wood in "Mlynská dolina" valley (10.43 ha) and "Sitina" (86 ha). Remnants of woods in urban area currently represent the topic of interest from different reasons as for their recreational and hygienic potential or in term of their values for nature and biodiversity protection. Hermy et al. (1999) mentioned that ancient forest plant species might be considered as important biodiversity indicators. In the sense of Zlatník (1970) and Laweson et al. (1998) true forest species are understood analogous to ancient forest species. In the contribution is presented analysis of the indicating plant species groups and types of diaspore dispersal at the selected forest fragments of Bratislava. Generally 101 species of vascular plants have been recorded; in a tree layer it was 26 species, in a shrub layer 36 species and in an herb layer 86 species.

Key words: *forest fragments, urban area, Bratislava, Slovak Republic, indicating groups of species, dispersal*

Introduction

Remnants of woods in urban areas represent currently the topic of interest from different reasons as for their recreational and hygienic potential (Nilssen, Randrup 1997, Gyllin 1999), or in term of their value for nature and biodiversity protection in cities (Sukopp, Weiller 1988, Supuka 1995, Godefroid 2001, Massant et al. 2002). The state of biodiversity could reflect by Šeffer (1998) three groups of basic and complementary indicators, which indicate quantity and quality of ecosystems, condition and extinction of endangered species and biotopes. Quantitative indicators could record loss of diversity and fragmentation, qualitative indicators could describe the structure and distribution of ecosystems. Hermy et al. (1999) mentioned that ancient forest plant species may be considered as important biodiversity indicators for forests due to their distinct ecological profile and low colonising abilities. In the sense of Zlatník (1970) analogous to ancient forest species are understand true forest species. Zlatník (1970) defined true forest species as species clearly ecologically specified from the demand on light with optimum in shadowed or partly shadowed conditions of the forest interior (hemisciofyts and sciofyts). The same terminology applied Laweson et al. (1998) who used the indicating group of true forest species (forest specialists) in the research of forest biodiversity in correlation with an area. Hermy et al. (1999) presented the ecological characteristic of ancient forest species and compare them with other forest plant species of Europe. The group of ancient forest species has afinity for a forest higher order syntaxon. The majority (56%) of ancient forest species is typical of *Fagetalia*-forest communities and further 16% characterize *Querco-Fagetea*-forests in general, more than expected by chance in comparison with all forest species. Ancient forest species tend to be shade or semi-shade tolerant plants, they are more likely to be shade-tolerant plants than other forest plants. The low colonisation capacity of ancient forest plant species severely restricts the possibilities of habitat re-creation. In addition, most ancient forest species do not have persistent seed banks, suggesting that even temporal land use changes may have dramatic effects on the survival of the ancient forest flora, and reduces the probability of successful restoration of degraded habitats.

In the central part of Bratislava (the capital city of Slovak Republic) there remained remnants of natural Carpathian oak-hornbeam forests mainly on the steep slopes (gradient of slope about 45°). They are represented by woods ”Horský Park” (22.4 ha), ”Kalvária” (4.25 ha), the wood in ”Mlynská dolina” valley (10.43 ha) and ”Sitina” (86 ha), which belonged to forest land resources. Natural oak-hornbeam coppice of ”Horský Park” was during nineteen century adapted to a forest park with planting of the different introduced species as e. g. *Aesculus hippocastanum*, *Pinus ponderosa*, *Pseudolarix amabilis*, *Metasequoia glyptostroboides*, *Pseudotsuga canadensis*. The wood in ”Mlynská dolina” remains only as a narrow strip (120 m at average) in the slopes of the valley. The area of the mentioned forest fragments changed during the twentieth century. According to the map of Bratislava from 1932 (Steiner, 1932) the area of ”Horský Park” was reduced by about 4.6 ha, but the area of ”Kalvária” increased in that period by about 1.4 ha. The wood in ”Mlynská dolina” remained preserved on the steepest slopes in the similar contours, however all the wider territory of Machnáč (whose part is the wood in Mlynská dolina) was anymore in 1932 covered by forests, vineyards and gardens. Contemporary intensive building-up is realised there. From the status of nature protection ”Horský Park” is declared as protected area, the ”Sitina” wood belonged till 1998 to Protected landscape area Malé Karpaty and now it is under consideration to acclaim it as protected landscape element.

The purpose of the study is evaluation of plant species diversity under strong anthropogenic influence. In contribution there is presented the indicating plant species analysis of the selected fragments as the preliminary phase of on-going monitoring.

Methods

Data collection from the forest communities was done by zürrich-montpellier phytosociological method in the sense of Braun-Blanquet (1964) and Westhoff and van der Maarel (1978). At the selection of patches for sampling older, homogenous and relatively undisturbed place (400 m^2) was preferred. Field survey was realised in the years 2002, 2003 in spring (ephemeral species were noticed) and in summer time. Twenty-one phytosociological releveés were recorded. The following groups of plant species were chosen for monitoring in context to forest fragmentation: 1/ **natural plant species** in the sense of potential natural vegetation (Michalko et al. 1977, 1986), 2/ **alien species** by Benčať (1982), 3/ **true forest species** according to Zlatník (1970) and Hermy et al. (1999), 4/ **protected, endangered** and **rare species** after the Order of the Slovak Ministry of Environment No. 24/2003, which engaged of the Act No. 543/2002 on Nature and Landscape Protection and according to Feráková et al. (2001), 5/ **synanthropic species** (ruderal and semiruderal) in the sense of Jurko (1990) and 6/ **invasive species** after Cvachová, Gojdičová (2003). The indicating groups of species were evaluated within plant communities in term of species number.

Presence of natural taxons in opposition with unoriginal species we regarded as the significant indicator of anthropogenic influence degree in forest communities. As mentioned Moravec (1994): in evaluation of an area ecological quality by means of species composition of vegetation it is confrontation of actual vegetation with potential or reconstructed vegetation, which in the best way shows changes in landscape caused by human activities. By Míchal (1994) is the step of ecosystem naturalness value indirectly commensurable to the step of human influence to it. Consequent on changes in species composition and structure of the real community in comparison with potential natural vegetation in the same site conditions.

The group of protected, endangered and rare species is significant from the viewpoint of their ecosozological value, rare occurrence and high sensitivity to the disturbance or loss of their biotopes. The true forest species could be mostly affected by a disruption of the forest interior. Suitable indicator of biotopes current situation is the occurrence of invasive and synanthropic plant species, which could spread more intensively due to ecosystem disturbation.

The following step was evaluation of diaspore dispersal type of determined vascular plant species in the sense of Jurko (1990).

Results

The investigated woodland fragments in the study area are located at easy and steep slopes at the altitude 162–257 m a. s. l. We classified forest communities as oak-hornbeam of the alliance *Carpinion betuli* Isler 1931. In species composition the following taxons are present: *Carpinus betulus, Quercus petraea* agg.*, Cerasus avium, Acer campestre, A. platanoides, Fraxinus excelsior, Fagus sylvatica, Tilia cordata, Sorbus torminalis, Lonicera xylosteum, Corylus avellana, Ligustrum vulgare, Crataegus monogyna, Euonymus europaeus*, admixed are also *Euonymus verrucosus, Staphylea pinnata* and *Rhamnus cathartica*. Herb layer is dominated by *Melica uniflora, Poa nemoralis* and *Hedera helix*. In the canopy we found also e.g. *Galium sylvaticum, Convallaria majalis, Polygonatum odoratum, P. latifolium, P. multiflorum, Hepatica nobilis, Brachypodium sylvaticum, Carex pilosa.* Generally 101 species of vascular plants have been recorded. In the tree layer it was 26 species, in the shrub layer 36 species and in the herb layer 86 species (Table 1). The ratio of tree and shrub species in the herb layer is 37.21% (32 species). In the tree layer we record 69.23% of natural species composition, 19.23% of introducted species (*Aesculus hippocastanum, Castanea sativa, Robinia pseudoacacia, Pinus nigra,*). Our domestic species (*Pinus sylvestris, Taxus baccata*), that naturally grow in the different types of communities, compose 11.54%. Among trees we found only one invasive species *Robinia pseudoacacia* which occurs mainly in ”Sitina” and in ”Mlynská dolina” localities. The shrub layer is dominated by natural composition species as *Ligustrum vulgare*, *Euonymus europaeus, Lonicera xylosteum* and *Crataegus monogyna* (82.86%). Ecosozologicaly significant is *Staphyllea pinnata*, which before belonged to protected species and is abundant in shrub layer of ”Sitina”. Introduced species (e.g. *Mahonia aquifolia, Mespilus germanica* and *Laburnum alpinum*) create 17.14% of shrub species. From the group of invasive species *Ailathus altissima* and *Robinia pseudoacacia* were found. The herbal layer we suggest as the best indicator of changes in the species composition of vegetation. In assessed forest fragments species of natural composition create 76.54% of all species in the herbal layer. The results of classification according to the indicating groups are demonstrated on the Fig. 1. Substantial representation among herbs (39.53%) has the group of true forest species by ZLATNÍK (1970) and HERMY et al. (1999). The following species: *Brachypodium sylvaticum, Carex pilosa, Campanula trachelium, Convallaria majalis, Dactylis polygama,* in the investigated forest fragments are classified as true forest species by both authors.

Among protected species according to valid legislation there was registered only *Taxus baccata*, which is unoriginal in natural communities of given area. In the category of endangered and rare species were determined two species: *Lilium martagon* and *Convallaria majalis*, which create 3.49% of herbal species. The investigated woods are marked by synanthropisation as consequence of more and more intensive press from adjacent environment (building-up, spontaneous dumps). Presence of ruderal and semiruderal species reached 18.60%, very often are *Geum urbanum*, *Sambucus nigra* and *Urtica dioica*. The category of invasive species is represented by *Robinia pseudoacacia, Balota nigra* and *Impatiens parviflora* and attains 3.49%. For oak-hornbeam communities it is typical spring aspect of ephemeral herbs. In the area of interest in spring time appear species which ZLATNÍK (1970) and HERMY et al. (1999) classified as true forest species as: *Anemone ranunculoides, A. nemorosa, Corydalis cava, C. solida, C. pumila, Gagea lutea, Galanthus nivalis, Isopyrum thalictroides* and *Pulmonaria officinalis*. Endangered species *Galanthus nivalis* occur on the observed localities massively in spring period. Diaspore dispersal is considered as one of the plant communities characteristic, which enable better understanding of biocenose ecology. Several authors deal with diaspore dispersal types in the contex of forest fragmentation (e.g. DZWONKO 2001, VERHEYEN, HERMY 2001). Mainly for forest community it is typical high presence of endozoochory and myrmecochory. We confirmed this opinion in the study area, when up to 50% of shrub species and 38.6% of tree species belong to endozoochores, especially taxons with fleshy fruit, berry and nut. The other very significant category of diaspore dispersal is anemochory, especially plants with winged seeds (e.g. genus *Tilia*). Herb layer is dominated by endozoochory species (24.42%), abundantly is represented also combination of endozoochory together with anemochory (11.63%). The other types of seed dispersal as anemochory (hairy and fuzzy diaspores), boleochory (shaking off), combination of autochory (dispersal by plant itself) with myrmecochory and combination of boleochory with endozoochory are equally (about 6%) represented. The seed dispersal by myrmecochory and epizoochory (adhesion on animals) is also typical for forest plants, in the study area these kinds get to 3.49% each (Fig. 2).

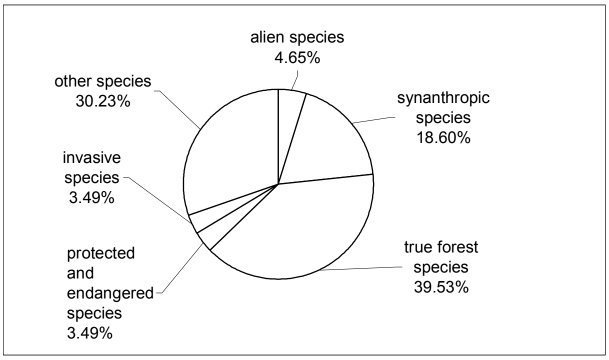

Fig. 1. Indicator groups of plants in herbal laver

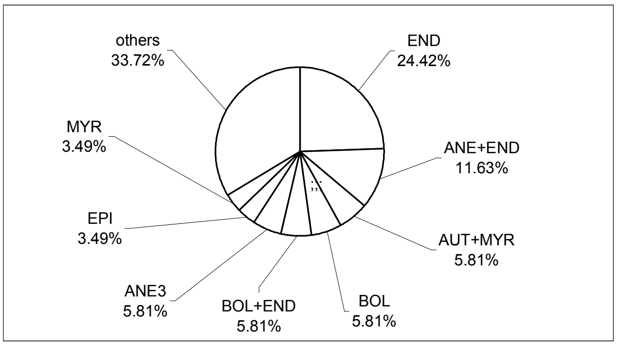

Fig. 2. Diaspore distribution types of plants in herbal laver

Table 1. The list of determined plant species

Latin name	P	I	Synanthropic sp.	L (H)	L (Z)	Diaspore dispersal type
Acer campestre	+	-	-	+	-	ANE+END
Acer platanoides	+	-	-	-	-	ANE+END
Acer pseudoplatanus	+	-	-	-	-	ANE+END
Aesculus hippocastanum	-	+	-	-	-	END+HEM
Ailanthus altissima	-	+	•	-	-	ANE+END+HEM
Alliaria officinalis	-	-	S	-	-	BOL+END
Anthericum ramosum	+	-	-	-	-	BOL+END
Anthriscus sylvestris	-	-	S*	-	-	END+EPI
Arum alpinum	+	-	-	-	+	END
Avenella flexuosa	+	-	-	-	+	ANE+END
Ballota nigra	-	-	S	-	-	EPI+HEM
Brachypodium sylvaticum	+	-	-	+	+	ANE+END
Calamagrostis arundinacea	+	-	-	-	+	ANE+EPI
Campanula trachelium	+	-	-	+	+	BOL
Carex pilosa	+	-	-	+	+	ANE+EPI
Carpinus betulus	+	-	-	-	-	ANE+END
Castanea sativa	-	+	-	-	-	BOL+HEM
Cerasus avium	+	-	-	-	-	END
Clematis vitalba	+	-	-	+	-	ANE+END+EPI+OMB
Convallaria majalis	+	-	-	+	+	» END
Corylus avellana	+	-	-	+	-	END
Crataegus curvisepala	+	-	-	-	-	END
Crataegus monogyna	+	-	-	-	-	END
Dactylis polygama	+	-	-	+	+	ANE+END
Digitalis grandiflora	+	-	-	-	-	BOL
Dryopteris filix-mas	+	-		-	+	ANE1
Euonymus europaeus	+	-	-	+	-	END
Euonymus verrucosus	+	-	-	-	-	END
Fagus sylvatica	+	-	-	-	-	END
Fallopia convolvulus	-	-	S	-	-	MIR
Fraxinus americana	-	+	-	-	-	ANE+END
Fraxinus excelsior	+	-	-	-	-	ANE+END
Galeopsis pubescens	+	-	-	-	+	BOL+END
Galium odoratum	+		-	-	+	EPI
Galium sylvaticum	+	-	-	-	+	EPI
Genista tinctoria	+	-	-	-	-	AUT+MYR
Germanium robertianum	-	-	S*	-	-	AUT+EPI+END+HEM
Geum urbanum	-	-	S*	-	-	EPI
Glechoma hederacea	-	-	S*	-	-	MYR+END+AUT+OMB
Grussularia uva-crispa	+	-	-	-	-	END
Hedera helix	+	-	-	-	-	END
Hepatica nobilis	+	-	-	+	+	END+MYR
Hieracium racemosum	+	-	-	-		ANE3
Hieracium sylvaticum	+	-	-	-	+	ANE3
Hieracium umbelatum	+	-	-	-	-	ANE3
Chelidonium majus	-	-	S	-	-	AUT+MYR
Chrysanthemum corymbosum	+	-	-	-	+	BOL
Impatiens parviflora	-	+	S	-	-	AUT+HEM
Juglans regia	-	+	-	-	-	BOL+HEM
Laburnum alpinum	-	+	-	-	-	ANE+END
Lapsana communis	+	-	S*	-	+	BOL+END
Ligustrum vulgare	+	-	-	-	-	» END
Lilium martagon	+	-	-	+	-	BOL
Lonicera xylosteum	+	-	-	+	-	END
Luzula luzuloides	+	-	-	+	+	ANE+MYR

Continue Table 1

Malus sylvestris	+	-	-	+	-	END
Melanpyrum pratense	+	-	-	+	+	MYR
Melica uniflora	+	-	-	+	+	ANE+END+HYD+MYR
Melittis melissophyllum	+	-	-	+	-	OMB
Mercurialis perennis	+	-	-	+	+	AUT+MYR
Mespilus germanica	-	+	-	-	-	END
Mycelis muralis	+	-	-	-	+	ANE+EPI
Padus racemosa	+	-	-	-	-	END
Pinus nigra	-	+	-	-	-	ANE2
Pinus sylvestris	-	-	-	-	-	ANE+END
Poa nemoralis	+	-	-	+	+	ANE3
Polygonatum latifolium	+	-	-	-	+	END
Polygonatum multiflorum	+	-	-	+	+	END
Polygonatum odoratum	+	-	-	-	-	END
Pyrus pyraster	+	-	-	-	-	END
Quercus cerris	+	-	-	-	-	END
Quercus petraea	+	-	-	-	-	END
Rhamnus catharticus	+	-	-	+	-	END
Ribes rubrum	+	-	-	-	-	END
Robinia pseudoacacia	-	+	•	-	-	ANE+END
Rosa canina	+	-	-	-	-	END+HEM+MYR+OMB
Rubus caesius	-	-	S*	-	-	END+HEM+MYR+AUT
Rubus fruticosus	-	-	S*	-	-	» END
Sambucus nigra	+	-	S*	-	-	END+HEM+MYR+AUT
Sedum maximum	+	-	S*	-	-	BOL+END
Solidago virgaurea	+	-	-	-	-	ANE3
Sorbus aucuparia	+	-	-	-	-	END
Sorbus torminalis	+	-	-	+	-	END
Staphylea pinnata	+	-	-	-	-	ANE+END
Stellaria holostea	+	-	-	+	+	BOL
Swida sanquinea	+	-	-	-	-	END
Symphytum tuberosum	+	-		+	-	MYR
Syringa vulgaris	-	+	-	-	-	» HEM
Taxus baccata	-	-	-	-	-	END
Tilia cordata	+	-	-	+	-	ANE2
Tilia platyphyllos	+	-	-	+	-	ANE2
Tithymalus cyparissias	-	-	S*	-	-	AUT+MYR
Ulmus glabra	+	-	-	-	-	ANE2
Ulmus minor	+	-	-	+	-	ANE2
Urtica dioica	-	-	S*	-	-	ANE+END+HEM+AUT
Veronica hederifolia	-	-	S	-	-	END+HEM+MYR+AUT
Veronica officinalis	+	-	-	-	-	END+HEM+MYR+OMB
Viburnum lantana	+	-	-	-	-	END
Vincetoxicum hirundinaria	+	-	-	-	-	ANE+HYD+EPI+MYR
Viola odorata	+	-	S*	-	-	AUT+MYR

Explanation:

P taxons of natural composition

I alien species

S synanthropic species (Jurko, 1990)

L
(H) ancient forest species (Hermy et al, 1999)

L
(Z) true forest species (Zlatník, 1970)

◘ invasive species

♣ protected and endangered species

* species natural in the other tyoe of community (Jurko, 1990)

Diaspore dispersal type (Jurko, 1990)

ANE – anemochory, ANE 3 – anemochory, hairy or parachute-like diaspores

AUT – autochory, BOL – boleochory (shaked out), END – endozoochory

EPI – epizoochory, **HYD** – hydrochory, MYR – myrmecochory,

OMB – ombrochory (by rain), HEM – hemerochory (by man)

» vegetative expansion

Discussion

According to our findings the studied forest fragments in the city of Bratislava still have markedly natural character. The combination of species in these woods is identical to the combination of species that the natural Carpathian oak-hornbeam forests have. Very important is high ratio 39.53% (36 species) of true forest species. This fact indicates long-lasting remaining of these remnants on given sites. The ratio of protected, endangered and rare species is not very high in these woods, but they have great importance from the biodiversity viewpoint. The Order of the Slovak Ministry of Environment No. 24/2003, which engaged the Act No. 543/2002 on Nature and Landscape Protection, labelled Carpathian oak-hornbeam woods as biotopes of national importance. In fact, investigated woods are vital communities which is documented by the natural rejuvenation of species *Quercus petraea* agg., *Acer campestre, Acer platanoides* and *Fraxinus excelsior*. According to JURKO (1990) taxons *Viola odorata*, *Sedum maximum, Sambucus nigra* and *Rubus caesius* are included into group of the synatrophic species, but it is questionable to consider these species as synanthropic in these types of forest fragments. According to DZWONKO, LOSTER (1992) the high representation of endozoochory species noticed positive relationship among a number of forest endozoochory shrubs, cover of tree layer and origin of wood. CATHY et al. (2000) in the study about distribution of plants in New England forest (USA) found that plants with berries and fleshy fruits with high dispersal potential by birds, were associated with the habitats having the least past disturbance, possibly reflecting the greater use of these areas by birds. On the other hand passive (anemochory) dispersal of diaspores was in narrow relationship with higher site disturbance.

Conclusions

The indicating groups of species seem to be suitable methodological approach for assessing of forest fragments ecological quality in urban area. The results of research from two years study period are good beginning for planned monitoring of forest fragments in Bratislava. In the future research it would be necessary to put attention on historical context of urbanisation and on the consequent process of forest fragmentation. As follows it would be important to evaluate negative factors and to propose measurements to protect these biotopes.

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ANALÝZA DRUHOVÉHO ZLOŽENIA VEGETÁCIE FRAGMENTOV LESOV NA ÚZEMÍ BRATISLAVY

Súhrn

V centrálnej časti mesta Bratislava ostali zachované fragmenty pôvodných karpatských dubovo-hrabových lesov, zväz *Carpinion betuli* Isler 1931. Ide o lokality Horský park s výmerou 22,4 ha, Kalvária (4,25 ha), les v Mlynskej doline (10,43 ha) a les Sitina (86 ha). V súčasnosti sú zvyšky lesov v urbanizovanom území predmetom odborného a vedeckého záujmu. Za dôležitý indikátor stavu biodiverzity lesov pokladá Hermy et al. (1999) výskyt pôvodných lesných druhov (ancient forest species). V zmysle Zlatníka (1970) môžeme hovoriť o pravých lesných druhoch (hemisciofyty až sciofyty). V príspevku sú prezentované výsledky hodnotenia druhového zloženia fragmentov lesov v urbanizovanom prostredí z hľadiska indikačných druhov rastlín a spôsobov rozširovania diaspór. Celkom bolo zaznamenaných 110 druhov vyšších rastlín. Významný je podiel pravých lesných druhov v bylinnej vrstve 39,53 % (36 druhov), čo indikuje dlhodobé pretrvávanie lesov na daných stanovištiach. Pre lesné spoločenstvá je charakteristické vysoké zastúpenie endozoochórnych druhov rastlín, čo sa potvrdilo aj v záujmovom území.

ESTIMATION OF MORPHOLOGICAL PARAMETERS FOR EUROPEAN BEECH LEAVES ON SPRING SHOOTS USING THE METHOD OF CALCULATION COEFFICIENTS

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Abstract: *Cicák, A.: Estimation of morphological parameters for European beech leaves on spring shoots using the method of calculation coefficients. In Folia oecologica. ISSN 1336-5266, 2003, vol. 30, no. 2, p. 131–140.*

A new method of measuring morphological parameters in European beech (Fagus sylvatica L.) leaves, namely area, length and width of on spring shoots, using the method of calculation coefficients is presented. For each of the mentioned morphological parameters, the calculation coefficient is a dimensionless variable. Mathematically, it is defined as the ratio of the sum of the values of the relevant characteristic measured on all the leaves on the observed shoot and the value of the characteristic for the given leaf. The method is based on a recent knowledge about regularities in distribution of morphological traits of beech leaves growing on spring shoots. In practice the method of calculation coefficients is applied as follows:

a) in each spring shoot sampled, morphological parameters such as area, length and width of leaves are measured in a single leaf only,

b) to evaluate observed parameters the selection of particular leaf for the whole shoot is determined statistically by choosing the leaf which enables the highest precision of estimation,

c) the value of a particular parameters multiplied by the corresponding calculation coefficient gives the value representing the whole shoot.

The results are not influenced by tree age and/or energy supply during the tree growth.

Key words: *Fagus sylvatica L., beech leaves, morphological parameters, method of calculation coefficients*

Introduction

Up to the present time, the measurements and determination of leaf area has been performed by four basic approaches: a) direct, b) indirect, c) assessment of leaf area through estimation, d) combined, using the three above mentioned principles (Šesták 1966; Dykyjová 1989). The leaf area measurement and determination methods belonging to these four basic groups have the following disadvantages: time consuming-measuring using a planimeter, computation of squares and weighing of leaf copies; destruction of whole plants – photometric methods, weighing of the leaves themselves and vacuum metric methods; necessity for particular calibration for each plant species-linear measurements on leaves, comparative methods, etc. The choice of a method for leaf area measurement and determination depends on demands following from the given experiment or observation. An important choice criterion is the accuracy, in the case of the above-mentioned methods ranging from ±1% (square computation) ±7.5 – ±10% (comparative methods and linear measurements on leaves).

Technologies used in many of these methods have already become out-of-date. At present they have been replaced by a wide scale of measuring equipment enabling us to reach the accuracy from ±1 to ± 3%, even in non-destructive leaf area measurements (on intact plants). However, namely in the case of the equipment constructed for non-destructive measurement, the question of leaf area measurement accuracy for plants with leaf stalks shorter than the distance between the light diodes and the margin of the scanning head still remains open. Also, these findings may be applied for the European beech, *Fagus sylvatica* L. Several equipment have the distance between light diodes and scanning head longer than 6 mm. In the case of leaves with petioles shorter than the distance between the light diodes and the scanning head margin, the part of leaf near the leaf base cannot be involved in the measurement. The consequent measurement error depends on the length of leaf petiole and the size of the measured leaf area. To avoid the error, it is necessary to measure the leaf after its separation from the plant, which results in whole plant destruction.

Compared to the measurement of leaf area, the measurement of leaf length is remarkably simpler. When the modern measuring equipment for simultaneous measurements of leaf area, leaf length and width is not at one's disposal, it is necessary to perform linear measurement. However, the actual equipments cannot avoid plant destruction in precise leaf length measurement.

Considering the current situation in measurement equipment availability and possibilities, the same is true as in the case of measurement of leaf length. However, plant destruction is not necessary.

Negative aspects of the above described approaches for measuring morphological parameters of beech leaves can be avoided using the method of calculation coefficients proposed by this invention.

Material and methods

The basic research material for obtaining the calculation coefficients represented leaves on spring shoots of beech trees. We examined leaves on beech trees of various age and leaves on trees growing in various conditions in terms of energy supply. The details of the method, including the data about the extent of the examined samples, will be published. In this paper the procedure how to obtain the calculation coefficients and several examples of their practical application is presented. The morphological parameters of leaves were measured using the equipment LI-COR LI – 3000A Portable Area Meter.

Calculating coefficients defining morphological parameters of leaves

The leaf area coefficient is obtained as follows:

$$CC_A = \frac{\sum_1^n A}{A_i}$$

CC_A – leaf area calculation coefficient,
n – number of measured leaves on the shoot,
A – leaf area,

i = 1…*n*.

The leaf length coefficient is obtained as follows:

$$CC_L = \frac{\sum_{1}^{n} L}{L_i}$$

CC_L – leaf length calculation coefficient,
n – number of measured leaves on the shoot,
L – leaf length,
i = 1…*n*.

The leaf width coefficient is obtained as follows:

$$CC_W = \frac{\sum_{1}^{n} W}{W_i}$$

CC_W – leaf width calculation coefficient,
n – number of measured leaves on the shoot,
W – leaf width,
i = 1…*n*.

Calculation coefficients and determination of the morphological parameters of beech leaves

Leaf area

To express the total leaf area in a beech shoot, measurements performed on a single leaf is satisfactory. The final result obtained by the classic approaches – measuring all leaves on the shoot – will also be obtained by multiplying the one measured leaf area by the appropriate calculation coefficient (Table 1).

Leaf length

To express the mean leaf length in a beech shoot, length measurement performed on a single leaf is satisfactory. Multiplying the measured leaf length by the appropriate calculation coefficient (Table 2) and by dividing this value by the total number of leaves on the shoot we obtain the mean length of the leaves on the shoot.

Leaf width

To express the mean leaf width in a beech shoot, width measurement performed on a single leaf is satisfactory. Multiplying the measured leaf width by the appropriate calculation coefficient (Table 3) and by dividing this value by the total number of leaves on the shoot we obtain the mean width of the leaves on the shoot.

Table 1. Calculation coefficients and standard error for leaf area. In brackets are the values of relative error (accuracy) at 95% significance level ($P = 0.95$).

Leaf number on the shoot	Leaf position from the shoot-base						
	1	2	3	4	5	6	7
2	2.593 ± 0.038 (2.86)	1.655 ± 0.014 (1.70)					
3	5.148 ± 0.090 (3.44)	2.665 ± 0.016 (1.19)	2.407 ± 0.021 (1.70)				
4	8.129 ± 0.181 (4.35)	4.078 ± 0.034 (1.62)	3.054 ± 0.019 (1.22)	3.554 ± 0.062 (3.42)			
5	11.749 ± 0.460 (7.67)	5.147 ± 0.056 (2.14)	3.857 ± 0.022 (1.10)	3.885 ± 0.035 (1.78)	6.008 ± 0.164 (5.27)		
6	15.070 ± 0.913 (11.93)	6.340 ± 0.092 (2.85)	4.511 ± 0.033 (1.43)	4.431 ± 0.032 (1.42)	5.428 ± 0.075 (2.70)	9.080 ± 0.197 (4.27)	
7	17.538 ± 0.849 (9.52)	7.183 ± 0.130 (3.57)	5.113 ± 0.039 (1.52)	4.889 ± 0.036 (1.44)	5.736 ± 0.061 (2.08)	8.050 ± 0.133 (3.24)	13.668 ± 0.299 (4.31)

Table 2. Calculation coefficients and standard error for leaf length. In brackets are the values of relative error (accuracy) at 95% significance level ($P = 0.95$).

Leaf number on the shoot	Leaf position from the shoot-base						
	1	2	3	4	5	6	7
2	2.264 ± 0.015 (1.33)	1.801 ± 0.009 (1.00)					
3	3.967 ± 0.030 (1.51)	2.806 ± 0.010 (0.69)	2.583 ± 0.012 (0.92)				
4	5.795 ± 0.059 (2.00)	4.059 ± 0.017 (0.81)	3.420 ± 0.010 (0.59)	3.543 ± 0.028 (1.55)			
5	7.609 ± 0.119 (3.06)	5.112 ± 0.028 (1.09)	4.333 ± 0.013 (0.60)	4.240 ± 0.020 (0.94)	5.108 ± 0.061 (2.35)		
6	9.344 ± 0.188 (3.93)	6.225 ± 0.045 (1.42)	5.187 ± 0.021 (0.78)	5.004 ± 0.021 (0.84)	5.427 ± 0.037 (1.32)	6.888 ± 0.074 (2.10)	
7	10.882 ± 0.232 (4.18)	7.076 ± 0.059 (1.63)	5.953 ± 0.027 (0.89)	5.748 ± 0.024 (0.81)	6.092 ± 0.034 (1.10)	7.124 ± 0.062 (1.71)	9.088 ± 0.093 (2.00)

Table 3. Calculation coefficients and standard error for leaf width. In brackets are the values of relative error (accuracy) at 95% significance level (P = 0.95).

Leaf number on the shoot	Leaf position on the shoot base						
	1	2	3	4	5	6	7
2	2.292 ± 0.020 (1.74)	1.789 ± 0.011 (1.22)					
3	3.886 ± 0.035 (1.77)	2.760 ± 0.011 (0.80)	2.672 ± 0.015 (1.11)				
4	5.600 ± 0.064 (2.25)	3.903 ± 0.018 (0.87)	3.403 ± 0.013 (0.73)	3.802 ± 0.035 (1.80)			
5	7.345 ± 0.128 (3.42)	4.863 ± 0.027 (1.10)	4.251 ± 0.016 (0.75)	4.356 ± 0.026 (1.19)	5.549 ± 0.074 (2.61)		
6	9.119 ± 0.234 (5.03)	5.880 ± 0.044 (1.46)	4.964 ± 0.022 (0.85)	5.040 ± 0.025 (0.98)	5.689 ± 0.046 (1.59)	7.619 ± 0.090 (2.32)	
7	10.699 ± 0.247 (4.52)	6.739 ± 0.061 (1.79)	5.672 ± 0.023 (0.81)	5.602 ± 0.026 (0.93)	6.239 ± 0.042 (1.32)	7.517 ± 0.067 (1.75)	10.255 ± 0.132 (2.53)

If assessing morphological parameters we can consider possibility when the leaf number on a shoot exceeds 7 – in our case the stated value for the calculation coefficient determination. In such a case we can use regression equations derived individually for each morphological parameters – leaf area, length and width (Fig. 1, 2 and 3). The equations were derived from a very close relation between the values of the calculation coefficients for each morphological parameter represented by the third leaf from the shoot base and by the leaf number on the shoot. In the case of a shoot with leaf number greater than seven, the appropriate morphological parameter will be obtained using the calculation coefficient for the third leaf. The value will be calculated from the equation of the regression line.

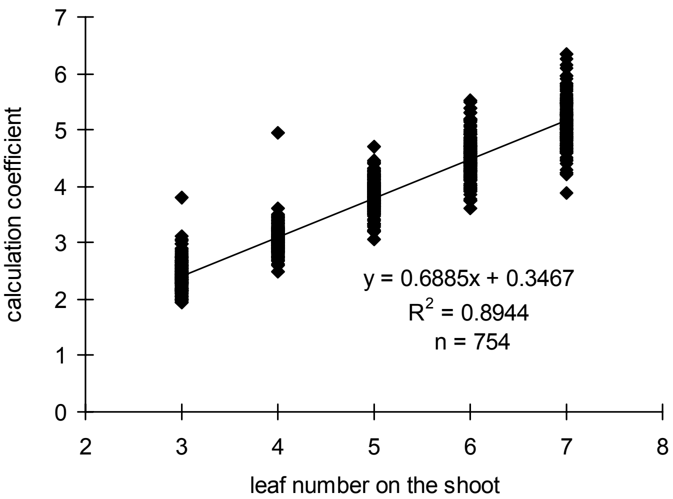

Fig. 1. Calculation coefficient values (leaf area) in the 3rd leaf from the shoot base related to the number of leaves

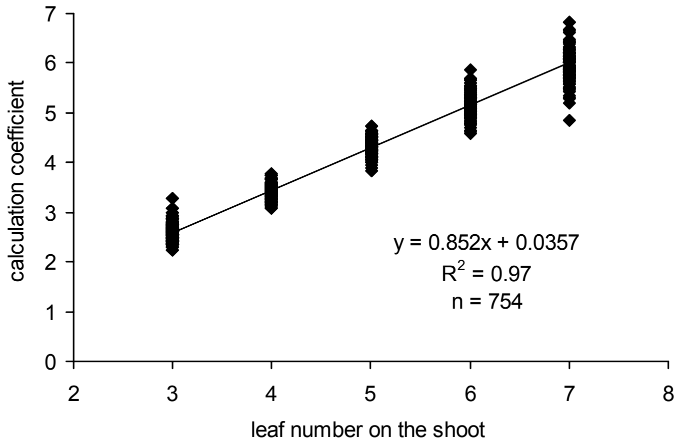

Fig. 2. Calculation coefficient values (leaf length) in the 3rd leaf from the shoot base related to the number of leaves

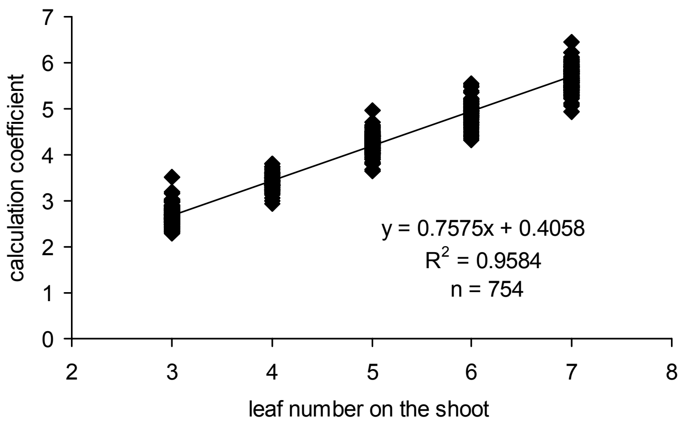

Fig. 3. Calculation coefficient values (leaf width) in the 3rd leaf from the shoot base related to the number of leaves

Results and discussion

Examples of the morphological parameters determination

Example 1

The accuracy of the morphological parameters determination – area, length and width of beech leaves – using the calculation coefficients as well as testing significance of differences (one-way ANOVA) between data based on the use of calculation coefficients and those obtained through the classical method were performed on a sample of two-year-old beech trees (n = 26) selected from natural regeneration under full-developed foliage of the parent stand at the 0.062 MJ. m^2. day^{-1} energy supply (STŘELEC 1992).

Example 2

The procedure was the same as that given in Example 1. The accuracy of the morphological parameters determination using the method of calculation coefficients was tested on a sample of two-year-old beech trees (n = 26) selected from natural regeneration growing under full-developed foliage of the parent stand at the energy supply of 0.588 MJ. m^2. day^{-1} (STŘELEC 1992).

Example 3

The procedure was the same as that shown in Example 1. The accuracy of the morphological parameters determination using the method of calculation coefficients was tested on a sample of two-year-old beech trees (n = 26) selected from natural regeneration growing under full-developed foliage of the parent stand at the energy supply of 1.685 MJ. m^2. day^{-1} (STŘELEC 1992).

Example 4

The procedure was the same as that given in Example 1. The accuracy of the morphological parameters determination using the method of calculation coefficients was tested on a solitarily growing beech tree (25 years old). From this tree we took sample sets of shoots bearing two to seven leaves (n = 26).

Example 5a, b

The procedure was the same as that shown in Example 1. In this case the accuracy of morphological parameters determination using the method of calculation coefficients was tested on the two shoot sample sets. The first set was taken from selected the two-year-old beech trees which were not damaged by game browsing during winter (example 5a). The second one was collected from the two-year-old beech trees damaged by browsing (example 5b). The choice of such sample sets was intentional. The aim was to find out whether the winter browsing connected with enhanced leaf area creation in the following vegetation period influenced the accuracy of leaf area determination using the calculation coefficient method. In both cases we sampled a set of five-leaves shoots (n = 26).

Results of determination of morphological parameters of leaves in all examples are given in Table 4, 5 and 6. The results are not influenced by tree age and/or energy supply during the tree growth. The method is based on recent knowledge about regularities in distribution of morphological parameters of beech leaves on spring shoots (Cicák 1992, 1994, 1998).

Table 4. Mean leaf area (cm^2 ± standard error) of the shoot, one-way ANOVA

Example	CM	MCC	d.f.	F-value	*P*
1	43.88 ± 2.09	43.92 ± 2.09	1, 50	0.0002	0.989
2	49.65 ± 3.85	49.11 ± 1.99	1, 64	0.0104	0.919
3	50.09 ± 5.09	50.40 ± 4.96	1, 106	0.0019	0.965
4	96.56 ± 3.89	97.00 ± 3.91	1, 308	0.0064	0.936
5a	42.38 ± 2.44	42.29 ± 2.36	1, 50	0.0007	0.979
5b	97.47 ± 5.45	102.69 ± 8.28	1, 50	0.2767	0.601

CM – classical method, MCC – method based on calculation coefficients, d. f. – degree of freedom

Table 5. Mean leaf length (cm ± standard error) of the shoot, one-way ANOVA

Example	CM	MCC	d.f.	F-value	*P*
1	4.77 ± 0.13	4.80 ± 0.12	1, 50	0.0218	0.883
2	4.63 ± 0.16	4.63 ± 0.16	1, 64	0.0000	0.997
3	4.29 ± 0.15	4.36 ± 0.15	1, 106	0.1264	0.723
4	6.53 ± 0.08	6.58 ± 0.08	1, 308	0.1295	0.719
5a	4.47 ± 0.12	4.49 ± 0.11	1, 50	0.0063	0.937
5b	6.72 ± 0.17	6.85 ± 0.25	1, 50	0.1862	0.668

CM – classical method, MCC – method based on calculation coefficients

Table 6. Mean leaf width (cm ± standard error) of the shoot, one-way ANOVA

Example	CM	MCC	d.f.	F-value	*P*
1	2.82 ± 0.07	2.80 ± 0.07	1, 50	0.0376	0.847
2	2.83 ± 0.10	2.83 ± 0.10	1, 64	0.0004	0.985
3	2.61 ± 0.11	2.61 ± 0.11	1, 106	0.0003	0.986
4	4.35 ± 0.05	4.35 ± 0.05	1, 308	0.0002	0.990
5a	2.60 ± 0.08	2.58 ± 0.08	1, 50	0.1667	0.898
5b	3.91 ± 0.11	3.99 ± 0.15	1, 50	0.2158	0.644

CM – classical method, MCC – method based on calculation coefficients, d. f. – degree of freedom

The invention can be applied in production ecology, in studying the morphogenesis and variability of the assimilatory organs, in tree health-state monitoring in connection with influences of various biotic and abiotic factors, in protection and regeneration of beech gene pool in areas under industrial imission impact, in forest tree improvement programmes, silvicultural activities as well as in paleobotany.

The described method of determination of morphological parameters of beech leaves on spring shoots has been protected by patent (Cicák 2001). The Industrial Property Office of the Slovak Republic in Banská Bystrica, 15 May 2001, issued the Document Number 281860. The owner of the patent is the Institute of Forest Ecology. The owner provides interested public with rights of using the invention – offering the licence.

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MERANIE MORFOLOGICKÝCH PARAMETROV LISTOV JARNÝCH VÝHONKOV BUKA LESNÉHO METÓDOU PREPOČTOVÝCH KOEFICIENTOV

Súhrn

Metóda prepočtových koeficientov, ktorú predstavujeme v príspevku, zjednodušuje meranie morfologických parametrov – plochy, dĺžky a šírky listov jarných výhonkov buka lesného (*Fagus sylvatica* L.). Prepočtový koeficient každého z uvedených morfologických parametrov je bezrozmerná veličina, matematicky definovaná ako podiel súčtu nameraných hodnôt príslušného parametra všetkých listov na výhonku a hodnoty parametra konkrétneho listu. Postup aplikácie metódy prepočtových koeficientov je nasledovný:

a) na každom zo súboru jarných výhonkov sa zmeria každý morfologický parameter len na jedinom liste,
b) jeho voľba pre stanovenie zvoleného parametra za celý výhonok je štatisticky definovaná najvyššou presnosťou, ktorá sa mení s pozíciou listov na výhonkoch (tab. 1, 2 a 3),
c) výsledok súčinu hodnoty zvoleného parametra a jemu prislúchajúcim prepočtovým koeficientom je hodnota morfologického parametra, ktorá reprezentuje celý výhonok.

Výsledky nie sú ovplyvnené ani vekom jedincov buka, ani podmienkami prísunu energie v procese ich rastu.

Metóda je chránená patentom. Patentovú listinu č. 281860 vydal Úrad priemyselného vlastníctva Slovenskej republiky v Banskej Bystrici dňa 15. mája 2001. Majiteľom patentu je Ústav ekológie lesa, ktorý poskytuje komukoľvek právo na jeho využitie – ponúka licenciu.

ECOPHYSIOLOGICAL ASPECTS OF GROWTH OF THE EUROPEAN CHESTNUT (*CASTANEA SATIVA* MILL.) IN SLOVAKIA

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Abstract: *Kmeť, J., Šalgovičová, A.: Ecophysiological aspects of growth of the European chestnut (Castanea sativa Mill.) in Slovakia. In Folia oecologica. ISSN 1336-5266, 2003, vol. 30, no. 2, p. 141–147.*

In this work we present the results of a study focused to the eco-physiology of the European chestnut (Castanea sativa MILL.) in our conditions. The research was realised on the permanent research plots (PRP) in Horné Lefantovce, in growing seasons 2000, 2001, and 2002. On a plot under stand shelter and on an open plot 5 sample trees aged of about 15 years were selected. The parameters of rapid kinetics of the chlorophyll a fluorescence (F_0, F_m, F_v, F_v/F_m, Area, T_m, F_m/F_0) were measured on the adaxial side of leaves using a transportable fluorometer PEA. The concentration of assimilatory pigments (chlorophyll a, chlorophyll b) and the total content of carbohydrates were determined spectrophotometrically. The research results point out different eco-physiological responses of chestnut trees corresponding to the site conditions. The work has confirmed a statistically high significant influence of the locality on all the studied physiological and biochemical characteristics.

Key words: *chlorophyll fluorescence, pigments, carbohydrates, Castanea sativa MILL.*

Introduction

European chestnut (*Castanea sativa* MILL.) is a woody plant characteristic for the warmer part of the temperate zone. Nevertheless, it has been cultivated outside its natural area of distribution. The cultivation of this tree species has a quite long tradition also in the Slovak Republic. As to its biological properties, production capacity, quality of fruits and wood, the chestnut has also found a wide spectrum of use in the forest management. According to the most recent data, there have been recorded 203 localities with occurrence of chestnut trees (JUHÁSOVÁ 1999). In spite of the fact that the chestnut has already been adapted to the climate in Slovakia, at present we still experience a lack of knowledge about the enviromental factors influencing physiological processes running in chestnut trees and, consequently, their health state in our environmental conditions. The actual above-mentioned facts entail an urgent necessity to understand these problems. This work is focused to assessment of influence of various site conditions (under the stand shelter and on the open area) on selected physiological and biochemical characteristics of assimilatory organs in chestnut trees in growing seasons 2000–2002.

Material and methods

The physiological state of chestnut trees was studied separately under a stand shelter and on an open plot. The study run on the series of permanent research plots (PRP) in Horné Lefantovce (Forest Enterprise Topoľčianky, Forest District Nitrianska Streda). On both plots we selected by 5 trees (sample trees) aged about 15 years. Over the growing seasons 2000–2002 we measured the parameters of the rapid kinetics of chlorophyll fluorescence *a* : F_0, F_m, F_v, F_v/F_m, *Area*, T_m, F_m/F_0 – symbols according to Kooten and Snel (1990). The measurements were always performed on two branches of the relevant sample tree, on the adaxial side of the assimilatory organs. We used a transportable fluorometer PEA /Hansatech Ltd., Kings Lynn, UK/.

Simultaneously with measuring of the chlorophyll *a* fluorescence we also measured the values of the photosynthetically active radiation (FAR), air temperature (T_A) and temperature of the assimilatory organs (T_L) – using an apparatus Quantitherm – QRT1 (not included into the text of this paper).

The sampling for quantitative analysis of chlorophylls were performed directly in the field, on the leaves selected in each sample tree. The values of absorbance of chlorophylls *a* and *b* were measured spectrophotometrically. The concentration of chlorophylls was calculated according to Lichtenthaler. (1987). In the samples of the assimilatory organs we further determined the contents of total and reducing carbohydrates according to the method of Somogyi-Nelson. The measured values of chlorophylls and carbohydrates were expressed per leaf dry mass ($mg.g^{-1}$).

Statistical evaluation of the results was accomplished using 4-way analysis of variance (program SAS). The separate components of the variance belonging to the individual factors were compared to the residual variance using the F-test (Šmelko 1998).

Results

Parameters of the rapid kinetics of the chlorophyll fluorescence

From the parameters of the rapid kinetics of chlorophyll *a* fluorescence (F_0, F_m, F_v, F_v/F_m, *Area*, T_m, F_m/F_0) measured in growing seasons 2000-2002 we evaluate here (limited by the extent of this paper) in details only F_v/F_m having the highest description value from all discussed characteristics. The maximal, the minimal and the mean annual values for the individual years are presented in Table 1.

The value of the parameter F_v/F_m decreased as a result from influence of the stress factors. The threshold value of this parameter which characterizes the physiological disturbances is 0.725. From the measured values we can recognize that none of them was equal or lower than the threshold value. The closest was a value of 0.734 measured on 24. 5. 2001 (sample tree 5) on the open plot. This value was at the same time the minimum value over all the period of study. The maximum value (0.841) was measured on 24. 6. 2002 (sample tree 5) under the stand shelter. In general we can summarise that the mean as well as the maximum and minimum values of F_v/F_m measured in 2000–2002 were unambiguously higher in the leaves of sample trees under the stand shelter compared to the open plot.

The statistic evaluation of the results using the variance analysis (Tab. 4) has revealed a statistically significant difference in the parameter F_v/F_m between the two localities (at a significance level 99.9%). Exploring the residual components of variance we can confirm an evident influence of the random factors – represented in the parameter F_v/F_m by 64.82%.

Besides the influence of the locality on the selected physiological and biochemical characteristics we also studied the influence of the individual trees (sample trees), the year of sampling and the timing of the sampling in the growing season.

Table 1. Maximum, minimum and mean values of parameter F_v/F_m in the years 2000–2002

Year	Values	Shaded plot	Date of measurement (Number of tree)	Open plot	Date of measurement (Number of tree)
2000	max.	0.838	28.6.(3)	0.811	15.8.(4)
	min.	0.779	28.6.(4)	0.748	26.9.(1)
	mean	0.815		0.779	
2001	max.	0.828	14.8.(1)	0.824	26.6.(2)
	min.	0.767	14.8.(5)	0.734	24.5.(5)
	mean	0.804		0.794	
2002	max.	0.841	24.6.(5)	0.838	24.7.(2)
	min.	0.818	24.7.(4)	0.788	24.7.(5)
	mean	0.830		0.816	

Concentration of the chlorophylls

Considering the close correlation between the fluorescence of the emission spectre of leaves and the concentration of chlorophylls, we studied the changes in the concentrations of chlorophylls *a, b, a + b* in the leaves of chestnut trees growing on both plots. Maximum, minimum and mean values of chlorophyll *a + b* concentration over the period of study are summarised in Table 2.

Table 2. Maximum, minimum and mean values of chlorophyll *a*+*b* concentration ($mg.g^{-1}d.m.$) in the years 2000–2002

Year	Values	Shaded plot	Date of measurement (Number of tree)	Open plot	Date of measurement (Number of tree)
	max.	9.06	26.9.(5)	5.11	15.8.(1)
2000	min.	4.95	24.5.(2)	2.18	26.9.(5)
	mean	6.40		3.48	
	max.	11.94	14.8.(1)	7.61	14.8.(1)
2001	min.	3.21	2.10.(3)	2.20	2.10.(4)
	mean	6.01		4.24	
	max.	8.32	24.6.(1)	4.61	24.6.(1)
2002	min.	3.20	24.7.(2)	2.61	24.6.(3)
	mean	5.69		3.56	

Based on the obtained results we could conclude that the values of the concentration of chlorophyll $a + b$ were higher in the leaves sampled under the stand shelter. This naturally corresponds to the fact that the assimilatory organs with shade-loving character have higher chlorophyll content per weight unit compared to the sun leaves (the opposite tendency is observed in the chlorophyll content converted per unit area).

The maximum value of the total chlorophyll $a + b$ (11.94 mg.g^{-1}d.m.)was found on 14. 8. 2001 (sample tree 1) on the sheltered plot. The minimum (2.18 mg.g^{-1}d.m.) was estimated on 26. 9. 2000 (sample tree 5) on the open plot.

From the values of the F-test performed with variance analysis (Tab. 4) we can judge about statistically significant differences between the both localities, individual trees as well as between the individual samplings over growing season. The values of the individual components of the total variance (50.87%) confirmed the decisive influence of the locality (significance level 99.9%). The influence of random factors was low (22.75%).

Contents of leaf carbohydrates

Carbohydrates belong to indicators of the tree physiological state and of the functioning of their inherent assimilatory processes. We also used the leaf samples of chestnut to determine the total content of carbohydrates. This study has been realised during growing season 2000, 2001 and 2002. Maximum and minimum contents of total carbohydrates as well as the means of values measured in the individual years on both plots are summarised in Table 3.

Table 3. Maximum, minimum and mean values of total carbohydrates concentration in the leaf (mg.g^{-1}d.m.)

Year	Values	Shaded plot	Date of measurement (Number of tree)	Open plot	Date of measurement (Number of tree)
2000	max.	37.13	28.6.(5)	59.25	28.6.(3)
	min.	14.35	24.5.(5)	25.62	15.8.(1)
	mean	20.79		38.79	
2001	max.	39.22	2.10.(1)	61.96	2.10.(3)
	min.	17.30	14.8.(2)	30.13	26.6.(1)
	mean	28.01		40.56	
2002	max.	44.17	24.7.(5)	39.64	24.7.(2)
	min.	11.31	24.6.(4)	20.93	24.6.(4)
	mean	25.39		28.80	

Maximum value of total carbohydrates (61.96 mg.g^{-1}d.m.) was estimated on the open plot (sample tree 3) 2. 10. 2001. The minimum (11.31 mg.g^{-1}d.m.) over the whole period of study was found under the stand shelter (sample tree 4) 24. 6. 2002. Based of the obtained results we can judge that both maximum and minimum values of content of the individual carbohydrates were always higher on the open plot compared to the plot under the stand shelter. The statistical evaluation of the total carbohydrates content (Table 4) resulted in a decisive (at a significance level 99.9) difference between the localities and also between the individual samplings performed over the same growing season – evidently connected with the growth and the development of the leaves. The influence of random factors was low (21.39%).

Table 4. Analysis of variance performed on values of selected physiological and biochemical characteristics of chestnut leaves ($p < 0,05^*$, $p < 0,01^{**}$, $p < 0,001^{***}$)

Source of variability	Degrees of freedom	Physiological and biochemical characteristics					
		Parameter of chlorophyll *a* fluorescence F_v / F_m		Concentration of chlorophyll *a+b* ($mg.g^{-1}$d.m.)		Concentration of total carbohydrates ($mg.g^{-1}$ d.m.)	
		F-test	Components of variance (%)	F-test	Components of variance (%)	F-test	Components of variance (%)
lokality	1	43.67***	25.20	30.41***	50.87	49.27***	46.32
Tree on plot	8	0.46	0.00	3.80***	6.37	2.24*	2.66
Zdar	2	17.84**	9.73	0.14	0.00	0.71	0.00
Sampling	7	0.44	0.25	9.88***	20.01	14.94***	29.63
Residua	81		64.82		22.75		21.39

Discussion

The vitality of woody plants is evidently influenced with a range of specific species-specific and individual properties as well as with the site environmental factors. In a forest stand, the vitality also depends on the other factors (canopy, method of regeneration, grade of shelter, etc.). The interactions between these characteristics and factors resulted in complex physiological and biochemical relationships (Dimitri in Kmeť 1993).

Measurement of the chlorophyll fluorescence is one of methods enabling us to determine promptly the physiological state of woody plants. Together with the local microclimate data it offers a possibility for assessment of stands through the stress physiology (Kmeť 1998).

The relationship between the variable and the maximum fluorescence provides us with the substantial information about the photo-chemical capacity of the photosystem II (PSII), and is in a close correlation with the amount of the arising oxygen. The photochemical capacity PSII is not fully identical with the photosynthetic capacity. Nevertheless, there is no doubt that a lowered ratio F_v/F_m, entails an equally lowered amount of the fixed carbon dioxide CO_2. That means that the measurement of F_v/F_m is an appropriate method how to determine the theoretical photosynthetic capacity as viewed through the limitation of the electron transport chain (Kmeť 1999).

Tylakoid membranes are very sensitive to stress factors such as: air pollutants, high temperature, frost, dryness, and high radiation. There has been demonstrated a very close correlation between the inhibition of photosynthesis and the decrease in F_v/F_m (Bolhar-Nordenkampf, Götzl 1992).

The structure and content of leaf pigments determine the fluorescence characteristics of these assimilatory organs. Well known are also a close correlations between the fluorescence emission spectre of leaves and the structure and concentration of pigments (primarily the chlorophyll a) and the correlation between this spectre and the ultra-structure of the assimilatory tissue (Lichtenthaler et al. 1986).

If we want to study the changes in chlorophyll in plants or in their separate organs, it is necessary to have a reference unit enabling us the common conversion of the analytically determined amounts (Haspelová-Horvatovičová 1981). It is well known that the shade assimilatory organs contain higher chlorophyll amounts per weight unit compared to the sun leaves (Masarovičová, Štefančík 1990). The sun leaves are thicker; they contain more chlorophyll per leaf area and differ from the shade leaves in the morphology. The shade leaves have higher intensity of fluorescence compared to the sun leaves. This fact has also been confirmed with our results: in growing seasons 2000–2002 we observed higher mean values of concentrations of chlorophylls *a, b*, *a + b,* and higher values of the main parameter of the chlorophyll fluorescence F_v/F_m in the leaves sampled from trees growing under the stand shelter.

Carbohydrates are the primary products of photosynthesis. Therefore they are important for the whole plant metabolism. They belong to the indicators of the physiological state of plants. The content of carbohydrates is also connected with the plant resistance against frost. This resistance fluctuates over the year, influenced primarily with the accumulation of carbohydrates and transformation of starch to carbohydrates (Kincl, Krpeš 2000).

Conclusion

The aim of this work was, based on the measurements performed in the growing seasons 2000–2002, to assess the physiological state of the stands of European chestnut (*Castanea sativa* MILL.) growing in various site conditions. We evaluated the parameters of the rapid kinetics of the chlorophyll *a* fluorescence where the mean values of the main parameter F_v/F_m were over the whole study period higher on the plot under stand shelter compared to the open area. No case of the decrease of this parameter under the critical limit for physiological disturbances (0.725) has been detected. The lowest value, 0.734 was estimated on 24.5.2001 (sample tree 5).

The values of concentration of chlorophylls *a* + *b* (expressed per weight unit) observed in growing seasons 2000-2002 were higher in sample trees growing under the stand shelter what is in accordance with the data given in the literature.

The results of the carbohydrates content have confirmed that the mean total contents were in all three years higher in assimilatory organs of trees growing on the open plot.

The paper has confirmed a statistically high decisive influence of the locality as well as of the timing of the leaf sampling over the growing season on all the selected physiological and biochemical characteristics.

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EKOFYZIOLOGICKÉ ASPEKTY RASTU GAŠTANA JEDLÉHO (*CASTANEA SATIVA* MILL.) NA SLOVENSKU

Súhrn

V práci sa uvádzajú výsledky z ekofyziologického výskumu gaštana jedlého (*Castanea sativa* MILL.) v našich podmienkach.Výskum sa zabezpečoval na trvalých výskumných plochách (TVP) v Horných Lefantovciach na dvoch rozdielnych stanovištiach (pod clonou porastu a na voľnej ploche) v rokoch 2000–2002. Prenosným fluorometrom PEA sa na vrchnej strane listov merali parametre rýchlej kinetiky fluorescencie chlorofylu *a* (F_o, F_m, F_v, F_v/F_m, *Area,* T_m, F_m/F_o), pričom priemerné hodnoty hlavného parametra F_v/F_m boli v priebehu sledovaného obdobia vyššie na ploche pod clonou porastu v porovnaní s voľnou plochou. Nezaznamenali sme pokles tohoto parametra pod kritickú hranicu fyziologických porúch, t. j. pod 0,725. Práca vyhodnocuje i koncentrácie chlorofylov a obsah celkových sacharidov v listoch, ktoré boli stanovené spektrofotometricky. Hodnoty koncentrácie chlorofylov *a, b, a + b* (v $mg.g^{-1}$sušiny listovej hmoty) boli v rokoch 2000–2002 vyššie v listoch vzorníkov rastúcich pod clonou porastu, na rozdiel od sacharidov, kde priemerné hodnoty celkových sacharidov boli vyššie v asimilačných orgánoch stromov rastúcich na voľnej ploche. Práca potvrdila štatisticky vysokopreukazný vplyv lokality, ako i jednotlivých odberov v rámci roka na všetky sledované fyziologické a biochemické parametre.

DIFFERENTIATION BETWEEN CHESTNUTS (*CASTANEA SATIVA* MILL.) AT DIFFERENT LOCALITIES BASED ON MORPHOMETRIC DATA OF FRUITS

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Abstract: *Bolvanský, M., Užík, M.: Differentiation between chestnuts (Castanea sativa Mill.) at different localities based on morphometric data of fruits. In Folia oecologica. ISSN 1336-5266, 2003, vol. 30, no. 2, p. 149–156.*

Morphometric differences between groups of old chestnut trees grown at localities Bratislava, Radošiná, Jelenec and Modrý Kameň were studied. During three consequent autumns (2000, 2001, 2002) samples of 30 mature fruits were collected from a total of 99 chestnut trees and in each fruit 13 quantitative traits were measured. Morphometric data were undergone to analysis of variance and discriminant analysis (DA). Significant differences were observed among localities and among trees within localities in all nut traits. The highest percentage of correct classification of cases (95%) was observed in locality Jelenec. The second and third highest percentages of correct classification (87 and 88%) were found out in localities Bratislava and Modrý Kameň. Just these three localities are considered main historical centres of chestnut distribution in Slovakia. By the plot based on the first two discriminant functions, groups of trees from localities Jelenec and Radošiná were the most similar out of four localities studied. These two localities are situated the nearest each of other and apparently the trees from both localities have common origin.

Key words: *Castanea sativa, fruits, morphological traits, four localities, Slovakia, discriminant analysis*

Introduction

Distribution and site conditions of European chestnut (*Castanea sariva* Mill.) in Slovakia were studied in detail as early as in late 50-ties of 20th century (Benčať 1960). Five main area of chestnut cultivation in Slovakia were suggested according to oro-geographical division of Slovakia territory. These cultivation areas supposed to be congruent with introduction areas, which are linked with different periods of our era (Roman times, middle age, Turkey invasions). However no relevant study was accomplished so far to prove assumptions of different origin of chestnuts in Slovakia.

Several studies were conducted on morphological variation among chestnut trees within different orchards and stands in Slovakia. It holds for studies on variation of stamens and male catkin length (Benčať 1964, Benčať, Bolvanský 1983) and on variation of fruit size and shape (Benčať, Bolvanský 1984, Bolvanský 1988, Benčať, Tokár 1998). Only recently, differentiation between chestnut trees within one site was studied by means of multivariate analysis of several fruit traits (Bolvanský 2002). Similar method has been employed also in morphological characterisation of chestnut accessions and/or cultivars in Spain (Pereira et al. 1996) and Slovenia (Solar et al. 1998). Villani et al. (1992) used discriminate analysis based on morphological traits of fruits to differentiate between natural populations of European chestnut in Turkey.

This works aims to find out differences and/or associations between four chestnut orchards/stands situated at four different localities of Slovakia by means of discriminant analysis of fruit traits.

Material and methods

Three chestnut orchards and one chestnut stand situated at four different localities were involved to the study: Bratislava, site Koliba – orchard of 50 to 100 yrs old trees on the area of 2 ha, Radošiná – orchard of 120 yrs old trees on the area of 4 ha, Jelenec – old naturally regenerated stand of 100 to 300 yrs old tress on the area of 3.7 ha, Modrý Kameň site Prše series of orchards of 100 to 200 yrs old trees spread on the area of about 5 ha. Localities Bratislava, Jelenec and Modrý Kameň are ranked among the localities with the oldest occurrence of chestnut in Slovakia and are considered centres of chestnut distribution to other localities in Slovakia. Occurrence of chestnut at locality Radošina is of an earlier date and the chestnut orchard in this place was established from seed originated from some of the existing chestnut localities. Chestnut trees grown at all four sites were of seed origin.

Twenty-one to twenty-eight trees were randomly selected in each of four orchards and/ or stand. Originally intended sampling of thirty trees per locality was reduced in case of Bratislava (24 trees) and Jelenec (21 trees) because of lowered accessibility of fruiting trees. In case of Radošina and Modrý Kameň two and four samples respectively were finally exluded from analysis because of lower number of suitable fruits. During 2000, 2001 and 2002 samples of thirty mature fruits were collected from each of the selected trees at the time of fruit ripening (the end of September , beginning of October), from different parts of crown. In each of the sampled fruit 12 traits were measured and one variable, the ratio width/height, was calculated (Table 1, Fig. 1).

Table 1. Morphological traits of fruits employed in statistical analyses

Trait code	Trait symbol	Trait description
1	FWT	fresh weight of nut
2	HGT	height of nut
3	DFB	distance from the base to the largest section of the fruit
4	WTH	width of nut
5	WHR	width to height ratio x 100
6	THK	thickness of nut
7	LHY	length of the hylum
8	WHY	width of the hylum
9	LSB	length of the stalk's base
10	WSB	width of the stalk's base
11	NSD	number of seeds per nut
12	NIN	number of pellicle intrusions
13	LIN	total length of pellicle intrusions into kernel

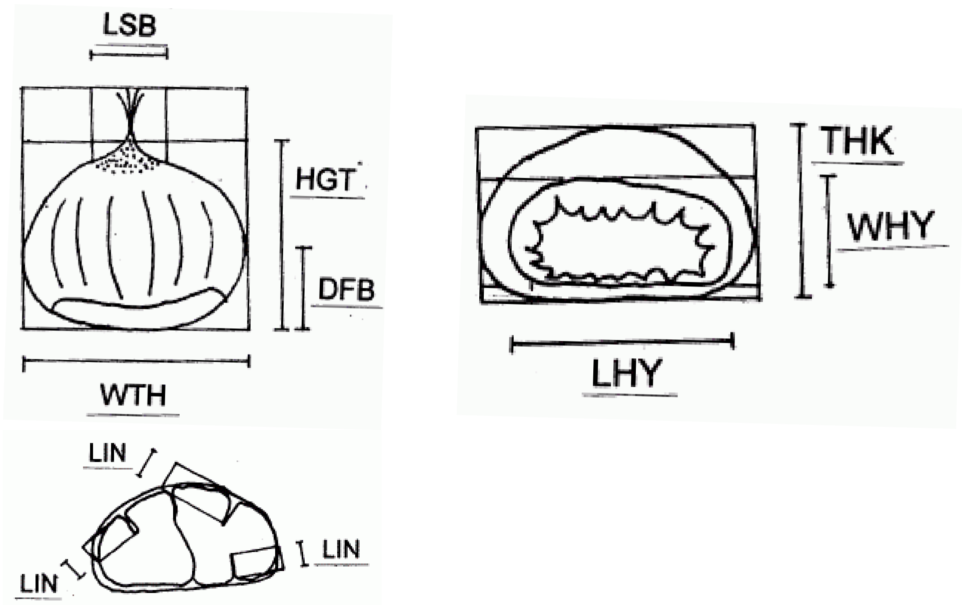

Fig. 1. Diagrammatic explanation of some fruit traits measured. See Table 1. for detailed description of each trait

Morphometric data of fruits were subjected to Analysis of variance, in which localities and trees within localities were assumed as source of variation. Fruit trait means and standard errors for each locality were calculated. Fruit trait means of the trees studied were used in classification and canonical discriminant analyses.

Statistical package STATGRAPHIC PLUS 5 was used to evaluate morphometric data of chestnut fruits.

Results

The mean weight (size) of fruit and next six fruit traits (width, thickness, scar length, scar width, stalk base length, stalk base width) were the lowest at the locality Jelenec (Table 2). The highest weight of fruit and the highest values of next nine traits (height, distance from base, width, thickness, scar length, stalk base width, seeds per nut, number of intrusions and length of pellicle intrusions into kernel) were observed in locality Modrý Kameň. The lowest values of number and length of pellicle intrusions were recorded at locality Bratislava. The two-way analysis of variance showed significant differences among localities and among trees within localities for all 13 analysed fruit traits (Table 3). Thus following the assumption that only significantly heterogenous characters can be employed in discriminatory analysis the analysis was performed on all 13 fruit traits.

The highest percentage of correct classification of trees based on the discriminant analysis of 13 nut traits was observed in locality Jelenec (95.2%). Only one tree from Jelenec was classified wrong, such as belonging to Bratislava's group. The trees from Radošiná were classified the least correctly (71.4%) and eight out of 28 trees were classified such as belonging to the remaining three localities (Table 4).

Canonical discriminant analysis has shown that differentiation and/or variability among four groups of trees (localities) can be explained by three discriminant functions (Table 5). The first discriminant function or first canonical axis, lined in direction of the highest variability among groups (localities), accounts for about 51%, second canonical axis for 31% and third axis for 18% of the ability of characters to distinguish among groups.

Table 2. Means and standard errors (in parentheses) for thirteen fruit characters in chestnut trees at four different localities of Slovakia

Trait		Localities				Total
Code	Name (measure unit)	Bratislava	Radošiná	Jelenec	M.Kameň	
1	Weight (g)	6.557 (0.070)	7.484 (0.054)	5.332 (0.071)	8.450 (0.055)	6.956 (0.032)
2	Height (mm)	24.718 (0.076)	24.397 (0.059)	22.860 (0.078)	26.321 (0.060)	24.574 (0.034)
3	Distance from base (mm)	10.598 (0.054)	9.981 (0.041)	9.831 (0.055)	11.451 (0.042)	10.465 (0.024)
4	Width (mm)	26.964 (0.100)	27.731 (0.077)	25.634 (0.102)	29.882 (0.078)	27.553 (0.045)
5	Width/height ratio	109.600 (0.350)	113.960 (0.269)	112.541 (0.357)	113.807 (0.273)	112.476 (0.158)
6	Thickness (mm)	16.248 (0.010)	16.620 (0.077)	15.036 (0.102)	17.755 (0.078)	16.415 (0.045)
7	Scar length (mm)	19.134 (0.114)	20.448 (0.087)	17.387 (0.116)	21.900 (0.089)	19.716 (0.051)
8	Scar width (mm)	11.057 (0.070)	10.533 (0.053)	8.960 (0.071)	10.524 (0.054)	10.268 (0.031)
9	Stalk base length (mm)	15.110 (0.092)	11.938 (0.071)	9.739 (0.094)	13.426 (0.072)	12.553 (0.042)
10	Stalk base width (mm)	10.030 (0.069)	8.866 (0.053)	7.447 (0.071)	10.066 (0.054)	9.102 (0.031)
11	Seeds per nut	1.068 (0.009)	1.018 (0.007)	1.027 (0.009)	1.083 (0.007)	1.049 (0.004)
12	Number of intrusions	1.547 (0.069)	2.346 (0.053)	2.169 (0.070)	2.939 (0.054)	2.250 (0.031)
13	Length of intrusions (mm)	7.095 (0.281)	9.649 (0.020)	8.244 (0.288)	14.403 (0.220)	9.848 (0.127)
Number of nuts		555	825	525	833	2 738
Number of trees		24	28	21	26	99

Grouping of trees belonging to particular localities can be depicted by the ordination diagram of the cannonical axes of the first two discriminant functions (Fig. 2). Differentiation among groups of trees is not very clear and is distinguished along axis of the first discriminant function. By this function the most different each of other showed to be sets of trees from Bratislava and Modrý Kameň and the most similar sets of trees from Radošiná and Jelenec.

Table 3. Analyses of variance of 13 quantitative traits of nuts between localities ($MS_{between}$) and within localities (MS_{within})

Trait		$MS_{between}$	MS_{within}
Code	Name		
1	Weight	1051.66**	99.69**
2	Height	1249.59**	138.89**
3	Distance from base	386.40**	28.13**
4	Width	2000.51**	210.25**
5	Width/height ratio	2320.05**	1796.86**
6	Thickness	758.29**	75.76**
7	Scar length	2198.30**	206.20**
8	Scar width	400.33**	68.68**
9	Stalk base length	2604.35**	355.09**
10	Stalk base width	822.36**	121.06**
11	Seeds per nut	0.7116**	0.1677**
12	Number of intrusions	202.45**	13.47**
13	Length of intrusions	6935.76**	414.23**

Table 4. Results of the classificatory discriminant analysis of the trees from the localities Bratislava (BRA), Radošiná (RAD), Jelenec (JEL) and Modrý Kameň (MKA) based on 13 fruit characters. Percentage of correct classification is depicted with bold numbers

Actual locality	Number of trees	Predicted locality membership (in %)			
		BRA	RAD	JEL	MKA
BRA	24	87.50	4.17	4.17	4.17
RAD	28	7.14	71.43	10.71	10.71
JEL	21	4.76	0.00	95.24	0.00
MKA	26	3.85	0.00	7.69	88.46

Table 5. Characteristics of canonical discriminant analysis based on 13 fruit characters

Discriminant	Eingenvalue	Canonical	Explained variability in %	
function		correlation	Proportional	Cumulative
1	1.630	0.787	50.86	50.86
2	0.985	0.704	30.72	81.58
3	0.590	0.609	18.42	100.00

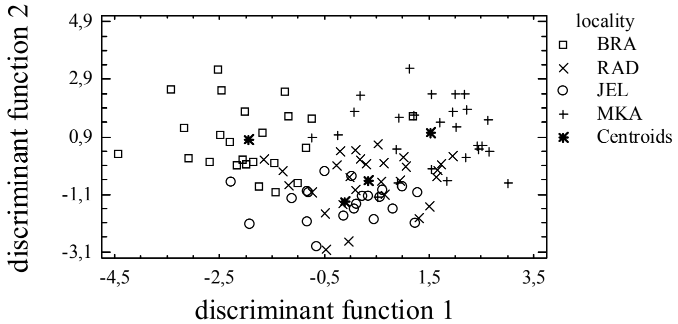

Fig. 2. Plot of the first two discriminant functions based on 13 fruit characters from four localities (BRA – Bratislava, RAD – Radošina, JEL – Jelenec, MKA – Modrý Kameň)

Discussion

Morphometric differentiation of four groups of chestnut trees from four different localities by discriminant analysis has pointed at spatial pattern of this differentiation. The most remarkably were separated localities the most distant each of other (Bratislava, Modrý Kameň). Trees from localities Jelenec and Radošiná, geographically situated between former two localities, were mostly overlapped in the plot based on the first two discriminant functions. The observed differentiation among chestnuts on localities studied may, to a certain degree, result from different site and stand conditions on these localities but it can reflect also different origin of chestnut plantations. Assumption of different origin can be supported by Pereira et al. (1996), who found out no correlation between morphological traits of nuts in local Spanish cultivars and climatic variables as well as altitude variable. However concerning sampled material, our work was more similar to the work of Villani et al. (1992) who studied differentiation between chestnut populations in Turkey. Namely, all chestnut orchards involved to our study are of seed origin and can be considered populations affected by artificial selection carried out by chestnut growers. In the work of Villani et al. (1992) pattern of differentiation based on 13 nut characteristics showed to be remarkably similar to that based on genetic distances calculated from gene frequencies of 21 isozyme loci. As locality Jelenec belongs to the oldest introduction centres of chestnut in Slovakia going back to 13th century and the orchard in Radošina was established at the end of 19th century, it can be suggested this orchard origins from the seed collected in chestnut stand in Jelenec. Also differentiation between localities Bratislava and Modrý Kameň can be explained by the historical data on chestnut introduction to Slovakia. While chestnuts were to the locality Bratislava introduced as early as during Roman times at the beginning of our era, chestnuts to the locality Modrý Kameň were driven during Turkish invasions in 15th and 16th centuries.

Conclusion

The results of morphometric study of chestnuts grown at four different localities of Slovakia have shown that: 1) quantitative traits of fruits seem to be very reliable characters to distinguish among different chestnut cultures propagated by seed, 2) pattern of morphometric differentiation between sets of chestnut trees determined by discriminant analysis is in rather high consistency with spatial pattern of localities distribution, 3) including more chestnut localities into to the morphometric study may help to reveal both relationship and dissimilarity of old chestnut cultures and historical introduction pathways of chestnut to Slovakia.

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ROZDIELY MEDZI GAŠTANMI (*CASTANEA SATIVA* MILL.) NA RÔZNYCH LOKALITÁCH NA ZÁKLADE MORFOMETRICKÝCH ÚDAJOV PLODOV

Súhrn

V práci sa hodnotila morfometrická variabilita plodov gaštana jedlého na štyroch rôznych lokalitách Slovenska za účelom potvrdenia predpokladaného pôvodu gaštanov na jednotlivých lokalitách. V troch starých gaštanových sadoch (Bratislava – Koliba, Radošina, Modrý Kameň – Prše) a v jednom starom gaštanovom poraste (Jelenec – Gýmeš) s jedincami semenného pôvodu na všetkých lokalitách bolo z 20 až 30 jedincov zobratých po 30 plodov, pri ktorých boli hodnotené nasledovné kvantitatívne znaky: hmotnosť, výška, šírka, hrúbka a tvar (šírka/hrúbka) plodu, dĺžka a šírka plodovej jazvy, dĺžka a šírka ochlpenia vrcholu plodu, počet semien v plode, počet a dĺžka záhybov osemenia na plod. Analýza variancie jednotlivých znakov ukázala na štatisticky významné rozdiely medzi stromami ako aj medzi lokalitami vo všetkých sledovaných znakoch. Priemery znakov za jednotlivé stromy boli potom podrobené klasifikačnej diskriminačnej analýze za účelom zistenia do akej miery sa skutočná príslušnosť stromov k jednotlivým skupinám – lokalitám zhoduje s očakávanou príslušnosťou podľa analýzy znakov plodov. Najvyššie percento správnej klasifikácie bolo pozorované pri jedincoch z lokality Jelenec (95,24 %). Na lokalite Modrý Kameň bolo správne zaradených do skupiny 88,5 %, na lokalite Bratislava 87,5 % a na lokalite Radošina 71,4 % stromov. Pri grafickom zobrazení vektorov jednotlivých stromov v sústave prvých dvoch diskriminačných funkcií, najbližšie pri sebe boli vektory stromov z Jelenca a Radošinej a najďalej od seba vektory stromov z lokalít Modrý Kameň a Bratislava. Toto rozmiestnenie súborov stromov sa zhoduje so zemepisným rozmiestnením sledovaných štyroch lokalít. Zároveň sa dá predpokladať, že gaštany na lokalitách Bratislava, Jelenec a Modrý Kameň majú rozdielny pôvod a gaštany na lokalite Radošiná sú príbuzné gaštanom z Jelenca.

INFLUENCE OF TEMPERATURE AND STORAGE ON POLLEN VIABILITY IN *PINUS MUGO* TURRA

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Abstract: *Ostrolucká, M. G., Čičová, L., Bolvanský, M.: Influence of temperature and storage on pollen viability in Pinus mugo Turra. In Folia oecologica. ISSN 1336-5266, 2003, vol. 30, no. 2, p. 157–162.*

Changes in pollen viability of Pinus mugo Turra affected by its storage and different cultivation temperatures were studied in vitro. Pollen viability was tested using germination test on agar medium with 12.5% sucrose. The one-year period of pollen storage in a fridge at 4 °C did not cause statistically significant differences in pollen germination percentage. The maintenance of constant pollen viability confirms that the conditions for pollen storage were suitable. The cultivation temperature had a significant effect on viability expression of the pollen. The temperature 32 °C was proved to be the best for pollen germination and also pollen tube elongation.
Key words: *Pinus mugo, pollen, germination in vitro, storage, temperature*

Introduction

Pollen grains of individual plant species exhibit different physiological (especially metabolic) activity that is under genetic and environmental control and affects the viability of the pollen. Studies of pollen germination processes including pollen viability are important not only from theoretical viewpoints, but also represent a significant aspect of breeding because they determine efficiency of fertilization and seed quality (Bolvanský, Ostrolucká 1998; Lux et al. 1998). The study of pollen germination *in vitro* allows us to determine the degree of pollen viability and to evaluate the male reproduction success. The results of *in vitro* studies bring us important knowledge about conditions for pollen germination, which are specific to individual plant species. Pollen activation from dormant state to pollen tube formation is regulated by pollen metabolites and environment components utilisation (which in case *in vitro* condition is cultivation medium) and depends upon ambient factors, e.g. temperature, humidity, etc. (Pfahler et al. 1997).

In vitro studies enable us to study pollen response to germination conditions and their impact on *in vitro* pollen germination process. One of the important factors of pollen germination is the temperature. It plays an important role in maintenance of pollen viability during storage (Chira 1971; Bolvanský, Ostrolucká 1998).

In our work we studied the impact of pollen storage on its viability maintenance and tested influence of the temperature on pollen germination and its viability expression in *Pinus mugo*.

Material and methods

For the study of pollen viability after storage we used *Pinus mugo* Turra pollen, collected in 2002 from localities Štrbské pleso (trees No 15, 26, 32), Skalnaté pleso (trees No 35, 38, 40), Popradské pleso (trees No 27, 28, 20) and Bratislava (trees 1, 5, 6). For the study of the effect of cultivation temperature on pollen viability, pollen from localities Štrbské pleso (trees No 16, 21), Skalnaté pleso (trees No 32, 36), Popradské pleso (trees No 8, 17) and Bratislava (trees No 2, 3) were used. Germinability and viability were tested using cultivation medium with 1% agar and 12.5% sucrose in Petri dishes.

Two factors were assumed to affect the pollen viability: storage and temperature. In the first experiment the viability of pollen (collected in 2002) after one-year storage (in refrigerator at 4 °C) was tested. The pollen viability test after one-year storage was performed at a constant temperature of 27 °C after 48 hours from pollen application on agar medium.

In the second experiment the influence of different cultivation temperatures (12, 27 and 33 °C) on pollen viability was evaluated.

The pollen viability was evaluated in all experimental variants on the basis of two parameters: the proportion of germinated pollen grains (%) and the length of pollen tubes (µm). The percentage of pollen germination was determined by evaluation of 100 pollen grains from 3 microscope's fields of view in 3 repetitions. The length of pollen tubes (in µm) was assessed by measurement of 30 pollen tubes of each sample in 3 repetitions. The values of pollen viability parameters achieved after 48-hour cultivation (at that time they showed the maximum) were processed using the statistical program Statgraphics, analysis of variance ANOVA including Scheffe's test (P = 0.05).

Results and discussion

The pollen storage in pollen banks without decrease or loss of viability is important for long-term germplasm conservation, preservation of important genes and maintenance of plant gene pool for long periods for plant breeding requirements. The problems of pollen viability and a long-time pollen storage in different conditions were investigated by many authors (Chira 1971; Stanley, Linskens 1974; Bolvanský, Ostrolucká 1998). The ability of pollen to retain its viability for long period depends on various factors, e.g. the pollen storage technique, moisture of pollen during its storage and also morphological characteristics of the pollen of particular species, especially exine thickness, which has the protective function. The pollen of conifers retains the viability also in unfavourable storage conditions in comparison with deciduous trees and other plant species, what is confirmed also by our results. The pollen germination of the tested individuals in 2002 varied from 44 to 89% and in 2003 from 54 to 87%. The pollen tube length was from 112.41 to 312.73µm in 2002 and from 60.86 to 168.77 µm in 2003 (Fig. 1, 2).

There were found statistically significant differences in pollen germination and pollen tube length among individuals. Percentage of germination and pollen tube length varied slightly in the same tree after one-year storage. However, the effect of one-year storage on germination percentage was not statistically significant. On the other hand, differences in pollen tube length were significant at the level of P = 0.05%. The mean pollen tube length reached higher value after one-year storage than in fresh pollen in 2002, but the difference in pollen tube length (expressed in µm) was not especially high (Table 1–4).

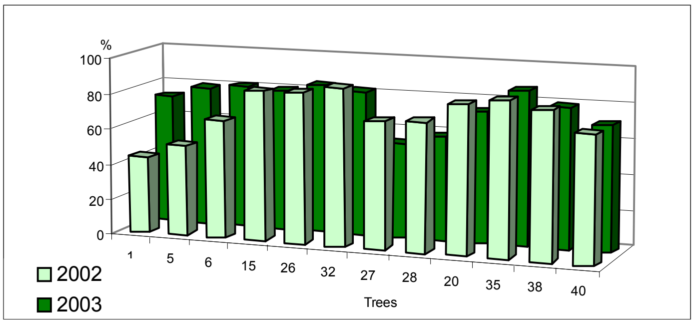

Fig. 1. Pollen germination in 12 trees of *Pinus mugo* Turra

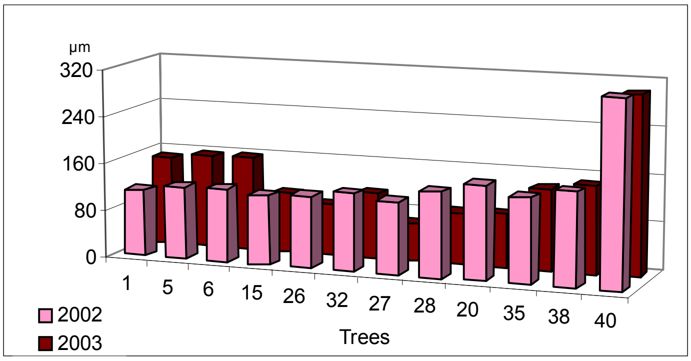

Fig. 2. Pollen tube length in 12 trees of *Pinus mugo* Turra

Table 1. Two-way analysis of variance for pollen germination (%) of fresh and one-year stored pollen in *Pinus mugo* Turra

Source of variation	Sum of squares	D.f.	Mean square	*F*-ratio	Significance level
Tree	8652.8	11	786.6	6.25**	0.0000
Year	32.0	1	32.0	0.25	0.6159
Error	7421.0	59	125.8		
Total	16105.8	71			

Table 2. Two-way analysis of variance for pollen tube length (µm) of fresh and one-year stored pollen in *Pinus mugo* Turra

Source of variation	Sum of squares	D.f.	Mean square	*F*-ratio	Significance level
Tree	1716646.0	11	156058.0	70.75**	0.0000
Year	11516.3	1	11516.3	5.22*	0.0223
Error	4735616.0	2147	2205.7		
Total	6463766.0	2159			

Table 3. Multiple range analysis for pollen germination and pollen tube length for source of variation year (2002, 2003)

Pollen germination			Pollen tube length		
Factor level	*n*	Mean (%)	Factor level	*n*	Mean (μ m)
2002	36	76.72 a	2002	1080	124.39 a
2003	36	75.39 a	2003	1080	129.01 b

Table 4. Multiple range analysis for pollen germination and pollen tube length of fresh and stored pollen in *Pinus mugo* Turra for source of variation tree

Pollen germination			Pollen tube length		
Tree code	*n*	Mean (%)	Tree code	*n*	Mean (μm)
5	6	52.3 a	15	180	64.2 a
6	6	60.0 a b	35	180	91.1 b
1	6	71.5 a b	20	180	111.3 b c
27	6	71.7 a b	26	180	117.8 c
40	6	71.7 a b	27	180	121.9 c d
38	6	72.8 a b	1	180	127.5 c d e
20	6	83.2 b	5	180	129.6 c d e
35	6	83.8 b	38	180	143.3 d e
15	6	84.7 b	40	180	143.4 d e
33	6	85.0 b	28	180	143.7 d e
28	6	87.2 b	33	180	147.3 e
26	6	88.8 b	6	180	179.2 f

n – number of observations

Taylor and Hepler (1997) reported that pollen tubes under *in vitro* conditions could be by about 30–40% shorter in comparison with *in vivo* conditions even with highly optimalised germination media. The achieved values of pollen germination and pollen tube length also confirmed that these two pollen viability indicators are not always in correlation. Similarly, Ostrolucká et al. (1995) state in their study that lower pollen germination can be compensated with higher germination energy, which is expressed by pollen tube length. Our results carried out on the one-year stored pollen proved significant impact of the temperature on germination induction and pollen viability expression. There were proved statistically significant differences in pollen germination percentage and also in pollen tube length under different temperature conditions (Table 5–8).

Table 5. Two-way analysis of variance for pollen germination percentage in *Pinus mugo* Turra in 8 trees at different cultivation temperatures

Source of variation	Sum of squares	D.f.	Mean square	*F*-ratio	Significance level
Tree	2148.2	7	306.9	3.59*	0.0026
Temperature	98117.6	2	49058.8	574.14**	0.0000
Error	5297.8	62	85.5		
Total	105563.0	71			

Table 6. Two-way analysis of variance for pollen tube length in *Pinus mugo* Turra in 8 trees at different cultivation temperatures

Source of variation	Sum of squares	D.f.	Mean square	*F*-ratio	Significance level
Tree	534688.0	7	76384.0	178.59**	0.0000
Temperature	5569966.0	2	2784986.0	6511.33**	0.0000
Error	919582.0	2150	427.7		
Total	7028236.0	2159			

Table 7. Multiple range analysis for pollen germination percentage and pollen tube length in *Pinus mugo* Turra for source of variation temperature (independent on trees)

Pollen germination			Pollen tube length		
Factor level	*n*	Mean (%)	Factor level	*n*	Mean (μm)
12 °C	24	0.0 a	12 °C	720	0.0 a
27 °C	24	69.3 b	27 °C	720	72.0 b
32 °C	24	84.9 c	32 °C	720	123.8 c

Table 8. Multiple range analysis for pollen germination percentage and pollen tube length in *Pinus mugo* Turra for source of variation tree (independent on temperature)

Pollen germination			Pollen tube length		
Tree code	*n*	Mean (%)	Tree code	*n*	Mean (μm)
36	9	44.3 a	21	270	47.3 a
8	9	46.3 a	16	270	50.9 a
16	9	47.2 a	36	270	51.1 a
32	9	48.9 a	32	270	59.2 b
3	9	53.7 a	8	270	59.4 b
2	9	54.0 a	2	270	79.9 c
21	9	57.0 a	3	270	85.8 c d
17	9	60.9 a	17	270	88.6 d

n – number of observations
D.f. – degree of freedom (*n* – 1)
*, ** – denote a statistically significant difference at $P = 0.05$, $P = 0.01$

The low temperature was not suitable for pollen germination of the stored pollen. The pollen grains did not exhibit any activity and any viability at 12 °C, compared to medium high pollen germination 69.29% at 27 °C and 84.96% germination at 32 °C (Tab. 7). The temperature had significant impact on pollen tube growth, too. We achieved the highest value for pollen tube length at 32 °C (Tab. 6) what is about 57.42 μm more than at 27 °C which was in our previous tests the optimum. This variation can be caused by the different temperature demands of fresh and stored pollen.

Conclusion

Our results indicate the possibility to preserve the *Pinus mugo* Turra pollen viability by storage. They confirmed that pollen of conifers has ability to maintain its viability during the long-term storage under certain specific storage conditions. The *Pinus mugo* pollen, stored in refrigerator at a temperature of 4 °C, exhibited good viability even after one year of storage. We also found that pollen shows its viability only at certain temperatures during *in vitro* cultivation. The most appropriate temperature for the *Pinus mugo* pollen seems to be 32 °C.

Acknowledgements

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VPLYV TEPLOTY A USKLADNENIA NA KLÍČIVOSŤ PEĽOVÝCH ZŔN DRUHU *PINUS MUGO* TURRA

Súhrn

Sledovali sme zmenu životaschopnosti peľu druhu *Pinus mugo* Turra vplyvom jeho uskladnenia a rozličnej kultivačnej teploty v podmienkach *in vitro*. Životaschopnosť peľu sme testovali metódou naklíčovania peľu na agarovom médiu s prídavkom 12,5 % sacharózy. Ročné uskladnenie peľu v chladničke pri teplote 4 °C nemalo preukazný vplyv na percento klíčiacich peľových zŕn. Peľ si zachoval klíčivosť aj po roku uskladnenia, čo potvrdzuje vhodnosť uvedených podmienok pre zachovanie jeho vitality. Významný vplyv na proces klíčenia uskladneného peľu preukázala kultivačná teplota. Najvhodnejšia na klíčenie peľu, ako aj rast peľových vrecúšok sa ukázala teplota 32 °C.

BULK DEPOSITION IN BEECH FOREST ECOSYSTEMS

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Abstract: *Bublinec, E., Dubová, M.: Bulk deposition in beech forest ecosystems. In Folia oecologica. ISSN 1336-5266, 2003, vol. 30, no. 2, p. 163–168.*

The paper presents results of a research into bulk deposition in beech forest ecosystems. There are evaluated annual and for 15-years (1987–2001) accumulated amounts of substances deposed in beech ecosystems in the Kremnické vrchy Mts. Over 15 years, the throughfall has driven to the forest soil surface (ha^{-1}) the following amounts of nutrients and pollutants (190.5 kg Ca, 382.5 kg K, 55.5 kg Mg, 181.5 kg N and 372 kg S). In comparison with other localities in Slovakia and in Central Europe, the studied beech stand in the Kremnické vrchy Mts. remains without remarkable impact of bulk deposition.

Key words: *European beech ecosystems, bulk deposition, nutrients, pollutants*

Introduction

Chemistry of precipitation and throughfall reflects the input of acid pollutants – sulphates, nitrates, fluorides (originating in fossil-fuel combustion), hydrogen ions (Anonym 2001; Bublinec, Dubová 1993a, Kellerová 1999) and of basic substances entering the forest ecosystems from the geological parent rock material (primarily calcium) (Bublinec, Dubová 1993b, Dubová, Bublinec 2002). Precipitation and throughfall sampling and their analysis enables us to obtain some knowledge on amounts, time dynamics and fluxes of nutrients and pollutants in forest ecosystems (Dubová, Bublinec 2003, Gregor 1991, Lovett et al. 1985, Parker 1983).

Material and methods

Precipitation and throughfall entering the studied forest ecosystems are sampled on research plots situated in a beech and in a spruce forest stands. The chemistry of the samples is analysed in the laboratories of the Institute of Forest Ecology of the Slovak Academy of Sciences (IFE SAS) in Zvolen. We determine electrical conductivity, pH, quantities of inorganic substances (Table 1) and, consequently, the time dynamics and fluxes of bulk deposition (Bublinec, Dubová 1989, Bublinec et al. 2002, 2003, Kellerová, Dubová 2002). The characteristics determined in precipitation and throughfall samples together with physical and chemical methods used in our laboratories are in Table 1.

Table 1. Physical and chemical methods used in analysing precipitation and throughfall in forest ecosystems

Characteristic	Method
Electrical conductivity	Conductometry
pH	Potentiometry
NO_3^-	ISE - potentiometry
NH_4^+, F^-	Spectrophotometry
SO_4^{2-}	Titrimetry
Ca^{2+}, Mg^{2+}	Atomic absorption spectrophotometry
K^+, Na^+	Atomic emission spectrophotometry

Atomic absorption/emission spectrophotometry (AAS) is used for determination of basic elements (calcium, magnesium, potassium, sodium) in analysing precipitation and throughfall (Fig. 1).

Fig. 1. Determination of basic elements (AAS) in samples of precipitation and throughfall in laboratory of IFE SAS

Results and discussion

Bulk deposition of substances (in %) evaluated on a clear-cut area (precipitation) and in the studied beech stand (throughfall) at the Beech Ecological Experimental Site (BEES) Kremnické vrchy Mts. is illustrated with Fig. 2. and 3. The crown-impact coefficient is the ratio of bulk deposition in a beech stand (in kg ha^{-1} $year^{-1}$) (throughfall) to bulk deposition on an equivalent clear-cut area (in kg ha^{-1} $year^{-1}$). Fig. 4 illustrates the crown-impact coefficients for the individual ions.

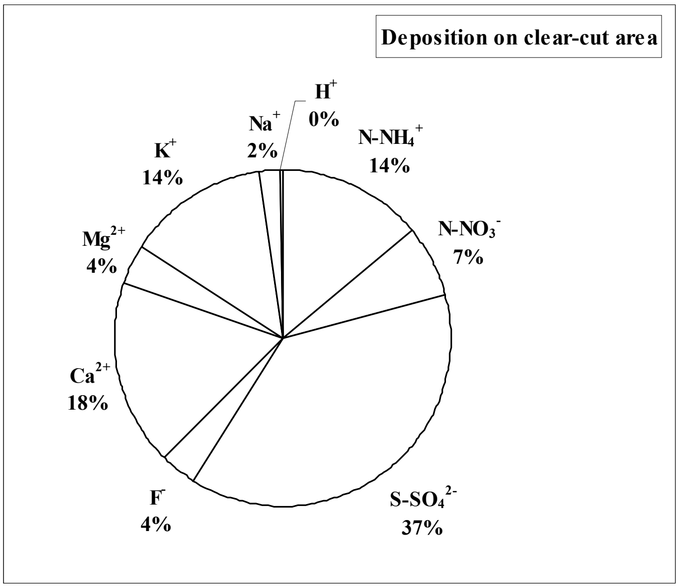

Fig. 2. Bulk deposition (in %) of elements onto clear-cut area at the Beech Ecological Experimental Site (BEES) Kremnické vrchy Mts.

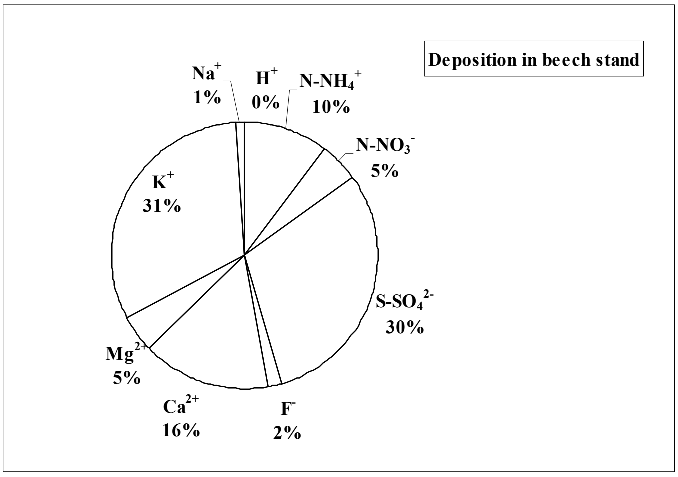

Fig. 3. Bulk deposition (in %) of elements into beech stand at the BEES Kremnické vrchy Mts.

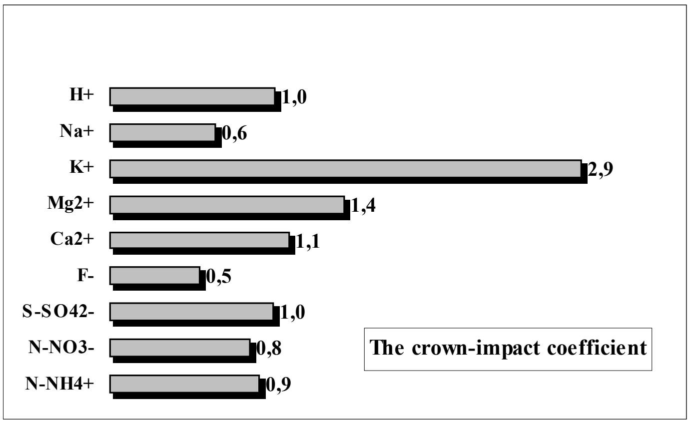

Fig. 4. Crown-impact coefficients at the BEES Kremnické vrchy Mts.

The quantities of elements (nutrients and pollutants) evaluated in the studied beech ecosystem are in Table 2. There are results of a 15-year bulk deposition onto two research plots at the Beech Ecological Experimental Site Kremnické vrchy Mts. The 15 years of the research covered period 1987-2001. We evaluated mean annual values on clear-cut area and in beech stand (in kg ha^{-1} year^{-1}) and for 15 years accumulated input of elements (cumulative values) into the forest soil (in kg ha^{-1}).

Table 2. 15-year (1987–2001) bulk deposition on the plots at the Beech Ecological Experimental Site: average (kg ha^{-1} year^{-1}) and cumulative (kg ha^{-1}) values

Characteristic	Clear-cut area	Beech stand	Input on forest floor
	(one year)	(one year)	(15 years)
$N\text{-}NH_4^+$	9.2	8.3	124.5
$N\text{-}NO_3^-$	4.5	3.8	57.0
$S\text{-}SO_4^{2-}$	25.0	24.8	372.0
F^-	2.4	1.3	19.5
Ca^{2+}	11.7	12.7	190.5
Mg^{2+}	2.6	3.7	55.5
K^+	8.9	25.5	382.5
Na^+	1.4	0.9	13.5
H^+	0.1	0.1	1.5

Nitrogen (both forms) – a nutrient element, participating in biomass production was present by an amount of 13.7 kg N ha^{-1} year^{-1}, the input of sulphur ($S\text{-}SO_4^{2-}$) had the highest value from all the elements determined in precipitation/throughfall (25.0 kg S and 24.8 kg S ha^{-1} year^{-1}, respectively). Basic elements in precipitation/throughfall reached:

calcium (11.7–12.7 kg Ca ha^{-1} year^{-1}), magnesium (2.6–3.7 kg Mg ha^{-1} year^{-1}), and potassium (8.9–25.5 kg K ha^{-1} year^{-1}). Potassium is to be pointed out, owing to its amount and the leaching from beech assimilatory organs (25.5 kg K ha^{-1} year^{-1}).

Over 15 years, the throughfall has driven to the forest soil surface (ha^{-1}) the following inorganic substances: nutrients – calcium (190.5 kg Ca), potassium (382.5 kg K), magnesium (55.5 kg Mg) and nitrogen (181.5 kg N); air pollutant – sulphur (372 kg S). Basic elements (Ca, K, Mg) lowered the acidity of precipitation/throughfall driven to the forest floor.

Conclusions

Input of sulfur deposition entering forest ecosystems is the highest from within all the elements contained in precipitation. The leaching of potassium from the assimilatory organs increased 2.9-times. The basic elements (Ca, K, Mg) at-the-site lowered acidity of precipitation/throughfall. In comparison with other localities in Slovakia and in Central Europe, the discussed beech stand in the Kremnické vrchy Mts. remains without any remarkable impact of bulk deposition.

Acknowledgements

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ZMIEŠANÁ DEPOZÍCIA V BUKOVÝCH LESNÝCH EKOSYSTÉMOCH

Súhrn

Práca predkladá výsledky výskumu zmiešanej depozície, ktorá vstupuje do lesných ekosystémov. Vyhodnocujú sa priemerné ročné hodnoty a 15-ročné kumulatívne hodnoty depozície v bukových ekosystémoch v období rokov 1987–2001. Počas 15-tich rokov vniesli podkorunové zrážky na povrch lesnej pôdy značné množstvá živinových i znečisťujúcich látok (190,5 kg vápnika, 382,5 kg draslíka, 55,5 kg horčíka, 181,5 kg dusíka a 372 kg síry na jeden hektár). V porovnaní s inými lokalitami na Slovensku i v strednej Európe, v bukovom ekosystéme v Kremnických vrchoch nedochádza k výraznému vstupu zmiešanej depozície.

THE STANDARD LEVEL AND LOCAL CHANGES IN ATMOSPHERIC LOAD IN A BEECH ECOSYSTEM

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***Abstract**: Kellerová, D.: The standard level and local changes in atmospheric load in a beech ecosystem. In Folia oecologica. ISSN 1336-5266, 2003, vol. 30, no. 2, p. 169–174.*

This contribution deals with the monitoring of the immission load at the Beech Ecological Experimental Station Kremnické vrchy Mts. Treated is the dependence of the air pollution situation on the cutting intensity, seasonal concentrations and the amount of vertical precipitation. The impact of the immission load on the open plot H is frequently stronger than in the forest stands (I, S, M, K) (Fig. 1). The results show how the change in density (Table 1) resulted in changes in the proton load on the particular plots (Fig. 2). The time trends in site conditions and air pollution are expressed by linear dependence and gliding mean (Fig. 3). The dependence of proton load on precipitation and the corresponding trends in vegetation periods 1996–2000 are in Fig. 4.
***Key words:** air pollution**,** hydrogen ion, proton load, beech ecosystem*

Introduction

Both coniferous and broadleaved woody plants are exposed to a prolonged immission load having a deleterious effect on the health stand of the forests. A continual monitoring of the situation requires cost and time demanding high-technology-automatic equipments. The daily attendance is a very frequent requirement. The common monitoring is performed on: sulphur dioxide, nitrogen oxides, atmospheric aerosols, ozone and other air pollutants. The wet deposition is primarily focussed on; on the other hand, systematic measurements of the dry and hidden deposition are frequently absent. In forest or agricultural environment we can measure the dry and hidden deposition using summation or sorption-accumulation methods (Alexander et al. 1991, Varšavová et al. 1999, Obr 1988, Grék 1991). The method measuring the proton load (hydrogen ions H^+) according to Obr (1989) determines the mean deposition load, dependence of this load on intensity of a cutting intervention, season-dependent differences in concentrations and the dependence on both horizontal and vertical precipitation.

Material and methods

Input of the proton load from the polluted environment and its long-term trend were studied on a series of permanent research plots (H, I, S, M, K) of the Ecological Experimental Station (EES) situated in the Kremnické vrchy Mts. The major part of the object is covered with a 100 year-old beech stand. In 1989 the series consisting of five partial plots with different densities resulting from different cutting intensities was established in the original stand (Greguš 1978): plot H (density 0.0) – a clear-cut, plot I (density 0.3) with a highly intense cutting, plot S (density 0.5) with medium-strong cutting, plot M (density 0.7) with mild cutting and a control K (density 0.9) – the original stand, without intervention.

In the subsequent years, the vegetation, primarily the trees, reflected the dynamics of the changes continually running at the site. Considering this fact, Barna (2000a, 2000b) provides with more precise data about the stand density on the particular plots.

The plots are situated at an altitude of 480-510 m a.s.l. on a western-oriented slope with an inclination of 15^{o}, in the SE part of the Kremnické vrchy Mts. in the upper catchments of the Kováčovský stream (Bublinec, Dubová 1989). The precipitation totals collected on the plots since 1986 up to the present time were from 510 mm to 1040 mm (annual), in vegetation periods from 160 to 530 mm (Dubová 2001). The mean annual temperature at the site is, according to Střelec (1988) 6.8 ^{o}C.

The method of measuring the proton load is based on interception of gases, liquid and solid particles on surface of filtering paper. The details are in Kellerová (1997). The proton load is a feature characterizing the acid component of the atmosphere and can be considered as belonging to dry and hidden deposition. The amount of the proton load is expressed in protons (hydrogen ions H^+).

Results and discussion

The results of quantitative research on the proton load point out the different intensities of the effect of the immission load in the stands (I, S, M, K) and on the open plot H where the load is often higher than is the load on the stand (Kellerová et al. 1997), Fig. 1. Similar results are known from literature from abroad where Grék 1991 used this method.

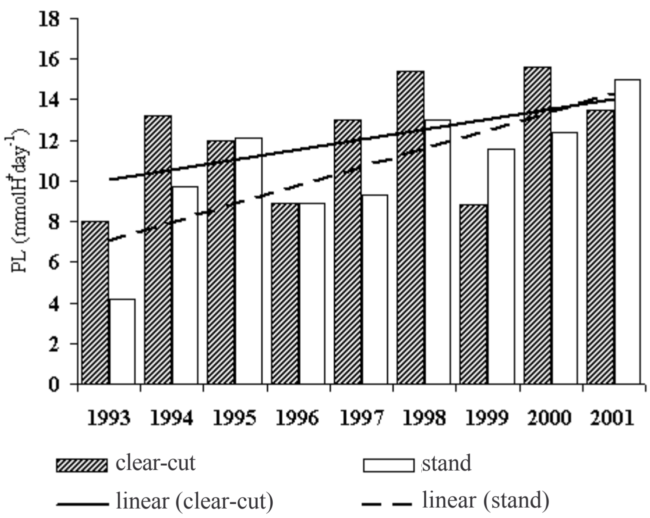

Fig. 1. Comparison between mean annual values of proton load on the open plot and stand

In period 1993–2001, the daily mean values of the proton load were calculated for each plot separately, compared mutually and also compared to the long-term mean values (1992–2001).

We can see as the change in density (Table 1) influenced the intensity of immission load impact on the separate plots (Fig. 2).

Table 1. Original and adjusted stand densities on the partial plots

Stand density	H Clear cutting	I Intense cutting	S Medium intense cutting	M Low intense cutting	K Control
1989 1996	0.0	0.3 0.4	0.5 0.62	0.7 0.78	0.9 0.87

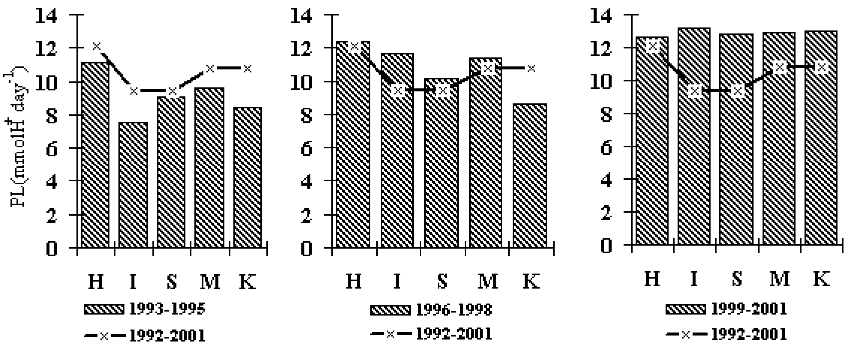

Fig. 2. Local changes in the proton load impact on the plots at the BEES Kremnické vrchy

In years 1993–1995 H plot was a clear-cut with the highest immission load values. The lowest values in this period were found on plot I: 7.5 m mol H^+ day^{-1}. The gradual change in the stand density was reflected on a gradual (1996-1998) change in the pollution; and the values of the proton load in years 1999–2001 were the highest on the plot after the intense cutting (I): 13.2 m mol H^+ day^{-1}. The values of the proton load on plot M were the highest from all the forested plots (I, S, M, K) in years 1993–1995. In the last three years were the values on all plots very similar: I 13.2, S 12.8, M 12.9, and K 13 m mol H^+ day^{-1}.

Time changes in the air pollution are summarised in Fig. 3. The trend of mean annual concentrations of the proton load is moderately increasing which is evident on the linear dependence and the gliding mean.

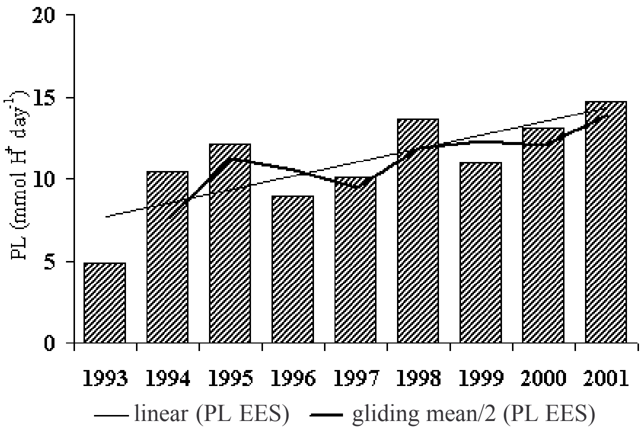

Fig. 3. Course of mean annual concentrations of proton load; linear trend and gliding mean

Fig. 4 illustrates trends in the studied variables in vegetation periods 1996-2000. We can see that the precipitation total was the highest (656. 5 mm) in 1999 with the second lowest value of the proton load (11.4 m mol H^+ day^{-1}); the second highest (601.4 mm) precipitation total was observed in 1996 when the value of the proton load was the lowest (7.5 m mol H^+ day^{-1}). It is evident that the impact of the immission load on the BEES is dependent on the vertical precipitation amount. The precipitation is an elutriating or cleaning factor to the atmosphere and a decrease in precipitation results in rather large amounts of protons (H^+) remaining in the atmosphere.

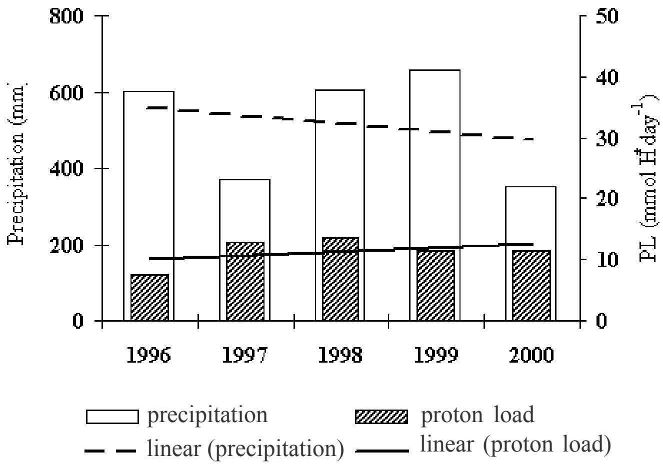

Fig. 4. Trends in the studied characteristics in vegetation seasons

Conclusions

The history of the proton load on the experimental plots in 1993–2001 corresponds to continual changes in vegetation that means to the stand density. The original state, when the highest load was on the former clear-cut H, has after 9 years totally turned over. The mean value of the proton load was on this plot lower than the values determined on the plots covered with forest stands (I, S, M, K), the values of which were very similar. The linear trends in the studied characteristics show that the vertical precipitation has an effect of elutriating or cleaning the atmosphere, that means that with decreasing precipitation the proton load is increasing and high amounts of protons (H^+) persist in the air.

Translated by D. Kúdelová

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ÚROVEŇ A PLOŠNÉ ZMENY ATMOSFÉRICKEJ ZÁŤAŽE V BUKOVOM EKOSYSTÉME

Súhrn

Práca sa zaoberá monitoringom imisnej záťaže v bukovom EES Kremnické vrchy a jej závislosti od intenzity ťažbového zásahu, rozdielov v sezónnych koncentráciách a od množstva vertikálnych zrážok.

Intenzita pôsobenia imisnej záťaže na voľnej ploche H je často vyššia ako vo vnútri porastu (I, S, M, K) (Obr. 1). Výsledky výskumu ukazujú, ako sa so zmenou denzity (Tab. 1) menilo protónové zaťaženie na jednotlivých plochách (Obr. 2). Časové zmeny a vývoj znečisteného ovzdušia znázorňuje lineárna priamka a kĺzavý priemer (Obr. 3). Závislosť protónovej záťaže od množstva zrážok a trend týchto charakteristík počas vegetačného obdobia rokov 1996–2000 zobrazuje Obr. 4.

ACIDITY OF PRECIPITATION IN A BEECH ECOSYSTEM AT THE ECOLOGICAL EXPERIMENTAL STATION KREMNICKÉ VRCHY MTS.

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Abstract: *Dubová, M.: Acidity of precipitation in a beech ecosystem at the Ecological Experimental Station Kremnické vrchy Mts. Folia oecologica. ISSN 1336-5266, 2003, vol. 30, no. 2, p. 175–179.*

In this contribution we summarise the results of a 15-year study into the acidity (pH) of the precipitation at the Beech Ecological Experimental Station belonging to the Institute of Forest Ecology in Zvolen, situated in the Kremnické vrchy Mts. We evaluated the precipitation acidity, its changes after the cutting intervention performed on two plots with different densities (H and K) and the time trends. Before the cutting, the precipitation on the plots was found acid, with the mean pH values practically equal: 4.74 (plot H) and 4.65 (plot K) – differing by only 0.1 pH. After the cutting (the resulting density on plot H – 0 %, the density on plot K 90 %), the difference in acidity was evident: 0.52 pH in 1989, but over the time it was getting smaller: 0.19 pH in 1998. Ten years after the cutting, the behaviour of the young stand on plot H became to be similar to the original 100-year-old beech stand on plot K. The current difference between the corresponding pH values was again about 0.1 pH. The mean pH value on plot H was 5.92, on plot K 5.99. During the study period we recorded a moderate decrease in acidity of the precipitation – by 1.6–1.8 pH on plot H and by some 2.0 pH on plot K. This favourable trend is primarily a result of a remarkable drop in amount of acid materials emitted to the atmosphere in the Slovak Republic.

Key words: *pH, precipitation, throughfall, beech ecosystem*

Introduction

The Earth's atmosphere accumulates air pollutants originating in human activities. The natural environment is especially endangered by acid materials (compounds of sulphur, nitrogen, fluorine, hydrogen ions…) but also by basic components (dust particles, calcium and magnesium ions), gases and aerosols. Entering forest ecosystems, primarily as a wet deposition, they often have negative impact on the vegetation, as a result of the direct contact with the vegetation surface. They also negatively influence the chemical aspects of forest soils and the water quality in surface water streams (Parker 1983; Lovett et al. 1985).

Material and methods

In 1986 we launched a continual, up to present sustained monitoring of acidity of precipitation at the Beech Ecological Experimental Station (BEES) Kremnické vrchy Mts belonging to the Institute of Forest Ecology of the SAS Zvolen. The BEES consists of a 100-year-old beech stand with an eco-series of experimental plots. The following plots with scaled stand densities were established in February 1989, after having performed cutting interventions of various intensities: plot H (clear cutting, stand density 0%); plot I (heavy, 30%); plot S (moderate, 50%); plot M (light, 70%) and control K (no cutting, 90%) representing the original stand. The BEES is situated in the SE part of the Kremnické vrchy Mts. (48°38´S, 19°04´E), in the upper part of the catchment of the Kováčovský potok stream, at 480–510 m a.s.l. on a 15° slope exposed predominantly to the west (Bublinec – Dubová 1989). The acidity of precipitation (pH) is influenced by the amount of precipitation water entering the forest ecosystem. The annual totals recorded from 1986 to 2001 ranged between 440–1040 mm on plot H and between 350–720 mm on plot K. The mean annual value of precipitation calculated over the all 15-year period was also higher on plot H (640 mm) than on plot K (470 mm) (Dubová 1996, 2001). Other site characteristics, experiments and observations on the plots at the BEES Kremnické vrchy Mts. can be found in literature sources (Barna 1999, 2000a, 2000b; Cicák – Mihál 2000; Gregor 1991; Janík 1998; Kellerová 1999; Kellerová – Dubová 2002; Kukla 1988; Pichler – Gregor 1994).

The precipitation collected on the BEES plots since 1986 was analysed in the laboratories of the Institute of Forest Ecology of the SAS in Zvolen. The precipitation acidity is expressed through pH values. The pH values of the sampled precipitation water were determined through potentiometry, using a digital potentiometer with glass and calomel reference electrodes. Them calibration of the measuring equipment was done using pH-metric reference materials.

Results and discussion

In this work we present the results of a 15-year study into the precipitation acidity (pH) in the BEES beech ecosystem. Our contribution has been focussed on the evaluation of precipitation acidity on two partial plots (H and K), in connection with the cutting treatment and its subsequent influence on the precipitation acidity for over the period 1986–2001. For each year we have calculated basic statistical characteristics (Klein et al. 1999) from the values measured on partial plots H and K. For both plots we also evaluated dynamic of mean annual pH values and their trends from 1986 to 2001 (Fig. 1).

The precipitation acidity (pH) was evaluated separately for the period before the cutting (1986-1988) and the period after the cutting (1989–2001). The period after the cutting was characterised with somewhat lowered acidity values. The pH values on plot H (0%) were slightly higher; the values on plot K (90%) increased more. The after-cutting period itself was again separated to two sub-periods: 1989–1997 and 1998–2001.

Before the cutting treatment (1986-1988), the annual pH values of precipitation on plots H and K ranged from 4.30 to 5.14. Both plots represented the original beech stand. The mean pH values on plot H (4.74) and plot K (4.65) were very similar (difference, less than 0.1 pH) and classified the precipitation into acid (range of pH scale 4.5–5.5). Acidity of precipitation considerably influences physiology of trees (Kincl, Krpeš 1994; Krpeš 2002) and pH of soil.

The values obtained with evaluation of precipitation acidity after the treatment show that the difference between the annual pH values on both plots was gradually decreasing.

While in the cutting year (1989) it was 0.52 pH, ten years after the cutting (1998) we obtained 0.19 pH (a 63.5% decrease).

In the period immediate after the cutting, 1989-1997 were the annual pH values on plot H from 4.47 to 5.90 and on plot K from 4.79 to 6.06. The mean pH values on both plots: 5.26 (H) and 5.39 (K) characterised the precipitation in this period as still acid.

With the ongoing time (1998–2001), the difference between the acidity values on plots H and K has returned to the original 0.1 pH. According to the results, ten years after the cutting (1998), the annual pH values on both plots (H and K) became to be equal. The behaviour of the young beech ecosystem on plot H was getting similar to the behaviour of the original 100-year stand on plot K. Over this period were the pH values of the precipitation water collected on plot H from 5.45 to 6.23 and on plot K from 5.64 to 6.34. Both mean pH values on plot H (5.92) and plot K (5.99) classified the precipitation at the site into mild-acid range (5.5–6.5). The difference between the annual pH values on plots H and K was again the same as before the cutting intervention, less than 0.1 pH.

The acidity of precipitation on both plots at the BEES gradually decreased (pH values increased) over all the period of the experiment (1986–2001). On plot H we recorded an increase by 1.6–1.8, on plot K even by 2.0 pH. This shift towards higher pH values reflects a decrease in acid pollutants emitted to the atmosphere. According to the data on the trends in basic acid pollutants to atmosphere (SO_2, NO_x, …) emitted from human activities in the Slovak Republic (SR), published by the Ministry of the Environment SR, over the ten-year period (1988–1997) there were recorded considerable decreases in emissions of sulphur dioxide – by 70% and nitrogen oxides – by 40% (Anonym 2001).

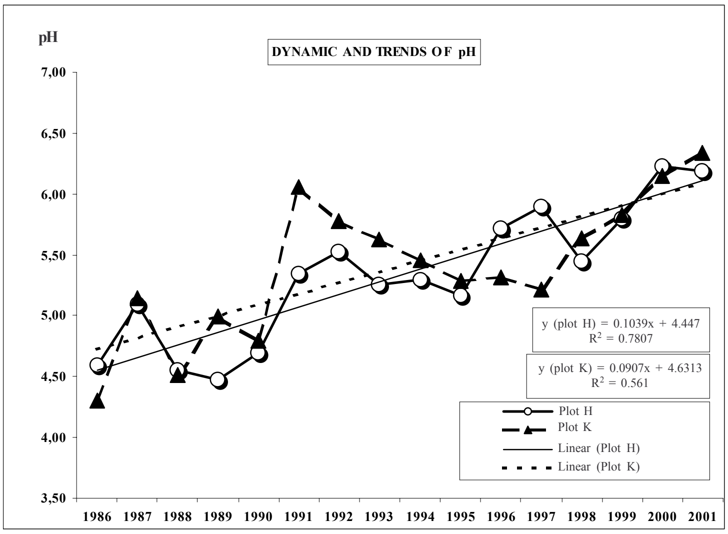

Fig. 1. Dynamic of annual pH values and trends on two partial plots (H and K) at the beech EES Kremnické vrchy Mts.

Conclusions

The pH values of precipitation entering forest ecosystems are a factor controlling the input of exogenous, primarily acid, but also alkaline compounds to these ecosystems. It is well known that a drop in pH values under 3.5 can entail visible damage to the assimilatory organs. Latent damage can be present at pH levels under pH 4.5 and above 6.0, because the optimum for plant physiological activities is within pH 5.6–6.0 (Bublinec – Dubová 1989). From the 15-year study into the precipitation acidity at the BEES Kremnické vrchy Mts. we can conclude that the mean pH values of the precipitation acidity at the site coincide with the optimum range for the plant physiological activities. The precipitation with the acidity exceeding the optimum limits (we have recorded several) can have unfavourable influence on the health state of the relevant forest ecosystems.

Acknowledgements

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KYSLOSŤ ZRÁŽOK V BUKOVOM EKOSYSTÉME NA EES KREMNICKÉ VRCHY

Súhrn

V príspevku sú výsledky 15-ročného výskumu kyslosti zrážok (pH) na bukovom ekologickom experimentálnom stacionári v Kremnických vrchoch, ktorý patrí Ústavu ekológie lesa SAV vo Zvolene. Hodnotíme kyslosť zrážok, zmenu po ťažbovom zásahu na dvoch plochách (H a K) a trend kyslosti. Zrážky pred ťažbou sú kyslé. Priemerná hodnota pH je 4,74 (plocha H) a 4,65 (plocha K). Rozdiel kyslosti v zrážkach na obidvoch plochách je do 0,1 pH. Po ťažbovom zásahu (plocha H je 0 % a plocha K 90 %) sa rozdiel pH na oboch plochách v jednotlivých rokoch postupne mení, zmenšuje. Kým v roku 1989 bol 0.52, v roku 1998 je 0,19 pH. Po desiatich rokoch od ťažby sa mladý bukový ekosystém, ktorý vyrástol na ploche H začína správať ako 100-ročný bukový porast na ploche K. Znova rozdiel pH na plochách H a K je okolo 0,1 pH. Priemerná hodnota pH je 5,92 (plocha H) a 5,99 (plocha K). V období výskumu dochádza k zmierneniu kyslosti zrážok. Trend ukazuje na zníženie kyslosti o 1,6 až 1,8 (plocha H), resp. o 2,0 jednotky pH (plocha K). Na pokles kyslosti vplývalo najmä zníženie množstva kyslých látok emitovaných do ovzdušia v Slovenskej republike.

SPATIAL VARIABILITY OF MICROBIAL SOIL CHARACTERISTICS UNDER A SINGLE BEECH TREE

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Abstract: *Gömöryová, E.: Spatial variability of microbial soil characteristics under a single beech tree. In Folia oecologica. ISSN 1336-5266, 2003, vol. 30, no. 2, p. 181–189.*

In our study we evaluated the changes of soil respiration and catalase activity below a single beech tree in association with the infiltration zone. Correlations between soil microbiological characteristics and the distances from the stem were observed. The highest microbiological activity was found downslope, immediately below to the stem (infiltration zone).
Key words*: soil respiration, catalase activity, spatial variability, beech*

Introduction

For several decades, attention has been paid to spatial heterogeneity of soil characteristics, among them changes of soil moisture and soil acidity have been the most frequently estimated (Papritz et al. 1991, Pichler 1991). Fewer data are available for heterogeneity of microbiological characteristics in soils, especially in forest soils, although trees in forest stand significantly influence the light, temperature and moisture conditions in under-ground environment. It is mainly a consequence of differences in the quality and quantity of stemflow and throughfall, in the differences of water uptake by roots of trees, in the differences of litterfall, etc. We can also suppose, that living conditions of soil microorganisms will be considerably affected by these changed relations and in connection with them their spatial and temporal variability will be also influenced. Among biological characteristics spatial variability of soil microbial biomass (Morris et al. 1998, Imberger et al. 2002), soil respiration (Stoyan et al. 1999, Buchmann 2000), enzyme activities (Decker et al. 1999), soil nitrification and denitrification (Lensi et al. 1991), have most frequently been estimated. The spatial heterogeneity has been assessed on plots with various grids. Some studies have examined differences at the millimetre scale (Parkin 1993), other studies have examined differences occurring at distances ranging from several metres to the landscape scale (Morris et al. 1998).

Interesting situation can be supposed in a beech stand. Beech exhibits a considerable stemflow as a consequence of a smooth bark and the crown architecture. In the infiltration zone, stemflow water significantly influence some soil characteristics – soil moisture, bulk density, soil acidity, content of Ca, Mg (Papritz et al. 1991, Pichler 1991).

In this study, we examined some microbial characteristics (soil respiration and catalase activity, because they are cheep and easy to perform) under a beech tree and evaluated their changes in association with the infiltration zone.

Material and methods

The study was performed in an 100-yr old beech stand (*Fagus sylvatica* L.) located in central Slovakia (Kremnické Mts.). The altitude of the study area is 530 m a.s.l., slope angle 5°, slope aspect SSW. Stand density is 0,8, herb layer (coverage 30%) is formed of *Dentaria bulbifera, Asperula odorata* and seedlings of beech and linden. Soils are Ando-Cambisol with 60% skeleton in the cambic Bv-horizon, created by andesite agglomerate tuff.

The soil samples were collected in the spring, on May 16, 2003. A single adult beech tree (DBH = 48 cm) was chosen in the stand within an area without apparent signs of a recent disturbance by logging or other forestry operations. Around the stem of the beech tree we aligned lines A, B, C, D, E, F, G, H, on which soil samples were taken each 20 cm (to the distance of 1m from the stem, each 10 cm) from the topsoil (depth 2–8 cm, A-horizon). The distances between the lines |EF|, |FA|, |AG| and |GH| were 40 cm. Figure 1 shows the position of lines on the investigated plot under the beech tree. The distances of sampling point from the tree were measured from the centre of the stem base (intersection of lines A–C and B–D). In total, we took 103 soil samples.

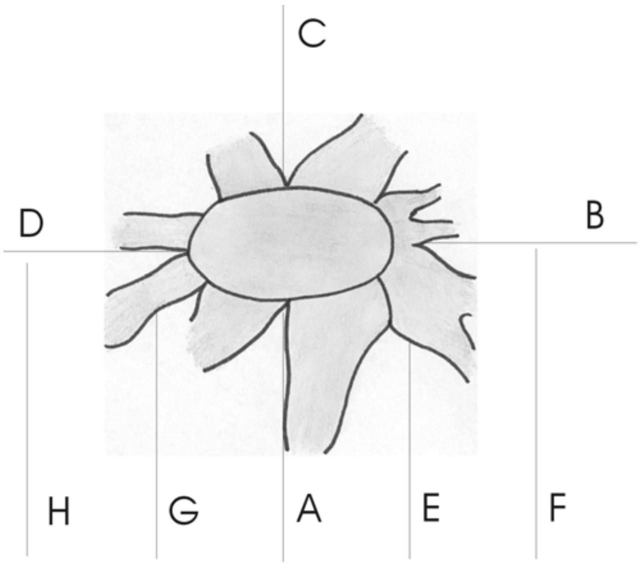

Fig. 1. The position of lines on the investigated plot under the beech tree

Soil respiration was measured using the Isermeyer´s method (in Alef 1991). Catalase activity was determined following the method of Kurbatov and Dvojnišnikova (Obr et al. 1986), soil moisture was determined gravimetrically by oven-drying fresh soil at 105 °C.

Since we expected monotonous, but not necessarily linear dependence of biological characteristics from the distance of sampling point from the stem base, Spearman´s rank correlation coefficients were used for a preliminary assessment of the relationships between biological characteristics and distances from the tree. For data subsets, where rank correlations indicated a significant relationship, non-linear regressions were calculated using Gauss-Newton iteration method. The program package Statistica 6 (StatSoft, Inc., Tulsa, USA) was used for the calculations.

Results

Fig. 2 and 3 show the spatial distributions of soil respiration and catalase activity under the beech tree. Both measured variables varied substantially on all lines; however, a higher variability was exhibited by soil respiration (Table 1). On all lines, except line A, the values of both parameters appear to be distributed almost randomly. On line A, soil respiration as well as catalase activity are the highest immediately below the stem base, approximately to the distance of 0.5 m.

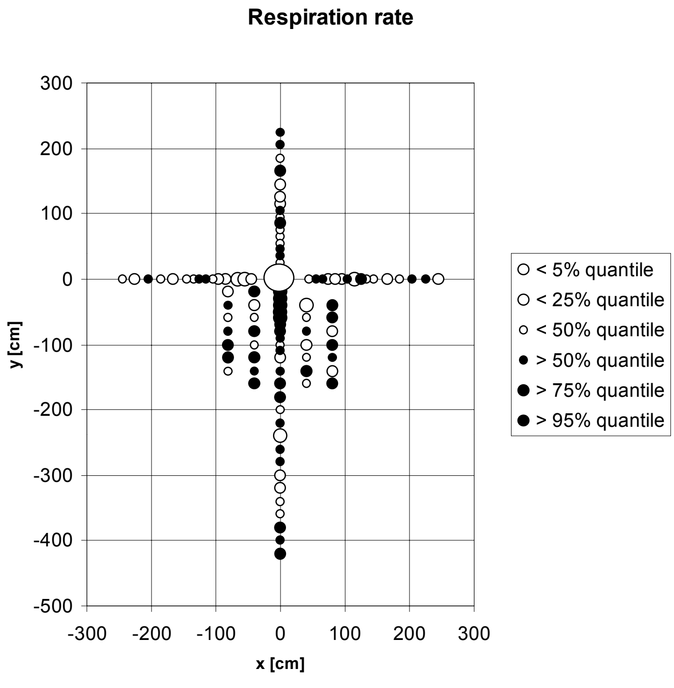

Fig. 2. The distribution of respiration rates under a single beech tree

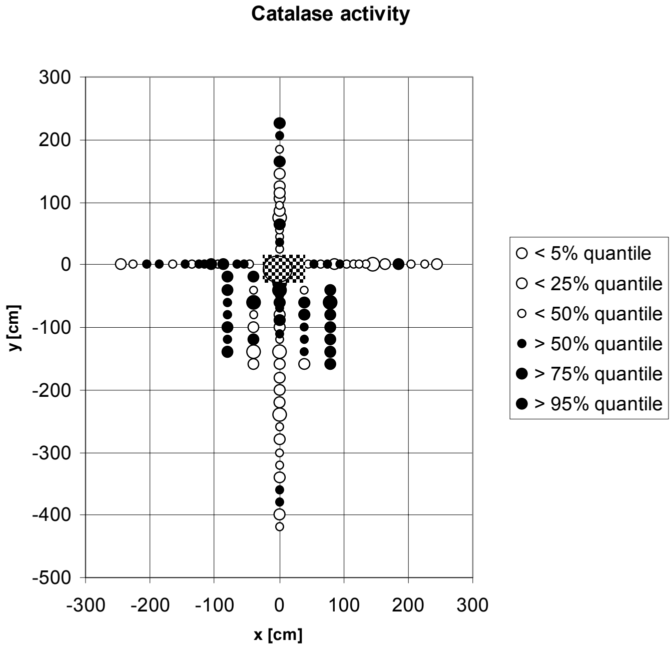

Fig. 3. The distribution of catalase activities under a single beech tree

Table 1. Summary statistics of selected soil attributes

Soil attribute	Average	Standard deviation	Coefficient of variation (%)	Range
Soil respiration ($mg\ CO_2.g^{-1}.day^{-1}$)	0.17	0.09	53.71	0.02–0.50
Catalase activity ($ml\ O_2.g^{-1}.min^{-1}$)	1.05	0.30	28.81	0.11–1.71
Soil moisture % (w/w)	30.76	6.11	19.86	16.13–56.57

The correlations between soil characteristics and distances from the tree are presented in Table 2. Surprisingly, soil moisture was not significantly correlated with the distance. On the other hand, there were significant relationships between the catalase activity and the distances from the tree, whereby the highest relationship were observed on the plot located downslope of the tree (lines A, E, F G, H), i.e. on the plot, which we can regarded as an infiltration zone. As compared with catalase activity, soil respiration proved to be more variable; the significant correlation coefficient is recorded only on line A. In general, the relationships between biological characteristics were higher downslope of the tree than upslope of the tree. When data for line A alone or for the lines downslope of the tree (lines A, E, F, G, H together) were separately analysed, some trends were evident, in contrast to pooled data of all lines.

Table 2. Spearman´s rank correlation coefficients between the characteristics of the biological activity of soil and the distance from the tree base

Dataset	Soil moisture	Catalase activity	Soil respiration
All data	0.07510ns	–0.29678**	–0.02461ns
lines A, E, F, G, H	0.07866ns	–0.51433***	–0.22180ns
line A	–0.15761ns	–0.46212*	–0.59521**

Significance labels: *** – $\alpha < 0.001$,
** – $0.001 < \alpha < 0.01$,
* – $0.01 < \alpha < 0.05$,
ns – nonsignificant ($\alpha > 0.1$).

Fig. 4 and 5 show that soil respiration and catalase activity exponentially decrease with higher distance from the tree on the line A. This pattern is predictable to the distance of approx. 3 m, so this seems to be the distance where the direct influence of the tree on soil characteristics can be observed. At higher distances from the tree the distribution of values becomes more and more random, since it may be affected by other factors.

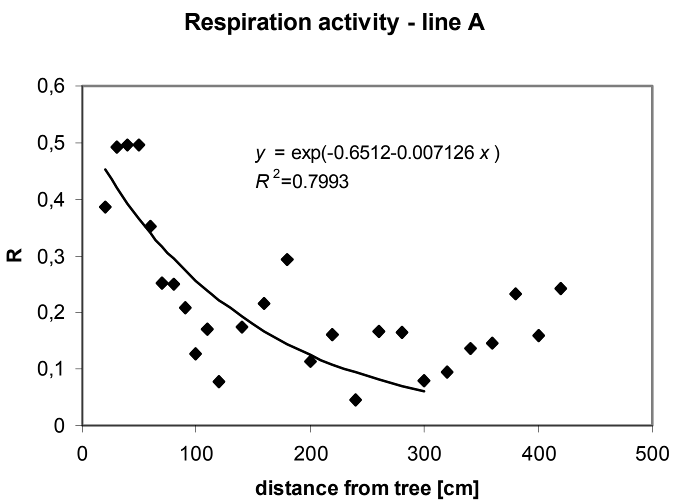

Fig. 4. The relationship between respiration rates (mg $CO_2.g^{-1}.day^{-1}$) and the distance from the tree (cm)

The relationships among soil characteristics are shown in Table 3. We found significant correlations between soil respiration and soil moisture, as well as between soil respiration and catalase activity, while no significant correlations were found between catalase activity and soil moisture.

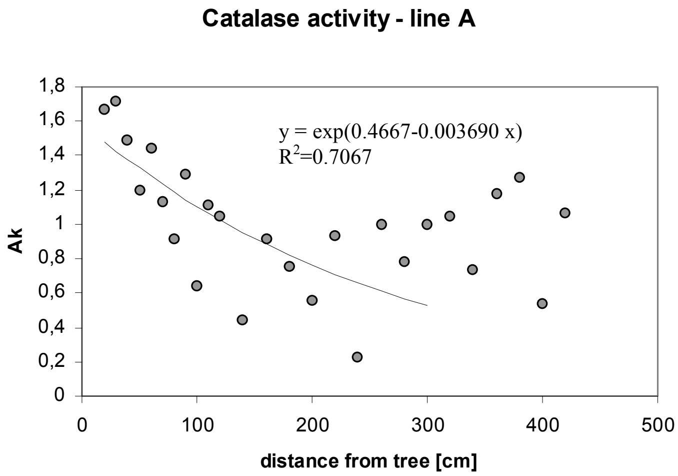

Fig. 5. The relationship between catalase activity (ml $O_2.g^{-1}.min^{-1}$) and the distance from the tree (cm)

Table 3. Correlations between the characteristics of the biological activity of soil

Variable	Moisture	Catalase activity	Respiration activity
Moisture	–	0.03154ns	0.33454***
Catalase activity	–0.15095ns	–	0.36805***
Respiration activity	0.18129ns	0.29643**	–

Above diagonal – Pearson´s correlation coefficients, below diagonal – Spearman´s rank correlation coefficients

Significance labels: *** – $\alpha < 0.001$,
** – $0.001 < \alpha < 0.01$
* – $0.01 < \alpha < 0.05$
ns – nonsignificant ($\alpha > 0.1$)

Discussion

Our overall goal was to determine the spatial heterogeneity of soil respiration and catalase activity under a single beech tree and to evaluate their changes in association with the infiltration zone.

The tree as a factor influencing the changes of soil characteristics in connection with soil heterogeneity has been confirmed in many studies. Especially, the effect of stemflow on beech on soil physical and soil chemical properties in the infiltration zone has frequently been investigated, because this process leads to the formation of extreme micro-sites, where the morphological, physical and chemical properties of soil near to the stem are strongly influenced. In the infiltration zone, the decline in mineralization, increase of organic matter, leaching of soil bases and soil acidity have been observed (Gersper et al.1970a, 1970b). Since the number, biomass and activity of soil microorganisms depend on given chemical soil characteristics, their changes can also be expected.

In our study, both assessed biological characteristics, especially soil respiration, exhibit considerable spatial heterogeneity. We expected this result, because soil respiration is one of the most variable parameters in soil – coefficient of variation for soil respiration ranges from 35% in grasslands to 150% in corn and soybean fields (Stoyan et al. 2000), and 37–54% in a beech stand (Gömöryová 2003).

The spatial distribution of microbes in forest soil below individual trees growing on slopes is not properly understood. Morris (1999) has established macro- and microplots upslope and downslope of the base of a red oak and found that there were significant differences between the microbial biomass and soil chemical and physical properties measured in the plot located upslope of the tree and the plot located downslope of the tree. Whole macroplot fungal biomass and F-to-B ratio were slightly but significantly greater upslope of the tree than downslope of the tree, soil moisture and soil pH were also significantly greater on the plot upslope, whereas organic C was significantly greater downslope of the tree. Only bacterial biomass did not differ significantly between macroplots.Below beech tree Kinzel (1991) has investigated the heterogeneity of some soil biological characteristics and found that all parameters of biological characteristics were distributed randomly. Left of the stem, all parameters were lower, below the stem microbial biomass and soil respiration were unexpectedly high and dehydrogenase activity lower, than he expected. In his opinion, near to the stem, a specific community of microorganisms exists, which differs considerably from surroundings communities.

We found that under a beech tree, the highest soil respiration and catalase activity were also found immediately below the stem base, whereby with increasing distance from the stem, both characteristics decreased. However, this trend was more pronounced in case of catalase activity.

Many factors control soil biological activity. However, we could relate this variation of biological characteristics only to soil moisture (at present, analyses of organic matter and pH estimation are underway). In this study, no relationship between biological activity and soil moisture have been assessed. It is a surprising result, because soil respiration is generally strongly influenced by soil moisture. This situation probably results from a long-term drought and high air temperature before and during the sampling. When the moisture is relatively constant, the respiration rates are controlled by other factors (Vanhala 2002). High values of soil respiration and catalase activity downslope of the tree may be thus associated with other parameters. Near to the stem basal, soil samples were very rich in organic matter. In many studies, it has been suggested that near to the stem higher content of organic C is present (Zinke 1962, Gersper 1970b). It can be the result of considerable content of organic C in stemflow water. Higher humidity in the infiltration zone can lead to the accumulation of organic material. On the other hand, near to the stem, fine bark particles are accumulated, which also are source of organic material. Because soil respiration is mainly regulated by moisture, amount of organic matter and pH (Vanhala 2002), the conditions for microbes' survival and activity immediately below the stem are favourable. Catalase activity is associated with soil acidity; a positive correlation between them was observed (Gömöryová 2003). In the infiltration zone, soil pH is generally decreased, because a large quantity of stemflow water from beech significantly contribute to base leaching and soil acidification on this microsites. We could thus expect lower catalase activity, but on our plot the highest catalase activity we have found just in this zone. The soil on the plot is formed from andesite agglomerate tuff, these soils exhibit generally with high buffer ability (Pichler 1991), the differences between pH in the infiltration zone and beyond it need not be significant. Probably, it can be connected with specific microflora on this plot, as Kinzel (1991) has supposed. The interesting question can be, what is the microbial diversity there, what is the representation of bacteria and fungi, and in what degree these results can be influenced by rhizosphere microorganisms.

As we demonstrated, at higher distances from the tree, the distribution of values becomes more and more random. Zinke (1962) stated that pH and other soil characteristics changed in radial symmetry to the stem. This trend was pronounced below isolated trees. With increasing stocking of stand, the factors determining soil characteristics interfere and the effect zones of trees melt one into another.

Conclusions

In our study, it was shown that under a single beech tree, the differences between soil microbiological characteristics (soil respiration and catalase activity) were correlated with the distances from the stem. The highest microbiological activity was found on the plot immediately below the stem (infiltration zone). However, our understanding of belowground biological processes is limited by our ability to integrate all factors determining the living conditions of microorganisms.

Acknowledgements

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PRIESTOROVÁ VARIABILITA NIEKTORÝCH MIKROBIÁLNYCH CHARAKTERISTÍK V PÔDE POD BUKOM

Súhrn

Cieľom práce bolo zistiť, ako sa menia niektoré mikrobiálne charakteristiky (pôdna respirácia a aktivita katalázy) pod individuálnym bukom a či predpokladané zmeny vlastností pôd v infiltračnej zóne ovplyvňujú aj zmeny aktivity mikroorganizmov. Najvyššiu mikrobiálnu aktivitu sme zaznamenali v tesnej blízkosti kmeňa, bezprostredne pod ním. So zväčšujúcou sa vzdialenosťou od kmeňa, aktivita katalázy aj pôdna respirácia klesali. Tento trend sa prejavoval do vzdialenosti asi 3 m, teda môžeme predpokladať, že do tejto vzdialenosti sa prejavoval priamy vplyv stromu. Pri väčšej vzdialenosti sa tento vplyv individuálneho stromu pravdepodobne prekrýval a splýval s inými určujúcimi faktormi.

NIGHT TIME FLUXES IN THE SLOPING TERRAIN

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Abstract: *Janouš, D., Havránková, K., Pavelka, M., Acosta, M., Zvěřinová, Z.: Night time fluxes in the sloping terrain. In Folia oecologica. ISSN 1336-5266, 2003, vol. 30, no. 2, p. 191–198.*

Influence of the terrain on CO_2 flux measurement over the young spruce forest in Bílý Kříž site is examined. The drainage flow is found to be developed in the Bílý Kříž spruce forest under the edge of the mountain and is enhanced with the distance it covers. It is observed even when there is a south wind above the canopy (up the slope). Drainage flow reaches several tenths of centimetres above ground. Its investigation consisted of 3 basic approaches: i/ the concentration CO_2 measurement in the slope gradient, ii/ the pulse CO2 concentration experiment, iii/ the termistor airflow sensors.

Key words: *CO_2 flux, slope, drainage flow, CO_2 concentration measurement, terrain effects*

Introduction

Mountain forest is a typical ecosystem in the Czech Republic. The investigation of its ability to bind atmospheric carbon is thus of a high importance. A standard methodology for measuring CO_2 flux between the canopy and the atmosphere uses eddy-covariance (Baldocchi 2003). A careful examination of the measuring place is required, as the measurement is dependent on the atmospheric characteristics influenced by the terrain. Main uncertainties with the CO_2 flux measurement lie in the night hours, when CO_2 respired in the lower ecosystem parts tends to accumulate within the forest canopy and than leaks the place (by katabatic flow or local convection cells) without necessarily being measured (Aubinet et al. 2000). This paper aims to uncover the influence of the terrain in the Bílý Kříž site on CO_2 flux measurement between the young spruce forest and the atmosphere and so prepare the basis for correct eddy-covariance measurement.

Material and methods

The Norway spruce study stand of the Experimental Ecological Study Site (EESS) Bílý Kříž is situated in the Moravian-Silesian Beskydy Mountains, 800–900 metres above the sea level. The locality is climatically classified as a cold region, with high humidity and precipitation. The detailed characteristics of the site are described in Pavelka at al (2003, in this issue). Above canopy flow characteristics (wind speed, wind direction) were measured by eddy-covariance system InSituFlux (InSituFlux, Sweden). The investigation of CO_2 leaking down the slope consisted of 3 basic approaches.

A. The first one was the concentration CO_2 measurement in the slope gradient. It was measured by the system using the infra red gas analyser (IRGA) (Li-800, Li-Cor, U.S.A). The air was sampled in 100 m profile down the slope. Each tube ends with 2 inlets, so the mixed air from one height was taken. The height of the profile was 0.25 to 1.75 m. (Fig. 1).

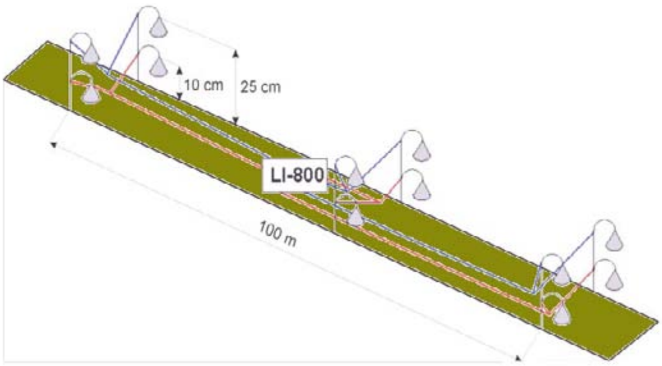

Fig. 1. Profil measurement of CO_2 concentration on the slope

B. The second one was the pulse CO_2 concentration experiment. Six tubes in the circle of 3 m radius leaded into IRGA. They were 10 cm above the ground. In the centre of the circle there was a CO_2 bomb enriching the air with CO_2 at certain time intervals (Fig. 2). The IRGA data determined the direction and speed of the flow.

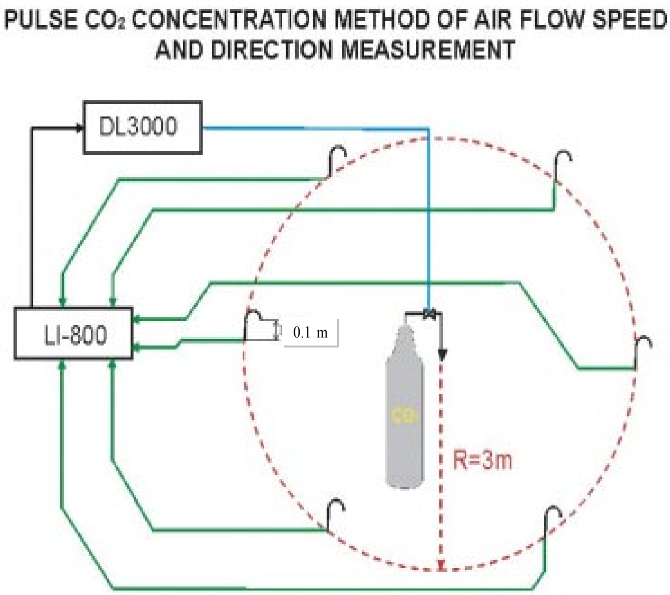

Fig. 2. Pulse CO_2 concentration method of air flow speed and direction measurement

C. The third method was based on termistor airflow sensors. Below canopy air flow was measured with termistor air flow sensors (Pt 100, Hit Uherské Hradiště) installed in the set of six in the gradient above the ground (0.25, 0.50, 1.00, 1.75 m).

Results and the discussion

Young spruce forest in Bílý Kříž site is situated on a SSW slope. The tower position and the footprint from the south-wind sector, which is the most important sector in our site (the evidence is the wind rose) is marked on the aerial photo (Fig. 3).

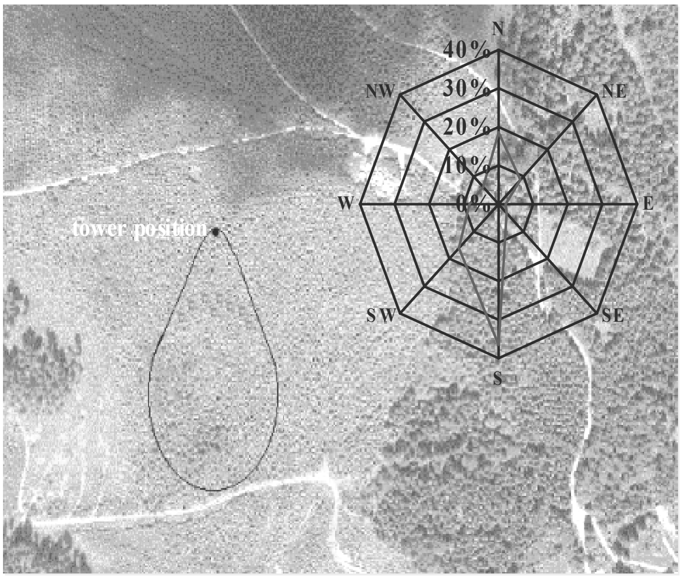

Fig. 3. Aerial photo of young spruce forest in the locality Bílý Kříž

The topography of the site (Carboeurope Workpackage 7, University of Bayreuth, 2002). (Fig. 4) is showing a south-south-west slope (going about 3 km down) and the edge of the mountain.

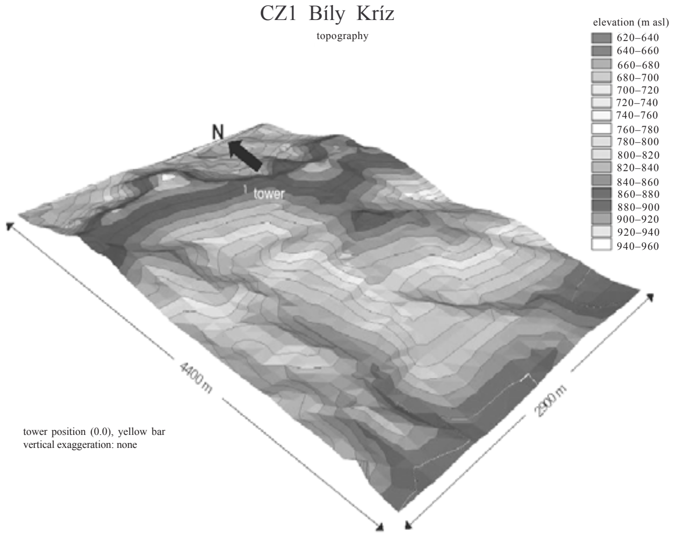

Fig. 4. Topography of the locality Bílý Kříž

The dependence of night CO_2 flux measured using eddy covariance method on the wind speed is obvious (Fig. 5). Position of the site on the slope (Fig. 6) allows us to conclude that CO_2 is leaking down the slope.

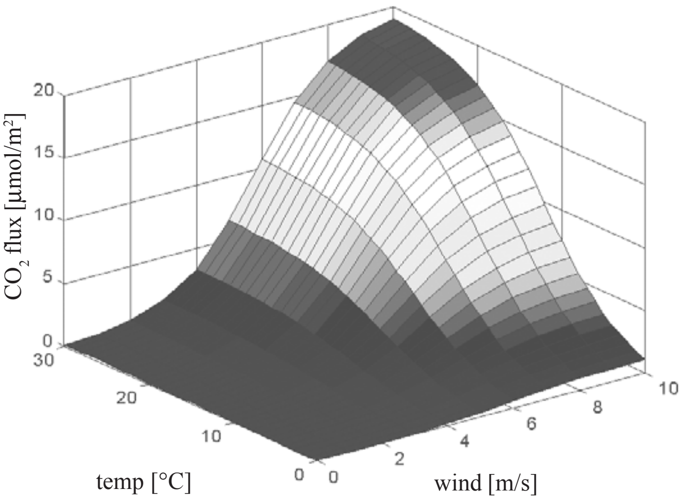

Fig. 5. The dependence of night time CO_2 flux (μmol.m^{-2}.s^{-1}) measured in Bílý Kříž site on the temperature (^{o}C) and wind speed (m.s^{-1})

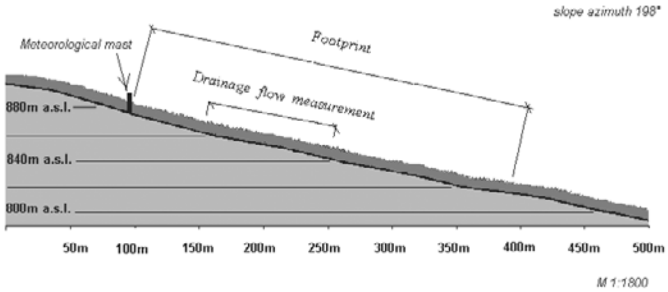

Fig. 6. Slope profile with marked footprint and area of drainage flow measurement

A. CO_2 concentration in the slope profiles

The highest concentration of CO_2 was found at the lowest point of the concentration CO_2 measurement at 10 cm, the lowest concentration at the highest point of measurement at 50 cm (Fig. 7a). The highest difference in CO_2 concentrations between up and down parts is at the height of 10 cm (Fig. 7b). Up the slope there is high CO_2 concentration near to the ground, whereas down the slope there is high CO_2 concentration higher over the ground.

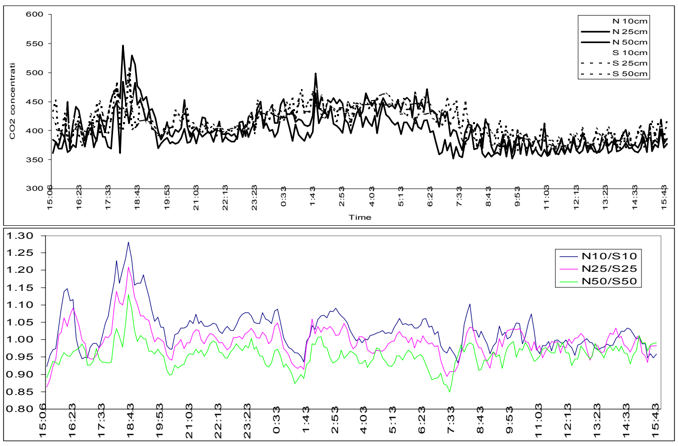

Fig. 7. a) CO_2 concentration (ppm) in the slope profile, b) ratio of CO_2 concentration between upper (N) and down part (S) of the slope measured at 10, 25 and 50 cm above soil surface (10th – 11th June 2003)

B. Drainage flow measured using CO_2 pulse concentration method

The pulse concentration method showed that there was north wind flow (down the slope) all night with a speed of 0.4-0.5 m/s (near the ground) (Fig. 8a), although the situation above the canopy was changing: the wind did not have high wind speed and there was change form north to south wind direction after midnight (Fig. 8b), but without distinctive influence on the drainage flow.

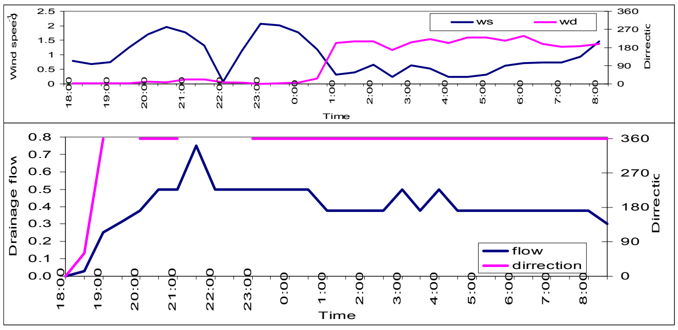

Fig. 8. Drainage flow measured using CO_2 pulse concentration method (3rd June – 4th June 2003)

C. Drainage flow measured with termistor air flow sensors

The changing conditions during the night was observed with termistor air flow sensors (Fig. 9). According to the situation above the canopy, in the first part of the night there was a low south wind and the drainage flow was increasing. During the middle part of the night, higher wind speed caused drainage flow to be calmed down or disappeared. During the third part of the night there was a change in wind direction and the wind penetrated to the canopy in upper part of slope and break the flow (Fig. 10). Measured wind profile at 9:30 p.m. confirmed the assumption of night time drainage flow (Fig. 11).

THERMISTOR AIR FLOW SENSOR MEASUREMENT

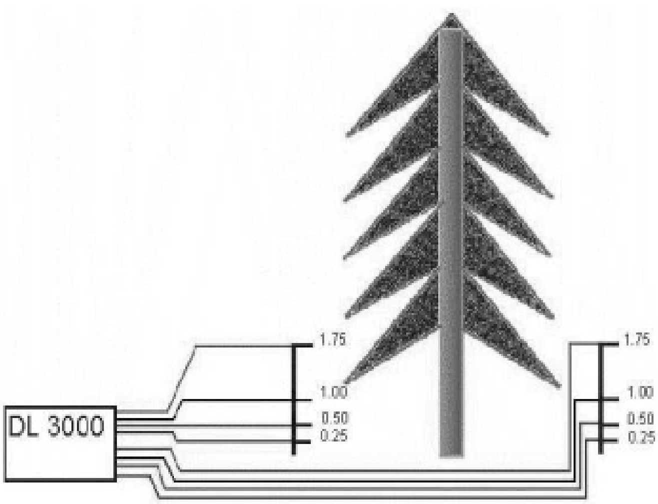

Fig. 9. Thermistor air flow sensor measurement

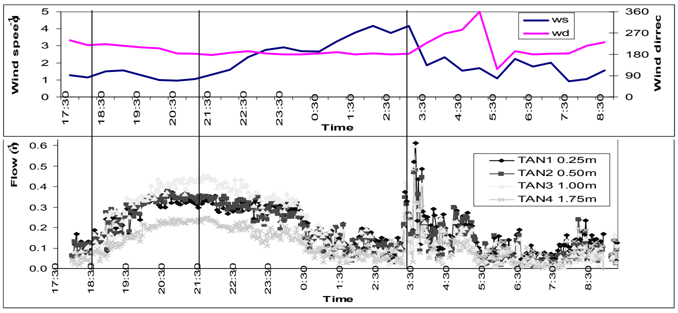

Fig. 10. Drainage flow measured with termistor air flow sensors (12th June – 13th June 2003)

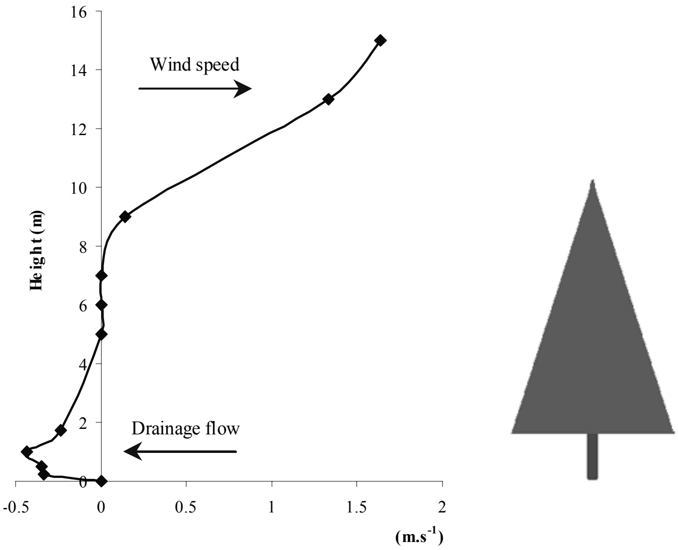

Fig. 11. Wind speed profile bellow, within and over the canopy 12th June at 9:30 p.m.

Conclusions

The leakage of CO_2 from the site downwards was evident in the Bílý Kříž forest site. The flow is not advanced and several metres high, so we do not call it catabatic flow but drainage flow. It reaches several tenth of centimeters above ground. The drainage flow is developed in the Bílý Kříž spruce forest under the edge of the mountain and is enhanced with the distance it covers. It is observed even when there is a south wind above the canopy (up the slope).

Acknowlegments

The authors are gratefull to the Grant Agency of AS CR (Project No. KJB3087301 and MSMT LN00A141) and the research intention AVOZ 6087904 for supporting our work.

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NOČNÍ TOKY VE SVAŽITÉM TERÉNU

Súhrn

V příspěvku „Noční toky ve svažitém terénu“ je posuzován vliv terénu na měření toku CO_2. Stékání CO_2 při povrchu půdy ze svahu dolů se v mladém smrkovém porostu na lokalitě Bílý Kříž rozvíjí pod horským hřebenem a je zesilováno se vzdáleností směrem do údolí. Je pozorováno i při jižním proudění nad korunami stromů (proudění po svahu vzhůru).

Stékavý proud dosahuje do výšky několika desítek centimetrů nad zemským povrchem. Ke zjišťování existence a charakteristik stékavého proudění byly použity tři různé metody: i/měření koncentrace CO_2 ve svahovém profilu, ii/ pulsní metoda měření koncentrace CO_2 a iii/měření rychlosti proudění termickými anemometry.

CARBON SOURCES IN VERTICAL PROFILE OF A NORWAY SPRUCE STAND

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Abstract: *Pavelka, M., Janouš, D., Urban, O., Acosta, M., Pokorný, R., Havránková, K., Formánek, P.: Carbon sources in vertical profile of a Norway spruce stand. In Folia oecologica. ISSN 1336-5266, 2003, vol. 30, no. 2, p. 199–206.*

CO_2 sources from Norway spruce forest stand were divided to different components (soil, stem, branch, and leaf). Fluxes from these components were measured using gas-exchange method during the vegetation season 2002. Carbon stock and respiration proportion in the forest stand were calculated for one meter high sections of stand height profile for day and night periods. Carbon stock in leaves represents 12% of the total carbon content of the stand, but the proportion of leaf respiration on the total stand respiration is 50% in the night time and 55% in the day time.

Key words: *CO_2, carbon stock, respiration, Norway spruce.*

Introduction

The increase of CO_2 concentration in the atmosphere and threat of climate change leads to the necessity of recognition and quantifying all components of the global carbon cycle. Respiration is an important component of forest carbon balance, releasing about 80 % of the fixed carbon (Janssens et. al. 2001). Temperature is a principal environmental factor influencing respiration rate. This contribution describes respiration activity of a Norway spruce stand in different height levels during the day time and night time periods.

Material and methods

The measurement is carried out in the Experimental Ecological Forest Site in Moravian Silesian Beskyds in the young spruce stand. Main characteristics of the locality and the forest are in Table 1 and 2.

Table 1. Site characteristic

Site	**Experimental ecological study site Bílý Kříž, Moravian – Silesian Beskydy Mts.**
Country	The Czech Republic
Position	N 49 ° 30′17 ′′, E 18° 32′28′′, about 870 m a.s.l.
Topography	hilly
Climate	temperate/continental
Annual mean air temperature	5.5 °C
Annual sum of precipitation	1000 – 1400 mm
Mean annual relative air humidity	80%
Average number of days with snow cover	160
Prevailing winds	south
Immission load	mild

Tabble 2. Stand characteristics in the year 2002

Stand density	[tree.ha^{-1}]	2500
Mean tree height	[m]	9.7
Mean stem diameter at the breast height	[cm]	11.5
Stand basal area	[m^2]	6.88
Stand sapwood area	[m^2]	5.75
Leaf area index (seasonal max.)	[m^2.m^{-2}]	11.68
Canopy layer width	[m]	7.9
Stem area index	[m^2.m^{-2}]	0.20
Branch area index	[m^2.m^{-2}]	1.72
Stem mass	[t.ha^{-1}]	43.98
Branch mass	[t.ha^{-1}]	19.92
Leaf mass	[t.ha^{-1}]	21.85
Stem mass increment	[t.ha^{-1}]	4.11
Branch mass increment	[t.ha^{-1}]	1.61
Leaf mass increment	[t.ha^{-1}]	1.77
Canopy coverage (1 = free place)	rel.u.	0.02

Soil and stem CO_2 efflux was measured using an automatic system SAMTOC (LEPFT, ILE, AS CR) (Pavelka et al. 2004) working as a closed system. Branch CO_2 effluxes were measured by portable IRGA system (Licor-6200), leaves effluxes using a portable IRGA system (CIRAS-1, PP systems). Amounts of the individual biomass components (stem, branch and leaves) were determined either from the diameter of breast height or by allometric relationships (site specific) obtained by the harvest experiment. The carbon storage and respiration were calculated for one meter high sections of the stand height profile.

Results

Total carbon content in the examined forest ecosystem presents important vertical differences (Fig. 1). Respiration activity of individual forest components depends on biomass quantity and temperature of the determined component. Thus, differences in total respiration were found at different levels of the vertical profile and different parts of forest stand mainly between night and day time. The proportion of leaf respiration on the total stand respiration during the white day was surprisingly high (Fig. 4). This result was obtained because the autotrophic process (photosynthesis) was separated from the heterotrophic processes (respiration) also within the level of leaves. Carbon bound in leaves represents 12% of the total carbon content of the stand (Fig. 2), but the proportion of leaf respiration on the total stand respiration is 50% in the night time and 55% in the day time (Fig. 4, 7). This can be explained with the high physiological activity of leaves. Vertical distribution of respiration activity influences instantaneous total carbon flux between forest and atmosphere. Atmospheric characteristics then influence final CO_2 concentration and its fluctuation within canopy (Fig. 5, 8).

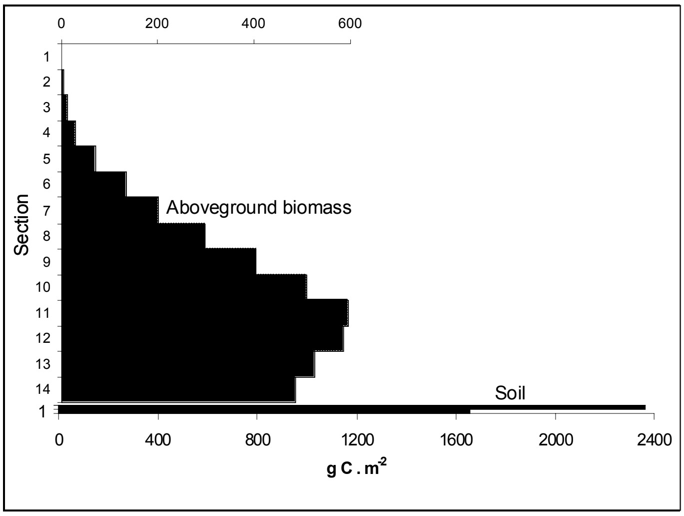

Fig. 1. Carbon storage in aboveground biomass (stem,branch and leave) and soil (total soil carbon including roots) in vegetation season 2002

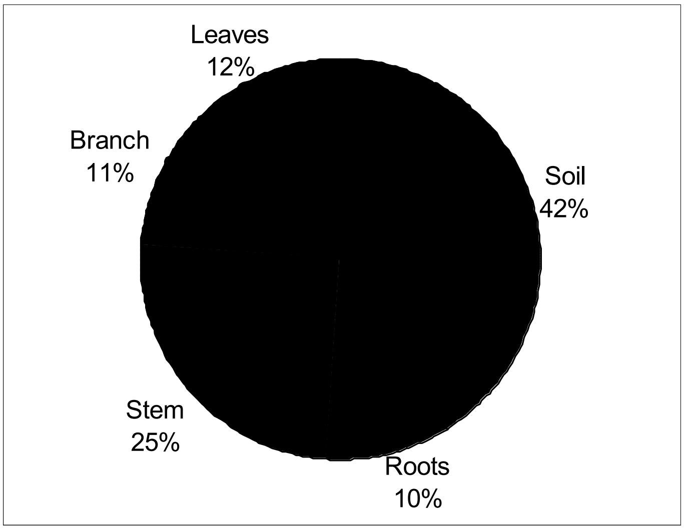

Fig. 2. Proportion of carbon storage in forest components in vegetation season 2002

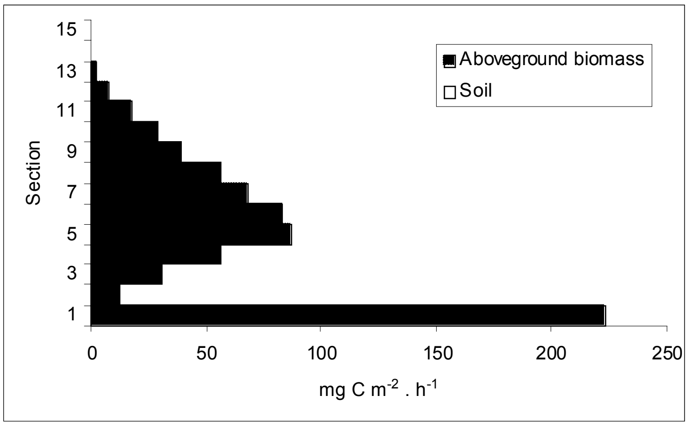

Fig. 3. Mean aboveground biomass and soil respiration during a day time periods (08:00–16:00) throughout vegetation season 2002

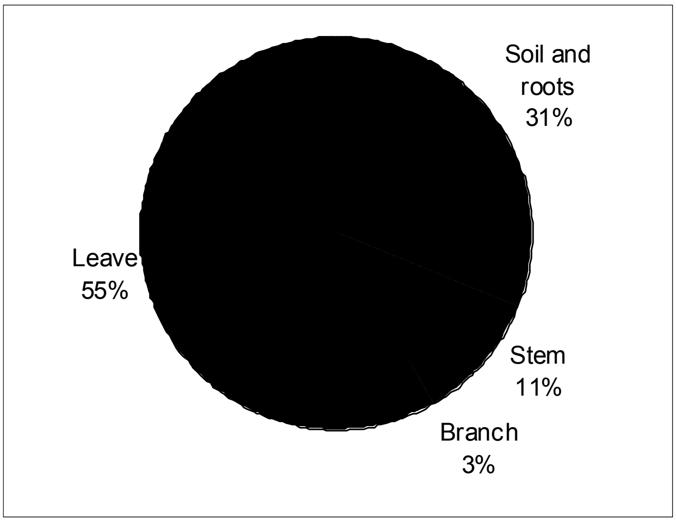

Fig. 4. Proportion of forest components in total respiration during a day time periods (08:0–16:00) throughout vegetation season 2002

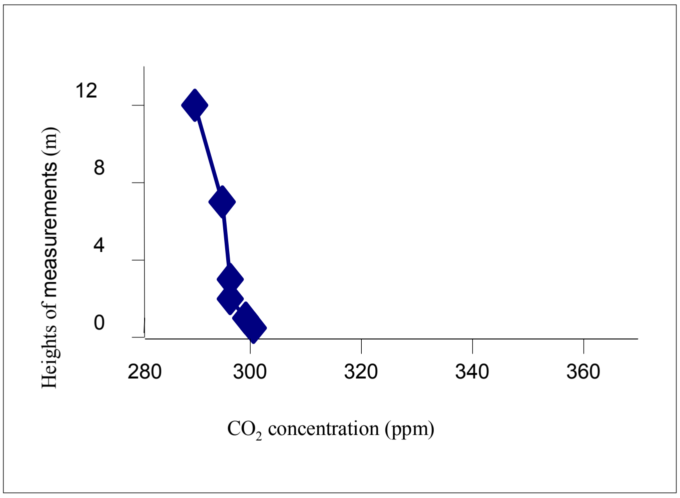

Fig. 5. Vertical profile of CO_2 concentration within spruce forest measured at 15:00 (sunny day)

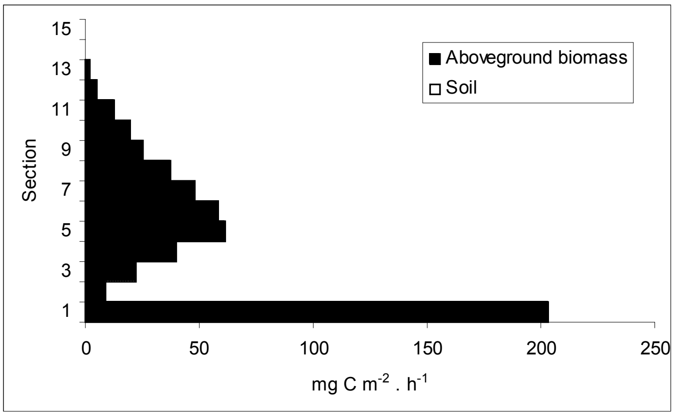

Fig. 6. Mean aboveground biomass and soil respiration during a night time periods (22:00–04:00) throughout vegetation season 2002

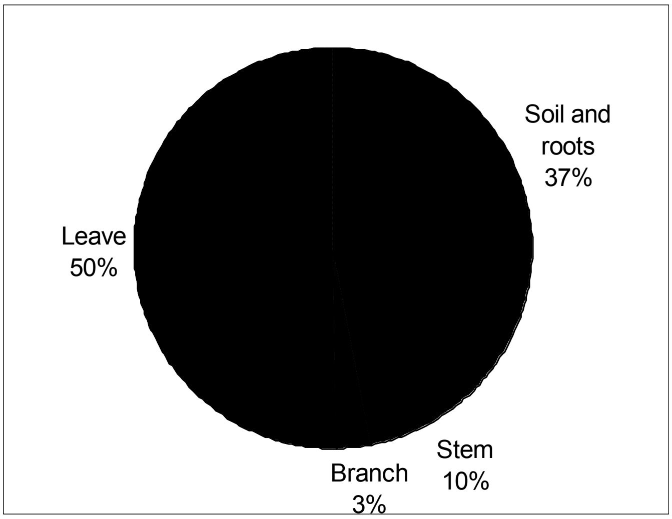

Fig. 7. Proportion of forest components in total respiration during a night time periods (22:00–04:00) throughout vegetation season 2002

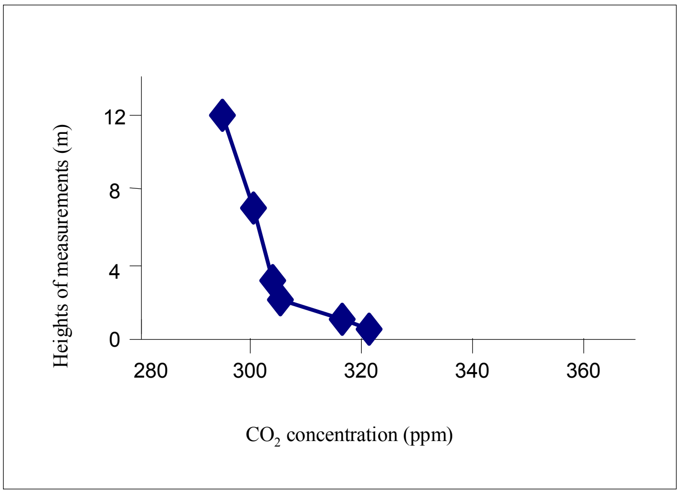

Fig. 8. Vertical profile of CO_2 concentration within spruce forest measured at 22:00

Conclusions

Vertical distribution of biomass and respiration activity within a Norway spruce stand was estimated. Respiration activity of different vertical sections of the stand depends on biomass distribution. Moreover, it depends on temperature of respiring parts. The highest proportion of the total stand respiration was found in leaf respiration during the white day period when the temperature of leaves is high, and the proportion of leaf respiration on the total respiration was about 50 %. Results are important for estimation of the amount of CO_2 flux leaving the stand in the way alternative to turbulent motion.

Acknowledgements

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ZDROJE UHLÍKU VE VERTIKÁLNÍM PROFILU SMRKOVÉHO POROSTU

Súhrn

Zdroje CO_2 ve smrkovém porostu byly rozděleny na jednotlivé části (půda, kmeny, větve, listoví). Toky CO_2 z těchto částí byly měřeny gazometricky pomocí infračerveného analyzátoru v průběhu vegetační sezóny 2002. Podíly zásoby uhlíku a respirace jednotlivých částí porostu byly počítány pro 1 m vysoké sekce pro celý vertikální profil porostu, a to zvlášť pro denní a pro noční periodu. Zásoba uhlíku v listoví činila pouze 12 % celkové zásoby porostu, ale listoví se podílelo na celkové respiraci porostu 50 % během nocí a 55 % během dní.

VERTICAL HYDRIC EDAPHOTOP DIFFERENTIATION DURING DRY WEATHER PERIODS

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Abstract: *Pichler, V., Gregor, J., Tužinský, L., Kontriš, J., Pichlerová, M.: Vertical hydric edaphotop differentiation during dry weather periods. In Folia oecologica. ISSN 1336-5266, 2003, vol. 30, no. 2, p. 207–213.*

Comprehensive soil physical analyses and field measurements were carried out at the Ecological Experimental Station Kremnické Vrchy Mts. from 1994 till 1995 with the objective to quantitatively assess the share of soil moisture potentialy available from deeper soil layers on the transpiration of the herbal layer consisting mainly of sedge Carex pilosa. The maximum upward flux measured during the two consequitive years was 0.03 mm per day from the depth of 50–70 cm to the topsoil. That amount covered just some 5% of the daily volume of water transpired by the ground flora.

Key words: common beach, herb layer, evapotranspiration, matrix potential

Introduction

The types of ecological conditions *sensu* Zlatník (1959) are indicated by patterns of corresponding phytocenoses and their members, location and ecotop patterns and other, ecologically derived site patterns. In this framework, a certain type of ecological conditions can be attributed to a phytocenosis, thus enabling the development of both forest phytocenological and typological systems that in turn serve a the well proven and tested basis for the close-to-nature forestry. Among the ecological conditions, the soil water regime ranks on the top of the list.

Plants take up soil water by extracting it from soil compartments adjacent to plant roots thus creating water potential gradients that in turn cause soil water to flow towards the roots. The soil water flux depends primarily on both the gradients and soil hydraulic conductivity that itself is a function of soil water content or potential respectively. There is a clear evidence that trees are able to extract soil water easily from depths up to four meters (Sternberg *et al*. 1996). But because the transpiration of the herb layer may reach 25–30% of the overall forest stand transpiration depending on the forest density (Buchter 1986), it can be assumed that the herbaceous layer generates measurable gradients inducing upward soil water movement when under certain conditions, i. e. in situations with the water content higher in deeper soil layers than in the topsoil. These situations are very common in beech forests (Bublinec 1990).

Soil water movement in the water potential gradient field towards tree root systems over distances of several meters has been suggested and partly documented by several authors (Borer 1982, Benecke 1984. Greminger 1984). The question remains open however whether herbaceous layer is able to generate similar gradient fields and thereby extract soil water from deeper soil layers as well. If not then the edaphotop of trees and herb layer wouldn't be the same. That would of course have significant consequences for the role of the forest floor vegetation as indicator of forest associations during periods featuring non-standard precipitation distribution due to climatic changes.

It is the objective of this paper and other contributions related to it to clarify whether, in principle, the herb layer is able to extract a physiologically significant amount water from soil layers outside of the direct reach of root systems, i. e. below 30–40 cm, and whether this ability depends on soil water distribution in the soil profile.

Material and methods

Experimental plots were established within the Ecological Experimental Station (EES) Kremnické Vrchy Mts., Central Slovakia (latitude 48° 38' N, longitude 19° 04' E). They were located on a clear cut area at an elevation 470 m a. s. l., on a western slope with an inclination of 15°. The mean annual temperature is 8.2 °C, 14.9 °C during the vegetation period. The mean annual precipitation is 664 mm, out of which 370 mm during the vegetation period. The soil was identified as Andic Cambisol with a 70 cm depth. The leading stand-forming association is *Dentario bulbiferae-Fagetum* Zlatník 1935 with locally present *Carici pilosae-Fagetum* Oberd. 1957.

Three measurement plots have been equipped with three series of tensiometers each, with suction cups installed at 10 cm, 30 cm, 50 cm and 70 cm depth. Measurements of soil water potential ψ_w were taken by means of Marthaler's transducer (Marthaler 1983), once a week in from 1994 till 1995. After the analysis of the time series of the matric potential data, two typical situations were identified, when the upward water flow occurred. Either there were high gradients accompanied by low soil hydraulic conductivity due to very low soil water potentials during the period of drying out, or *vice versa*, a higher hydraulic conductivity at lower gradients and higher water potentials after a precipitation cluster (Table 1). These two characteristic situations were not equal in terms of upward flux as the dependence of soil hydraulic conductivity on water potential is strongly non-linear (Fig. 1). In order to determine the upward soil water flux we employed the Darcy-Buckingham equation, i. e. Darcy law modified to fit unsaturated conditions.

$$í = -K_{øW} \cdot \frac{Äö}{z} \qquad (1)$$

$$\Delta\Phi = \Phi_1 = \Phi_2 \quad (2)$$

$$\Phi_1 = \psi_{w1} - \psi_{g1} \quad (3)$$

$$\Phi_2 = \psi_{w2} - \psi_{g2} \quad (4)$$

ν – flow velocity [cm.s^{-1}],
$K(_{\psi w})$ – hydraulic conductivity as a function of soil water potential at 40 cm [cm.s^{-1}],
$\Delta\Phi$ – difference in total water potential [hPa],
z – vertical distance between two measurement points of Ψ_{w1} [cm],
ψ_{w1} – soil water potential at 70 cm [hPa],
ψ_{w2} – soil water potential at 10 cm [hPa],
ψ_{g1} – gravity potential at 70 cm [hPa],
ψ_{g2} – gravity potential at 10 cm [hPa].

Table 1 Soil matrix potential vertical distribution at two different stages of the local hydropedological cycle

Soil depth	**Matrix potential [hPa]**	
	Dry period (9. 7. 1994)	Medium dry period (22. 6. 1995)
10 cm	–800	–400
30 cm	–700	–300
50 cm	–200	–100
70 cm	–80	–60

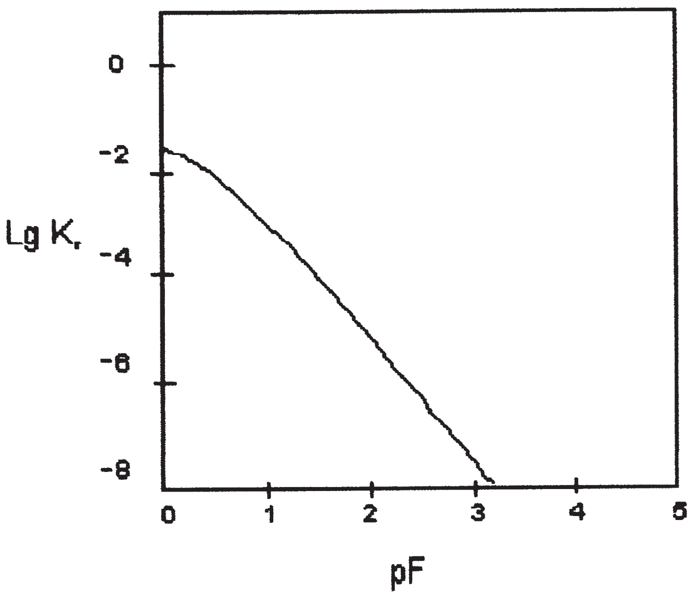

Fig. 1 Soil hydraulic conductivity as a function of soil water potential. pF = log($-\psi_w$). ψ_w is given in hPa

The reference point of the coordinate system was placed in the 70 cm depth whereas the positive part of the vertical axis pointed upwards. Sign convention was thereby defined. The unsaturated hydraulic conductivity was calculated based on Van Genuchten's equation (Van Genuchten 1980) and water retention curves measured in the laboratory using undisturbed soil samples. We proceeded by calculating the unsaturated hydraulic conductivity according to Mualem (1986). In doing so, we first determined saturated soil hydraulic conductivities using the method of falling pressure head (Klute, Dirksen 1986). Then we established relative unsaturated hydraulic conductivities for each respective soil depth and finally coupled both saturated and relative unsaturated conductivities.

Results

Based on the soil water potential distribution according to soil depth and the soil hydraulic conductivity we calculated the upward soil water flux from the 70 cm layer to 10 cm layer effected by the herb layer of the association *Carici pilosae-Fagetum*. When we considered the first situation with a high absolute gradient with a corresponding soil hydraulic conductivity at approximately – 450 hPa (Tab. 1, Fig. 2), the flux reached only 0.01 $mm.day^{-1}$ (1 mm equals 1 $l.m^{-2}$). This case was typical of the period drying when the soil was drying out most intensively in shallow depths while the deeper soil layers still retained a considerable amount of soil water. But even when the process of drying out was interrupted by a precipitation cluster at the end of August 1994 (Fig. 3) and subsequent rise of matrix potential in the topsoil, the maximal water flux still averaged 0.02 $mm.day^{-1}$ only. These fluxes were directly related to water extraction by roots from the topsoil and the evaporation from the soil surface (Novák 1995).

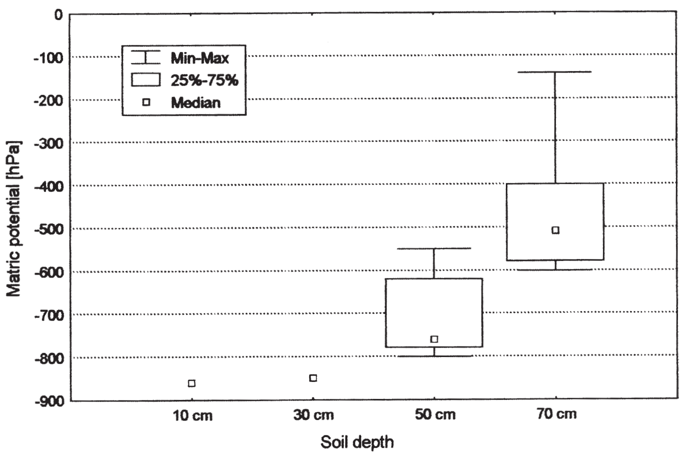

Fig. 2 Soil matric potential in the control stand on 22. 8. 1994, three days prior to the beginning of a rapid recharge

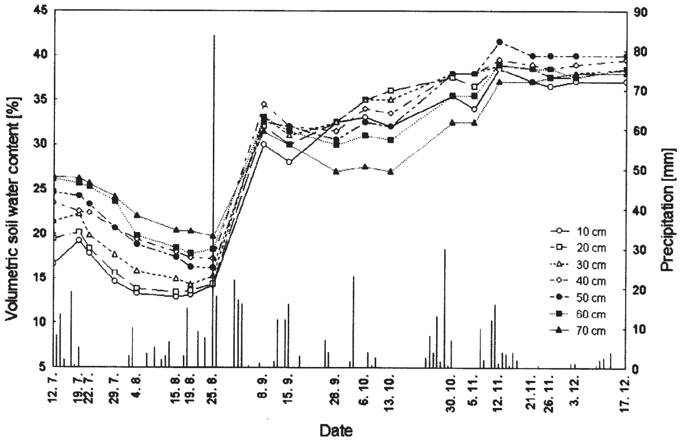

Fig. 3 Depth-specific volumetric soil water content in the control stand during the transition period from mid-July to mid-December 1994

Similar results in terms of upward water flux regardless different soil matrix potential distribution were due to a sharp decrease in the unsaturated hydraulic conductivity at – 250 hPa and – 450 hPa respectively. In other words, the driving force of the upward flow resulting from a high matrix potential gradient was strongly reduced by a low hydraulic conductivity. In the first case, the soil water potential $\Delta \Phi/z$ was 2.4 times higher than in the second case, but the hydraulic conductivity decreased by factor 6.3.

Discussion

The higher flux corresponding to daily transpiration of 0.02 mm.day^{-1} compares well to data obtained by Kantor (1995) who established an average daily evapotranspiration of well developed clearcut weeds vegetation to be about 0.88 mm.day^{-1}. The difference was related to different types of ground vegetation – *Carex pilosa* monocenose as opposed to rank clearcut vegetation, as well as to the fact that our calculation didn't include the interception component and water uptake from the topsoil. Similarly, our results were in line with those of Buchter (1986) who determined daily evapotranspiration of ground vegetation growing in a gap inside of a beech stand at 0.6 mm.day^{-1}. In this case, the effect of trees as well as interception must once again be accounted for, thus explaining the differences.

It ensues from our experiment, that in loamy soils the upward, gradient driven water flux lacks ecophysiological significance. During that period soil water extracted from the topsoil can hardly be replenished from deeper soil layers. With advancing decrease of soil water potential however the soil hydraulic conductivity drops much faster than the gradients rise and so water stored in deeper soil layers gets out of range for the roots of herbaceous layers and thus it becomes unavailable. It also implies that water in deeper soil layers can be effectively used up only by trees which in turn clarifies a positive role of forests in reducing run-off peaks compared to open areas.

Conclusions

Based on the soil water potential distribution according to soil depth and the soil hydraulic conductivity we calculated the upward soil water flux from the 70 cm layer to 10 cm layer induced by herb layer, association *Carici pilosae–Fagetum* Oberd. It ranged from $3.4.10^{-8}$ $cm.s^{-1}$ or 0.01 $mm.day^{-1}$ to $7.0.10^{-8}$ $cm.s^{-1}$, i. e. 0.02 $mm.day^{-1}$. The vertical soil water potential distribution along the soil profile that changed over time due to the advancing process of soil drying had only a limited influence on the upward water flux in the soil profile.

In case of a non-standard distribution of precipitation, e. g. intense rains at the cost of a more evenly distributed, less intense precipitation events, combined with hot and dry periods, considerable amounts of water can quickly infiltrate into deeper soil layers and thus escape the from the reach of the roots. Then the ability of individual plant species to extract water from depths below 30–40 cm may become crucial for the momentary or long–term stability of plant associations. Frequent occurrence of above mentioned unusual weather patterns could well lead to a widening gap between the edaphotops of trees and the herb layer with consequencies for forest phytocenology and typology.

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VERTIKÁLNA HYDRICKÁ DIFERENCIÁCIA LESNÉHO EDAFOTOPU V SUCHOM OBDOBÍ

Súhrn

Z hodnôt vlhkostného potenciálu pôdnej vody v suchej a mierne vlhkej lesnej pôde sme vypočítali makroskopickú rýchlosť prúdenia pôdnej vody z hĺbky 70 cm do hĺbky 10 cm. Toto prúdenie bolo indukované evaporáciou z pôdneho povrchu a transpiráciou bylín asociácie *Carici pilosae-Fagetum* Oberd. 1957. Stanovená rýchlosť bola $8{,}28.10^{-9}$–$2{,}18.10^{-8}$ cm.s^{-1}, resp. 0,01–0,02 mm.deň$^{-1}$.m^{-2}. Makroskopická rýchlosť prúdenia z hlbších do vrchných pôdnych vrstiev bola zjavne limitovaná nízkou hydraulickou vodivosťou pôdy v hĺbke 40 cm pri nízkom vlhkostnom potenciály. V prvom prípade bol gradient celkového potenciálu pôdnej vody 2,4-krát vyšší no hydraulická vodivosť 6,3-nižšia ako v druhom prípade. Napriek odlišnosti rozdelenia vlhkostného potenciálu podľa hĺbky preto nedošlo k dramatickej zmene schopnosti bylinnej vrstvy doplniť vlhkostný deficit z hlbších pôdnych vrstiev.

Pri vysušovaní lesných pôd v bezzrážkovom období rozhoduje diferencovaná schopnosť vegetácie prekoreniť hlbšie vrstvy profilu. Vplyv gradientov vlhkostného potenciálu na prúdenie pôdnej vody pri nízkych hodnotách potenciálu mal len podružný význam, daný nízkou hydraulickou vodivosťou. Bylinná vegetácia je preto na výkyvy vodného režimu pôdy podstatne citlivejšia ako dreviny. Príčinou toho je odkázanosť vrstvy bylín predovšetkým na vlahu vo vrchných 30–40 cm profilu, ktoré dokáže prekoreniť a kde naviac musí konkurovať sacím koreňom stromového porastu.

INFLUENCE OF LIMING OF HEAVY-METAL-POLLUTED SOILS ON MICROBIAL BIOMASS IN THE RIZOSPHERE OF *PICEA ABIES* (L.) KARST. AND *TILIA CORDATA* MILL.

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Abstract: *Kromka, M., Harnová, K.: Influence of liming of heavy-metal-polluted soils on microbial biomass in the rizosphere of Picea abies (L.) KARST. and Tilia cordata MILL. In Folia oecologica. ISSN 1336–5266, 2003, vol. 30, no. 2, p. 215–221.*

Massive decline of secondary spruce stands in the Slovenské rudohorie Mts. has been studied for nearly a decade in various aspects. For this purpose, two experimental plots in the cadaster of the Nálepkovo village were established (localities "Surovec" and "Zahájnica"). This contribution is principally focused on the influence of liming on the biomass of microorganisms in topsoil of the attacked soils on these experimental plots. Considering certain soil characteristics, along with the effect of liming, the effects of chosen tree species (Picea abies, Tilia cordata) and of site on soil properties were observed. Six years after the application of liming, an increase in soil pH and base saturation values was noted on both localities as a result, though leading to different microbial reactions of the plots to liming. The soil samples taken from below spruce in comparison with those from below linden displayed different soil properties as well as microbial biomass. Differences between plots in share of micromycetes and bacteria were noted as well.

Key words: soil acidification, heavy metals, bacteria, micromycetes, spruce, linden tree

Introduction

Secondary spruce forests of the Nálepkovo village are considered to be a typical example of massive forest dying. This area is strongly affected by soil acidification and a high content of pollutants (especially mercury – Hg, exceeding in soils of the polluted area values of 2 $mg.kg^{-1}$, being accompanied by arsenic – As). These got into to soils as a result of long-range transport and deposition of emissions issued from the supposed distant, but mainly local industrial sources in Rudňany and Krompachy towns (Šomšák et al. 1995). The extented soil acidity of this region results in mobility of pollutants (Hg, especially), consequently leading to further negative impacts, such as deficiency of macronutrients (Ca^{2+}, Mg^{2+}. K^{+}), the toxicity of alluminium and the inhibition of soil organic matter decomposition (Dlapa et al. 1997).

The effect of liming is monitored by means of chemical parameters of the tested soils, microbiological changes (arising after a certain delay), and also vegetation changes. In terestrial ecosystems, the buffer capacity of soil and the adaptability of microorganisms to soil acidity contribute to the resistance of ecosystems to acid rains, however, to certain limits only. In highly acidified or heavy-metal-loaded soils, the amount and share of bacteria and actinomycetes is strongly reduced, as a result micromycetes are taking the main role in the microbial soil processes (Šimonovičová, Kocianová 1997).

Brief characteristics of the experimental plots

In 1996, two experimental plots in the cadaster of the Nálepkovo village were established in localities Surovec and Zahájnica, in order to test artificial forest regeneration and the application of liming. These plots are located on clearings originated after clear-cutting realised in autumn 1995. Five tree species (*Picea abies*, *Abies alba*, *Fagus sylvatica*, *Tilia cordata* and *Acer pseudoplatanus*) were planted on 10 parallel side-by-side areas of 0.15 ha (20 x 72.5 m) on both localities (Fig. 1.). The application of liming was provided in 1996. Each of the tree areas was divided into two parts: to a variant limed by fine dolomite dust – Dolvapvarinit (in amount of 4 t.ha^{-1}) and a variant without liming (Antoni 1997). The basic site-geobotanical and pedochemical characteristics of the plots are presented in Table 1. Five applications of the fine dolomite dust in amount of 4 t.ha^{-1} at six year intervals were planned according to Šomšák et al. (1995).

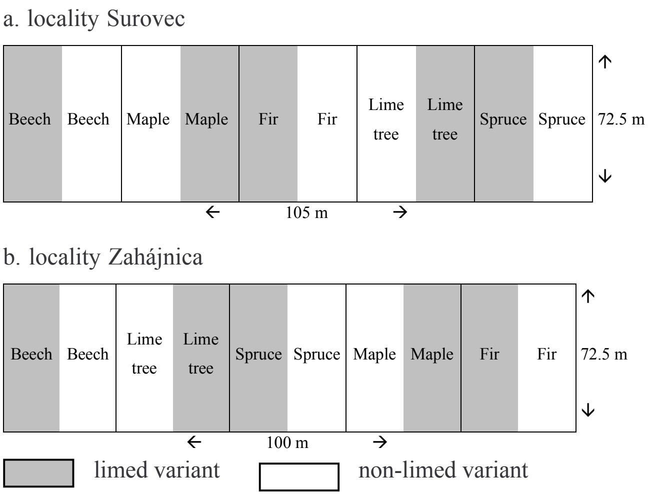

Fig. 1. Experimental plots schemes

Table 1. Experimental plots characteristics

Locality	Surovec	Zahájnica
Altitude	800–870 m a.s.l.	630–690 m a.s.l.
Aspect	E	NW
Slope (%)	50	30
Soil subtype	dystric cambisol*	dystric cambisol*
Potential vegetation	Circaeo alpini-Abietetum Šomšák 1982	Luzulo albidae-Abietetum Oberd. 1953
Pollutant contents (mg.kg^{-1}) in Ao horizon (0–5 cm)	As = 62.4 Hg = 2.40	As = 39.3 Hg = 4.73

* *according to ISSS-ISRIC-FAO (1994)*

Material and methods

Soil samples were taken on 9. 5. 2001. On each plot, samples were taken from the rizosphere soil of Ao horizon (depth 0–5 cm), from variants treated and non-treated with liming of spruce and lime-tree (spruce taken as the target coniferous tree species, lime tree as deciduous ameliorating tree species). Then, the 8 soil samples (4 from each locality) were treated by standard methods, consecutively by using fine earths the soil and microbial parameters were determined. All analyses were provided in the laboratories of the Department of Soil Science FNS CU in Bratislava.

A. Determination of the soil characteristics

– soil reaction by potentiometric method in water suspension (pH H_2O), and leachate of 1M KCl (pH KCl),
– Cox (%) oxidimetrically (the wet way) using Walkey-Black method, modified according to Novák and Pelíšek (Klika et al. 1954),
– percentage of humus by multiplying the Cox (%) value and the constant 1.724 (Sotáková 1982),
– soil adsorption complex characteristics (values H, S, T, V) by Godlin's method (Hraško et al. 1962),
– soil subtypes by ISSS-ISRIC-FAO (1994).

B. Microbiological analyses

In acid forest soils, soil micromycetes and bacteria are the main microorganisms participating the most in all soil processes. The determination of their biomass was provided as follows:

– biomass of micromycetes mycelium according to Bernát et al. (1984),
– the biomass of bacteria by fluorescent method according to Schinner et al. (1993).

Both determination methods belong to direct microscopic methods. Since soil microorganisms are mostly heterotrophic organisms bound to soil organic matter, according to Bernát, Barunová (1982) it is often useful to calculate their biomass to soil Carbon weight ($\mu g.g^{-1}$ Cox) rather than to soil weight ($\mu g.g^{-1}$of soil). Thus, in our case differences arose between individual samples.

Results and discussion

Based on the analyses of the soil samples taken 6 years after the establishment of the experiment, we noticed an improvement of certain soil characteristics due to liming. Also, the effect of chosen tree species, of sites and of liming expressed on the biomass of microorganisms.

Compared to the situation in 1995 (Šomšák et al. 1995), the values of soil reaction in variants with liming increased from the alluminium to silicate buffer zone (according to Ulrich 1983 in Dlapa et al. 1997). The increase in soil adsorption complex – base saturation values (V %) (Table 2) was also ascertained. Similar improvement did not occur in the variants without liming. The obtained values of microbial biomass are presented in Table 3. Compared to the lime tree, all samples taken from below spruce showed lower values of pH, base saturation (V %), as well as the amount of organic matter (Cox %), however we observed a higher biomass not only in the acidotolerant micromycetes, but also the bacteria demanding the neutral soil reaction (Table 3). The fact that spruce's root system is shallow compared to the root system of lime-tree might be the cause of these results. Still, a long-time influence is needed for manifestation of the effect of chosen tree species to soil profile.

Table 2. Soil parameters (samples taken 9. 5. 2001 from Ao horizon, depth 0–5 cm)

Tree species	Locality	Soil reaction		C_{ox} %	Humus %	H	S	T	V %
		pH $_{H2O}$	pH $_{KCl}$			mval/100g			
Spruce	Surovec	5.85	5.21	7.60	13.10	8.40	34.80	43.20	80.56
	Surovec	4.13	3.24	10.60	18.27	22.00	6.80	28.80	23.61
	Zahájnica	5.09	4.23	6.60	11.38	12.60	15.60	28.80	55.32
	Zahájnica	4.12	3.31	4.80	8.28	17.00	3.60	20.60	17.48
Lime tree	Surovec	6.27	5.73	10.20	17.28	7.20	47.20	54.40	86.76
	Surovec	4.15	3.38	13.20	22.76	21.40	10.00	31.40	31.85
	Zahájnica	5.40	4.83	13.20	22.76	11.60	31.60	43.20	73.15
	Zahájnica	3.78	3.16	11.80	20.34	22.80	6.00	28.80	20.83

limed variant   non-limed variant

Table 3. Biomass of soil micromycetes and bacteria

Tree species	Locality	Micromycetes		Bacteria		Total	
		$\mu g.g^{-1}$ of soil	$\mu g.g^{-1}$ of soil C_{ox}	$\mu g.g^{-1}$ of soil	$\mu g.g^{-1}$ of soil C_{ox}	$\mu g.g^{-1}$ of soil	$\mu g.g^{-1}$ of soil C_{ox}
Spruce	Surovec	143.03	1 881.97	112.36	1478.43	255.39	3360.40
	Surovec	187.91	1 772.74	87.42	824.74	275.33	2597.48
	Zahájnica	89.41	1 354.70	102.83	1558.08	192.24	2912.78
	Zahájnica	79.27	1 651.46	142.62	2971.29	221.89	4622.75
Lime tree	Surovec	112.76	1 105.49	161.96	1587.80	274.72	2693.29
	Surovec	96.56	731.52	77.06	583.75	173.62	1315.27
	Zahájnica	74.5	564.39	106.20	804.51	180.70	1368.91
	Zahájnica	81.26	688.64	87.14	738.49	168.40	1427.14

limed variant   non-limed variant

Since the existence of soil microorganisms is bound to the soil organic matter, the total soil carbon content (Cox %) displaying differently on both plots regarding liming, is dependent on the amounts of determined microbial biomass. In the soil samples taken from plot Surovec, we observed a higher biomass of micromycetes, but a lower biomass of bacteria than in samples taken from plot Zahájnica. In total, the amount of microorganisms is higher in plot Surovec in the variants with liming, in plot Zahájnica in the variants without liming (Table 3). Considering the values of Cox (%) we assume, that liming on plot Surovec had a positive influence on microbial biomass, thus increasing the speed of organic matter decomposition. It is confirmed by the lower values of Cox (%) in these variants (Table 2).

This is in accordance with KOPČANOVÁ (1983) stating that, as a consequence of liming of acid soils an accelerated soil organic matter decomposition takes place. Similar influence of liming wasn't ascertained on plot Zahájnica. No doubt this is mainly a result of different ecological site conditions (lower pH, temperature, precipitation), probably also of a different extent of pollution.

The share of micromycetes and bacteria in the samples is presented in Fig. 2. The ratio between the two microbial groups was in several cases close to 1, in the other cases the dominance of either bacteria or micromycetes was more evident. In locality Surovec micromycetes prevailed over the bateria in the soil samples taken from below spruce and the ones from below lime tree without liming. On the other hand, on plot Zahájnica the bacteria prevailed in all samples despite the extremely low soil reaction in variants without liming, and the considerable pollution extent as well. Both localities create different conditions for these microbial groups. According to KOPČANOVÁ (1983), liming of acid soils results in increasing of the biomass of bacteria and actinomycetes and, on the contrary, reduction of the micromycetes biomass. This can clearly be seen in case of soil samples taken from below spruce in locality Surovec, less evidently in case of samples taken from below lime tree in locality Zahájnica (Table 3).

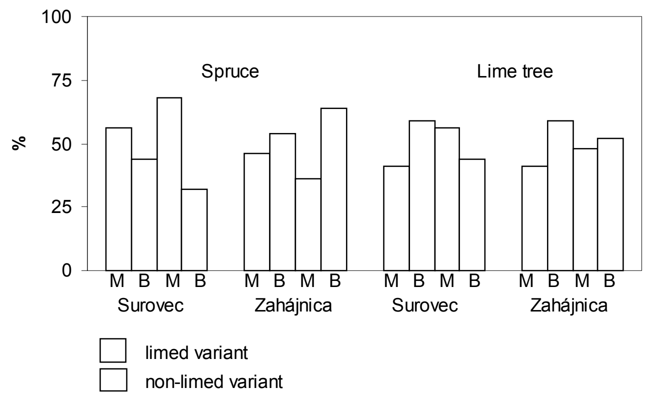

Fig. 2. Share of micromycetes (M) and bacteria (B) biomass from total biomass of both microorganisms

An overall comparison of experimental plots in localities Surovec and Zahájnica six years after the beginning of the experiment shows that these sites, besides ecological features (altitude, aspect, slope, climatic conditions etc.) differ also in soil and microbiological properties below spruce and lime-tree. To fully affect the soil profiles, a long-time influence of these factors is needed. Since our samples were taken in one term (May 2001), further experiments are needed to confirm the obtained results.

Conclusions

The effect of fine dolomite dust application as a treatment to polluted soils on the biomass of soil microorganisms was observed in the rizosphere part of topsoil of spruce and lime-tree. Liming of soils on both experimental localities had a positive effect on pH and base saturation values, though expressively different on the microorganisms biomass on these plots. It led to an increased biomass of microorganisms and thus to a faster organic matter decomposition on locality Surovec, but not on locality Zahájnica. The samples taken from below spruce, although displaying lower values of pH and base saturation showed higher biomass of both microbial groups (micromycetes and bacteria), compared to samples taken from below the lime tree. Both localities also provide different conditions for the existence of soil microorganisms. On locality Surovec, the biomass of micromycetes was higher than of bacteria, while on locality Zahájnica, bacteria prevailed in all samples, despite the less favorable topsoil properties.

Acknowledgement

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VPLYV VÁPNENIA PÔD ZNEČISTENÝCH ŤAŽKÝMI KOVMI NA MIKROBIÁLNU BIOMASU V RIZOSFÉRE SMREKA OBYČAJNÉHO (*PICEA ABIES* (L.) KARST.) A LIPY MALOLISTEJ (*TILIA CORDATA* MILL.)

Súhrn

V imisne zaťažených pôdach obce Nálepkovo (výskumné plochy na lokalitách Surovec a Zahájnica) sme sledovali vplyv vápnenia na mikróbnu zložku rizosférnej pôdy pod umelou obnovou smreka a lipy. Zároveň sme sledovali aj vplyv vybraných drevín a stanovišťa na biomasu pôdnych mikromycét a baktérií a stanovili niektoré pôdne vlastnosti. Po uplynutí 6 rokov od založenia pokusu sme na oboch plochách zaznamenali nárast hodnôt pôdnej reakcie a stupňa nasýtenia sorpčného komplexu. Avšak, vplyvom vápnenia došlo k zvýšeniu biomasy mikroorganizmov, a tým k zintenzívneniu mineralizácie pôdnej organickej hmoty len na lokalite Surovec. Z výsledkov ďalej vyplýva, že vyššia biomasa oboch skupín mikroorganizmov bola i napriek nepriaznivejším pôdnym vlastnostiam v pôde odobratej pod smrekom. Rozdiely medzi plochami sa prejavili i v pomernom zastúpení mikroorganizmov – na lokalite Surovec prevládali mikromycéty, na Zahájnici baktérie.

THE INFLUENCE OF AIR POLLUTION ON CONTENTS OF POLLUTANTS IN SOME COMPONENTS OF NATURE ENVIRONMENT IN THE PROTECTED LANDSCAPE AREA PONITRIE

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Abstract: *Ďurečková, E.: The influence of air pollution on contents of pollutants in some components of nature environment in the Protected Landscape Area Ponitrie. In Folia oecologica. ISSN 1336-5266, 2003, vol. 30, no. 2, p. 223–228.*

Since 1990 the investigations of quality of some components of nature environment were carried out on selected permanent plots in the PLA Ponitrie focused on pollutant contents. The sampling spots have been situated on the main ridge of the Tribeč Mts. and Vtáčnik Mts., as well as on windward slope on top area of the Vtáčnik Mt in altitudes of 530, 700, 1100 and 1340 m asl. oriented towards the Thermal power station in Nováky. The influence of air pollution on contents of pollutant in some components of nature environment in the Protected Landscape Area Ponitrie was studied.

The research was focused on

- *determination a development trend of precipitation quality within the observing period, furthermore to detect changes in pollutant concentrations after the passing through crown layer of the forest, as well as to define an influence of the distance from the emission source and influence of altitude of the permanent plot and, finally, to measure a deposition of pollutants.*
- *Seasonal changes of water chemistry of two selected mountain water springs.*
- *Dust fall (quality and quantity).*
- *Chosen heavy metals in biological mass.*

Key words: *pollution, precipitation quality, acidity, dust fallout, heavy metals.*

Introduction

The Protected Landscape Area (PLA) Ponitrie is composed of two orographic entities: the Tribeč Mts. and the Vtáčnik Mts. The vast area of the PLA is covered mostly by forest complexes. The highest point of the area, the Vtáčnik Mt (1346 metres above sea level), is included in the national nature reserve. The territory is under the direct impact of over-regional emission sources from thermal power station and aluminium works. Annually the both plants emit immense quantities of air pollutants, having the significant effect on health conditions in tree tops.

The most of the anthropogenic pollutants is transported into the territory of PLA Ponitrie by air masses, either in dry or wet way. At the same time, location and character of the emitters pose the determine role in dispersal of pollutants, as well as prevailing wind directions from the north and northwest, frequent occurrence of prolonged inversions and also a character of georelief. The main ridge of both mountains, ranging in the southwest – northeast direction, forms a natural barrier for pollutant transportation (Ďurečková 1999).

Material and methods

Since 1990 the immission load was controlled in forest ecosystems within the territory of the PLA Ponitrie by means of precipitation quality. The permanent research plots were located within forest stands and open forest-free areas as well. The sampling plots were situated firstly on the main ridge in direction of prevailing air flows from the pollution source (Fig. 1), secondly on windward slope in top position of the Vtáčnik Mt oriented towards the Thermal power station in the Nováky in altitudes of 530, 700, 1100 and 1340 metres a.s.l.

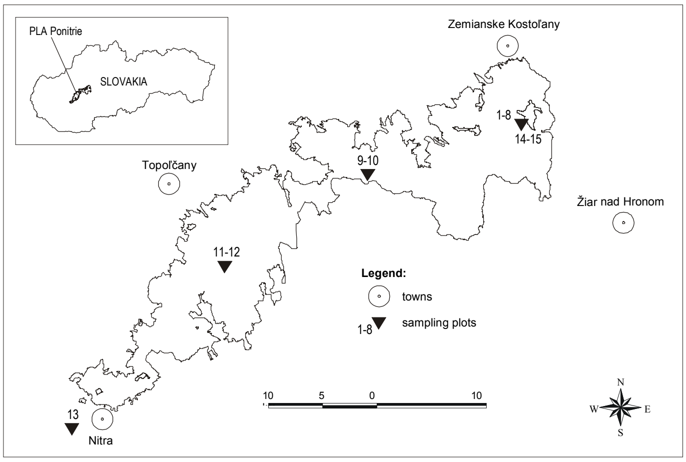

Fig. 1. Locality of sampling plots in Protected Landscape Area Ponitrie

Since 1997 was followed also quality and quantity of dust fallout at the same permanental plots. The analyses were realised in cooperation with The Institute of Geotechnics Slovak Academy of Science in Košice. At the same time were sampled leaves, needles and some higher plants. In the samples were determined contents of sulphur, fluorine and selected heavy metals. The analyses were realised in laboratory of Slovak environmental agency in Bratislava.

The samples of precipitation and underground water were taken monthly and analysed in the laboratories of the State Health Institute in Nitra. The content of sulphates, nitrates, fluorides, chlorides, arsenic and rate of hydrogen-ion concentration (pH) were measured.

The samples of dust fallout were exposed during 6 months and taken too times a year. The samples of biological mass (leaves, needles and plants) were taken at the end of vegetation period.

The objectives of the research were:

- to observe and evaluate precipitation water quality on selected permanent research plots within forest stands and open areas of different altitude in order to include positions from the foothill up to the apex to consider a vertical gradient of pollutant dispersal, to compare the rate of pollution in different sorts of precipitation (snow, rain, hoarfrost) and to detect a trend in precipitation quality development within the observing period,
- to estimate a change in precipitation quality within the crown layer and to characterise a stemflow in beech forests,

- to compare the precipitation quality in permanent plots on ridge area with respect of a distance from pollution source and to estimate a deposition of controlled pollutants in permanent plots on open areas and within the forest stands,
- to observe Quality of underground water in selected mountains with trends on their acidity under the early period influences from melting snow with an increase in contents of polluting matter,
- to estimate a quality and quantity of dust fallout with trends on heavy metal contents,
- to estimate contents of selected heavy metals in the leaves, needles and some higher plants at the monitoring plots.

Results and discussion

During the observing period, since 1990, the contents of sulphur and nitrogen oxides as well as solid pollutants decreased up to one third of the initial volumes. This was partly due to technical and technological measures, partly after production conversion in the thermal power station in Nováky and the aluminium works in Žiar nad Hronom, both sharing a significant rate of influence on air quality in this region. These facts had an effect also in precipitation quality, as the contents of chloride and fluoride anions as well as arsenic decreased roughly of one half. The decrease was not registered in a content of nitrate and sulphate anions. Moreover, there was no evident improvement in precipitation acidity. Apparently, this might relate to an effect of some global and over regional processes such as global decrease of total precipitation, an enormous increase of automobile transportation in the last decade, which could consequently reflect in chronically poor precipitation quality (Ďurečková 2000). Thereby, just the processes mentioned above can affect the emission abatement measures on regional level and related expectations of the precipitation quality improvement.

Following the analysis it is definitely claimed that the precipitation quality do not improve with increasing distance from the pollution source (Fig. 2).

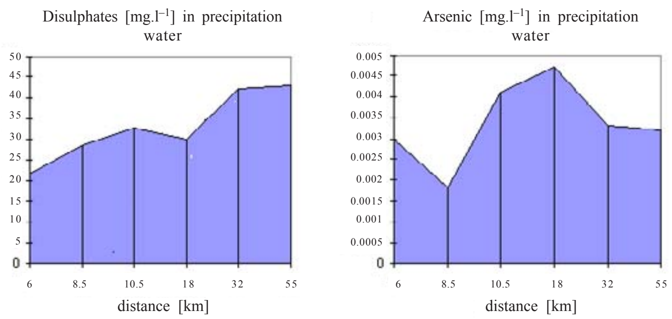

Fig. 2. Influence of distance on quality of precipitation water

A higher concentration of the measured indicators in the precipitation from central and eastern parts of the Tribeč Mts. was detected, comparable and in many cases considerably higher than that in the precipitation from the top areas of the Vtáčnik Mt, which primarily seemed to be more attacked area by the emissions from power station in Nováky. Explicitly, the influence of prevailing airflow directions as well as the construction of high smokestacks (200 and 300 m) in both plants was proved. The smokestacks of such height have different dispersal characteristics than lower ones existed there up to seventies, which affected mainly close neighbourhood of the source.

The influence of altitude on pollutant deposition in precipitation is not to be estimate explicitly. Generally, the concentrations in precipitation water increased with higher altitude (Ďurečková 1998), nevertheless the effect of prolonged inversions ascending up to 700 m a.s.l. was proved significantly. Also the precipitation acidity shows an increasing tendency with higher altitude (Fig. 3).

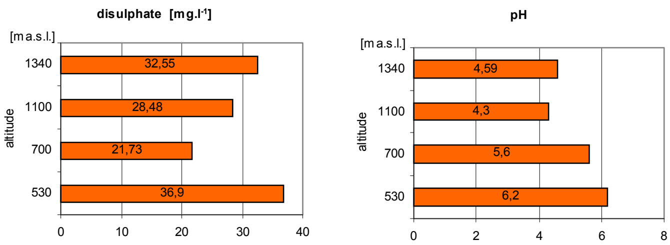

Fig. 3. Quality of precipitation water in open areas with respect on altitude of the permanent plots

Furthermore, the volume of measured indicators was compared in different sorts of precipitation (rain, snow, hoarfrost, icing, ice) from the top of the Vtáčnik Mt. (Table 1).

Table 1. Concentration of spotted indicators [$mg.l^{-1}$] on different types of precipitations in the top of the Vtáčnik Mt (1346 m a.s.l.)

	disulphate	nitrate	Fluoride	chloride	arsenic	pH
rain	32.6	2.91	0.064	4.05	0.0041	4.59
snow	27.7	3.65	0.052	2.17	0.0095	3.7
hoarfrost	17.5	9.5	0.195	4.26	0.0028	3.72
icing	9.6	0.2	0	1.42	0.005	2.47
ice	17.3	0	0.035	1.4	0.003	4.4

The icing and ice samples were collected by means of snap sampling (at a particular time and place). The increased content of nitrates, fluorides and chlorides in hoarfrost was observed as an effect of formation process by means of desublimation under freezing and calm together with the accumulation of higher volume of pollutants under the adverse dispersal conditions. The cumulation of pollutants in horizontal precipitation was confirmed also by Škvarenina (1998).

The polluting load of forest stands in territory of the PLA Ponitrie was calculated by means of multiplying the measured pollutant concentration in precipitation with total precipitation appropriate for a specific permanent plot. The most loaded areas were detected on plots in top positions of the Vtáčnik Mt. In the open forest-free areas, sulphate sulphur content per year reached to 14.5 g.m^{-2}, nitrate nitrogen 1.6 g.m^{-2}, fluorine 0.0845 g.m^{-2}, chlorine 4.77 g.m^{-2}, arsenic 0.0078 g.m^{-2} and hydrogen cations 0.098 g.m^{-2}. The nitrogen load in these areas exceeded the critical limit (Križová, Ďurečková 2000), representing the long-term nitrogen supplies greater than 15 kg.ha^{-1} per year (1.5 g.m^{-2} per year), having destabilising effect on the forest ecosystem.

Even more critical situation relates to pollution loads estimated from the precipitation under tree-crowns. The combine deposition of in spruce forest on the Vtáčnik Mt increases to 24.2 g.m^{-2} (per year), 3.3 g.m^{-2}, fluorine 0.0986 g.m^{-2}, chlorine 4.73 g.m^{-2}, arsenic 0.0158 g.m^{-2} and hydrogen cations 0.5075 g.m^{-2}. In beech forest on the Vtáčnik Mt the content of sulphate sulphur was 15.6 g.m^{-2}, nitrate nitrogen 2.3 g.m^{-2}, fluorine 0.1168 g.m^{-2}, chlorine 4.61 g.m^{-2}, arsenic 0.0154 g.m^{-2} and hydrogen cations 0.1062 g.m^{-2} per year.

The influence of the forest stand on precipitation enrichment expressed by enrichment coefficient registered the most in the spruce forest in top position of the Vtáčnik Mt as well as in the beech forest in Kolačno. The highest value of the coefficient was measured in spruce forest on the Vtáčnik Mt, where the deposition increased more than 5 times by protons because of the precipitation passing through the forest stand (Ďurečková 2002). Consequently, pH value of precipitation under tree-crown decreased extremely therefore induces secondarily soil acidification within the forest stand. Compared with another stands, the values of enrichment coefficients for sulphate sulphur, nitrate nitrogen and arsenic in top spruce forest are definitely the highest. The known ability of coniferous to absorb increasingly the immisions owing to larger active surface of their assimilatory organs is proved here remarkably.

The high enrichment coefficient was also documented in the precipitation sampled from the stemflow in beech forest in the Bystričianska valley. Acidity of waters in mountains springs increased during the period of the investigation especially in early period. There was proven the influence of melting snow with an increased contents of polluting matter.

Conclusion

The increased concentration of sulphates in the precipitation from the Vtáčnik Mt was confirmed by means of high deposition volumes of sulphate sulphur in comparison with other parts of Slovakia. According to Bublinec and Dubová (1993), the volume of annual sulphur deposition in spruce forests in Slovakia ranges from 70 to 90 kg on hectare per year. The volume recorded within our investigations on the Vtáčnik Mt was up to 242 kg on hectare per year. The volumes of annual sulphur deposition in beech forests in Slovakia range from 19.1 to 43.6 kg, on the Vtáčnik Mt 156 kg on hectare per year. These high volumes detected on the Vtáčnik Mt indicate an influence of close emission source of over regional importance, which burns coal with higher contents of sulphur. SO_2 represents a determining component of the emissions. Estimation of dry deposition of sulphur caused by SO_2 was roughly 15 % of total deposition in precipitation. The increased volume of pollutants in spotted samples on particular permanent plots documents a high polluting load of forest ecosystems in ridge part of the mountains.

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IMISNÁ ZÁŤAŽ LESNÝCH EKOSYSTÉMOV V CHRÁNENEJ KRAJINNEJ OBLASTI PONITRIE

Súhrn

Hlavným cieľom práce bolo podať obraz o imisnej záťaži lesných ekosystémov v Chránenej krajinnej oblasti Ponitrie. Územie je pod vplyvom dvoch zdrojov znečistenia ovzdušia nadregionálneho významu Tepelnej elektrárne Nováky a Závodov na výrobu hliníka v Žiari nad Hronom. Od roku 1990 sme sledovali kvalitu zrážok na trvalých výskumných plochách v lesných porastoch a na voľných plochách situovaných na náveternom svahu Vtáčnika orientovanom k Tepelnej elektrárni v Novákoch a na hlavnom hrebeni Vtáčnika a Tríbeča v smere prevládajúcich prúdení od zdroja znečistenia. V roku 1997 bolo na identických plochách zahájené sledovanie kvality a kvantity prašného spadu a odobraté vzorky listov, ihličia a vyšších cievnatých rastlín na analýzu obsahu ťažkých kovov.

Pokles emisií u oboch podnikov o viac ako polovicu množstva oproti pôvodnému stavu sa prejavil zlepšením kvality zrážok u viacerých sledovaných ukazovateľov.

Kvalita zrážok sa so zväčšujúcou vzdialenosťou od zdroja znečistenia nezlepšovala. Koncentrácia znečisťujúcich látok v zrážkach sa v globále zvyšovala s nadmorskou výškou. Najviac imisne zaťažené boli plochy v oblasti hlavného hrebeňa Vtáčnika, čo potvrdili aj údaje zo sledovania prašného spadu.

V práci bol porovnaný obsah znečisťujúcich látok v rôznych typoch zrážok (dážď, sneh, inoväť, námraza, ľadovka). Ďalej bola sledovaná sezónna dynamika znečisťujúcich látok v podzemných vodách horských prameňov v oblasti Vtáčnika (1346 m n. m.). Vplyv zvýšeného obsahu znečisťujúcich látok antropického pôvodu zistených v zrážkových vodách a snehu sa prejavoval acidifikáciou vôd prameňov predovšetkým v jarnom období pri rozsiahlom topení snehu.

ON ACTIVITY OF ARTHROPODS IN FOREST ECOSYSTEMS

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Abstract: *Majzlan, O., Fedor, J. P.: On activity of arthropods in forest ecosystems. In Folia oecologica. ISSN 1336-5266, 2003, vol. 30, no. 2, p. 229–237.*

The study of activity of arthropods in forest ecosystems requires using special methods. These are quantitative methods aimed to obtain information on structure and function of arthropod populations and communities. For more than 20 years we have been using various equipments to study activity of arthropods in forest ecosystems. They include the use of Malaise traps, tree, soil and air photoeclectors as well as biocoenometers. Using these techniques we have obtained plenty of faunistic and ecosozological data on beetles and other arthropods.
Key words: *arthropods, activity, ecology, forest ecosystems*

Introduction

Activity and life attributes of arthropods are based on influences of various intraspecific (endogenous) and interspecific (exogenous) relationships. Intraspecific dimension of activity appears among specimens of the same species and works in populations. Heterotypic groups of animals, considered as communities, are controlled mainly by territorial and trophic competition relationships.

Research on activity of arthropods, especially insects, is realised under in situ (field) or ex situ (laboratory) conditions. It is the activity under in situ conditions, that provides useful data and information on population dynamics. Recently more intensive research has been focused on territorial activities, recolonization of areas, revitalisation, renaturation, rehabilitation, restitution as well as recultivation. All these re-activities form suitable conditions to renovate damaged elements of biotope mosaic in whole ecosystems. Study of arthropod activities requires various methods and approaches as well as final synthesis.

Migration activity can be considered as one of insufficiently studied problems. In spite of this horizontal and vertical migration of insects has been studied especially on a level of tree protection.

Material and methods

To study activity of arthropods we chose less common methods (of quantitative character) in the field conditions:

- Using a Malaise trap (MP).
- Study on horizontal migration of arthropods with the help of tree photoeclectors (T-POT).

- Research on vertical migration using hung air trap (A-POT).
- Changes in population density of arthropods studied by soil photoeclectors (S-POT).
- Soil biocoenometers.

Malaise traps

A Malaise trap (Fig. 1a) works automatically during its exposition period. Its construction refers to a standard scale, accepted in various countries. The skeleton is formed by aluminium pipes with a fixed net textile. The side wall is made of black net textile, the roof is white. The plastic collection jar was filled by 75 % ethanol. The skeleton is fixed by tightening ropes to increase stability of a trap. The trap does nor require any attractants to attract arthropods.

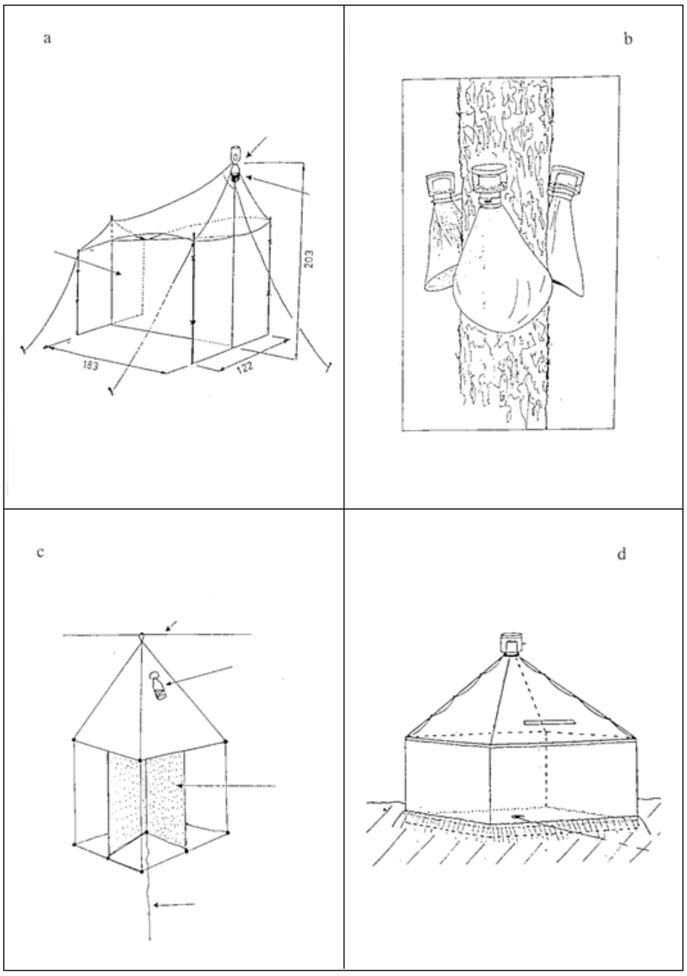

Fig. 1 A sketch of the traps. A – Malaise trap, B – tree photoeclector, C – air photoeclector, D – soil photoeclector

Placing a Malaise trap plays an important role. The traps were installed in various types of biotopes. Certain problems may appear due to its weakened durability. The analysed material of beetles has been deposed in the Slovak Museum of Nature Conservation and Caves in Liptovský Mikuláš. The rest is conserved in ethylalcohol and deposed at the Institute of Zoology SAS in Bratislava. Totally, we analysed material from 50 Malaise traps.

Tree photoeclectors

To study vertical migration of arthropods we used a method of tree photoeclectors (POT) according to the construction by Funke (1971).

For the first time we exposed tree photoeclectors in 1985–1986 to study a trachaeomycotic diseases of oaks in Slovakia (graphiosis). The tree photoeclectors were set on trunks of oaks in the Nature reserve Lindavský les (Trnavská plain) in the cadastral area of Píla. The traps were installed on unhealthy trees with different stage of damage and on an artificial tree at the height of 0.7 and 5 m above the ground. Together we exposed the photoeclectors on 4 living oaks, 2 on dead trees and 1 on the artificial trunk. A tree POT is equipped with 3 collection, containing picric acid as a conserving medium. (Fig. 1b).

In 2000 we set 2 tree photoeclectors on trunks of chestnut *Aesculus hippocastanum* in the park in the village of Ivanka pri Dunaji (Majzlan, Fedor 2003). One trap was installed at the height of 1 m (lower POT), the second one on the other tree at the height of 5 m above the ground (upper POT). The traps were fixed on trunks using a wire. Any space between the construction and trunk was filled by putty. Tree photoeclectors work on basis of positive phototaxy and negative geotropism as well as visual orientation of arthropods, especially insects. In 2001 and 2002 we continued studying vertical and horizontal migration of arthropods.

Air-photoeclectors

A hanging air trap – air POT is similar to a Malaise trap by its construction. The principle of capturing insects as well as other arthropods (Araneae, Pseudoscorpionidea), is based on active or passive flight activity. Landing is possible due to an open bottom, a jar with a preserving medium is located in the upper part (Fig. 1c). The trap was installed in crowns of chestnut trees (at the height of 10 m) with the help of pulley. It is made of aluminium and its side walls of net textile.

Soil photoeclectors

Soil photoeclectors are a rarely used and untraditional entomological method. They cover isolated space above certain soil area, usually 1 m^2. The trap is constructed of side walls (plastic, tin) with a bar skeleton covered by net textile and equipped with a collection jar (Fig. 1d). Huge space inside a trap even let us use ground traps, which can provide additional data on soil non-flying organisms (macrofauna, edaphon), orienting by a positive phototaxy. Picric acid may be used as an ideal conserving medium, ground traps work with 4 % formaldehyde or technical ethanol.

Such a type of soil photoeclector was used by Prof W. Funke in his MaB project in Sollingen in 1971. His team was able to solve several ecological problems connected with basic and applied research. They compared various changes in soil cover according to hatching of insect adults, expressed as a hatching phenology of insect adults. In a soil POT they simulated spraying by herbicides and pesticides, burning grasslands, contamination of soil by oil products and so on. Comparison of hatching phenology as well as total abundance per year or evaluation of biomass enabled them to study influences of these negative factors on soil fauna.

Biocoenometers

During the year 2001 we were focussed onto hatching phenology of arthropod adults (macrofauna, eclectorfauna), especially insects (Hexapoda s.l.), using biocoenometers. At a forest site under chestnut trees we installed 4 POTs with a mutual distance of 1 m. Each POT covers the area of 0.125 m^2. Four soil POTs reflected hatching of insect adults (their hatching phenology) from 0.5 m^2. Every month we reinstalled the POTs in a new place under chestnut trees to cover litter (Majzlan, Fedor 2002). This type of POT was non-stationary in comparison with a stationary one installed in the previous year. (Majzlan, Fedor 2001b). The stationary type was permanently situated on the area of 1 m^2 to record activity of arthropods during a whole year. This trap captures insects in their reproductive phase hence we did not snap a new generation. However, a non-stationary type has its advantages, e.g. it provides more realistic data on hatching phenology of insect adults.

Results and discussion

Malaise traps

Using this method we recorded 1,488 beetle species in the period of 1983–2002 (Majzlan 2002). This relatively rich material includes 64 ecosozologically significant species. Eight of them can be considered as endangered (EN), 15 classified in the lower risk category (LR) and 41 as vulnerable (VU), following the IUCN (1995) criteria. We enriched the last category (VU) by listing other species threatened in Slovakia: *Apion variegatum, Calopus serraticornis, Cicindela germanica, Hallomenus binotatus, Lomechusa paradoxa, Sparedrus testaceus, Xanthochroa carniolica*. Occurrence of these species refers to specific site conditions, they often occur locally and rarely.

Some of the beetle species recorded are listed in the directives of the European Union (considered as significant for European point of view and occurring in Slovakia): *Cucujus cinnaberinus* and *Lucanus cervus*. They require special conditions to conserve their biotopes, which can be included into the Networks of of Natura 2000.

The method also brought new species for the fauna of Slovakia: *Atheta nigerrima, Allonyx quadrimaculatus, Gabrius reitteri, Quedius semiaeneus, Ernobius pruinosus, Priobium dendrobiiforme, Psylliodes weberi, Apion semivittatum, Hydnobius spinipes*.

The method enabled us to evaluate a flight activity of the beetles. The average flight activity reached a value of 6.8 individuals per day, what is higher than in xerothermous habitats (5.2 ex./day). Even lower values (4.6 ex./day) were recorded at sites in submountainou and mountainous regions. The highest values, higher than the average, refer to wetland biotopes (10.5 ex./day). These sites provide conditions for bigger biomass and lower diversity of beetle communities (several dominant species). The species of *Cyphon, Oedemera, Silis* and *Anthocomus* usually occur in wetlands. They are hygrophilous and their larvae live in or near water. On the contrary xerothermous biotopes have higher diversity as well as equitability of beetle communities.

Study on flight activity enables to estimate hatching time to signal and predict problems with pests under in situ conditions (Majzlan et al. 2001).

Tree photoeclectors

Problems on horizontal and vertical migration of insects have been mainly solved on the level of tree protection.

In the period of 1985–1986 we installed POTs on trunks of oaks. The research took place in an oak forest (National nature reserve Lindavský les) in Trnavská plain. The traps were situated on unhealthy trees (various stage of deseasse and damage) and on an artificial tree at the height of 0.7 and 5 m. Totally we exposed 4 photoeclectors on living trees, 2 on dead trees and one on the artificial trunk. The research brought data on representatives of 21 arthropod orders, migrating vertically as well as horizontally.

The activity of beetles was characterized by 377 individuals in 1985 (199 days), which gives 2 ex/day and 1,224 beetles in 1986 (245 days – 5 ex/day).

During the period of 2000–2002 we recorded 129 beetle species on trunks of chestnuts, forming 0.4–1.8% of all the captured arthropods. The method of tree as well as soil photoeclectors always brings amazing data on new species of the Slovak beetle fauna: *Corticaria abietorum, Orthoperus improvissus, Atheta griepi, Chevrolatia egregia* and *Latheticus oryzae*. The parallel study on soil fauna at the same site recorded a new species for the fauna of Slovakia – *Scymnus sacium* (Majzlan, Fedor 2001a).

Some groups (Isopoda, Diplopoda, partially Araeae and Heteroptera) showed more remarkable preference for the lower than the upper traps. The representatives of these groups migrate from soil and undergrowth (up to 1 m) onto trunks of chestnuts. The communities of millipedes (Diplopoda) included an interesting species *Polyxenus lagurus* (Linnaeus, 1758).

A preference for the upper POT was proved at flying Hymenoptera and Diptera. They record dark strip silhouettes created by trunks. A crown has an orientation importance for phytophagous insects (caterpillars, butterflies, beetles). We observed reduced abundance of the dominant insect groups on artificial trees without a green crown (Majzlan 1986).

Changes in arthropod abundance reached their maximum in spring and autumn period. *Issus muscaeformis* (Schrank 1781) represented a dominant species of Auchenorrhyncha, *Schoettela ununguiculata* (Tullberg 1869) of Collembola.

Air-photoeclecor

Using an air-photoeclector we obtained a total of 14,077 arthropods classified within 15 orders. Lepidoptera (77.4%) were eudominant, 76% of them belonged to *Cameraria ohridella.* Hymenoptera (9.1%) and Diptera (5.7%) can be considered as dominant groups. Thysanoptera (3.3%) and Coleoptera (2.3%) belonged into subdominant orders. Non-flying arthropods formed 0.3% of all the caught specimens. The peak of the dynamics was recorded between July 1–15 (8,804 ex.). The average flight activity was characterized by 76 individuals per day.

We recorded 328 beetles of 53 species. *Rhagonycha fulva* can be classified as eudominant species (26.2%). The group of dominant beetles included *Oulema melanopus* (7.6%), *Phyllotreta vitulla* (8.5%), *Phyllotreta atra* (7.6%) and *Ceutorhynchus obstrictus* (6.1%). *Cyphon coarctatus* (4.3%) and *Apion semivittatum* (3.4%) belong to subdominant species. The peak of their dynamics (103–115 specimens) was found between June 15 and July 15. The average flight activity was characterized by 1.8 individuals per day.

Some of the species are interesting from the faunistic and bionomic point of view. *Mosocoelopus niger* and *Kissophagus hederae* develop in English Ivy (*Hedera helix*). They both are rare and occur only in southern Slovakia. *Cryptocephalus strigosus* is associated with warm forests of submountainous zone in southern Slovakia. It represents a local species. *Apion semivittatum* is a species infiltrating into Central Europe in recent 10,000 years. *Mercurialis annua*, considered as its feeding plant may be replaced by other species under our conditions.

In total we obtained 10,715 individuals of *Cameraria ohridella*, expressed as 58 specimens a day. Their flight activity peaked between June 15–30 (1,611 ex.) as well as between July 1–15 (8,315 ex.). The flight activity refers to one maximum. However comparing with the results from the Malaise trap, we recorded 3 peaks (Majzlan, Fedor 2003). The flight activity of this month reaches approximately the same values as those found in the Malaise trap and air-photoeclectors although in July there was a remarkable change in this variable. The values from a Malaise trap are 2–7 times higher. The third generation (August 15) did not appear in the air-photoeclector as significantly as in the Malaise trap. The third generation specimens did not fly up to the chestnut crowns. We suppose that these individuals do not lay their eggs and died before winter. Thus some of the individuals of the first and second generation survive as pupae till the end of a vegetation period.

Soil photoeclectors

Soil photoeclectors provide useful information on hatching phenology of adults on a soil surface (epigaeon) and upper horizons (hypogaeon). Funke (1971) has named this community as eclectorfauna, reflecting a method of gathering study samples.

In Slovakia we used soil POTs for the first time in a forest ecosystem in the Nature reserve Lindavský les near the village of Častá. In 1985 we established a study site here and used 5 POT in this Fageto-Quercetum forest. We actually obtained a rich study material of 12,568 arthropods of 21 orders with an average abundance of 2,469.2 ex.m^{-2} (Majzlan 1986). Collembola (40%) and Nematocera (Diptera) 27% were dominant groups here.

In 1984 we exposed 2 POTs in one abandoned orchard in Bratislava. The exposition period took 228 days during a growing season. We obtained data on abundance of arthropods (3,854 ex.m^{-2} and beetles (279.5 ex.m^{-2}) with eudominant species of Staphylinidae (54%) and Curculionidae (12.9%). The beetles of the family Carabidae and Cryptophagidae were considered as dominant (Majzlan, Holecová 1993).

In 1990 we exposed 5 soil photoeclectors at the study site near Čičov (Durmek et al. 1993). During a vegetation period (192 days) we obtained data on abundance of arthropods (5,937 ex.m^{-2}). Beetles were represented by 112 species of 36 families with the abundance of 384.6 ex.m^{-2}.

Two POTs were installed at the site of Rohožník, close to the cement factory in 1984. In the forest community of *Carici pilosae*-Fagetum we obtained 3,111 ex.m^{-2} during a vegetation period of 210 days. The research at the site Biely kríž in the Protected landscape area Malé Karpaty brought the data on abundance of 1,386 ex.m^{-2}. Diptera: Nematocera (34.5 %) predominated at both the sites. Therefore these forests can be considered as a ”nematocerous forest”. The abundance of beetles reached the value of 329.5 in Rohožník and 106.4 ex.m^{-2} at Biely kríž (Majzlan, Kožíšek 1995).

In 1994 we studied hatching phenology of beetle adults in the National nature reserve Devínska Kobyla (Majzlan, Rychlík 1996). We installed 2 POT in a xerothermous biotope of Festuco-Brometea and hence obtained a value of abundance per 2 m^2. The exposition period took 233 days in a vegetation period. We recorded 8,825 arthropods (Arachnoidea and Hexapoda) with abundance of 4,412.5 ex.m^{-2}. 774 of them belonged to beetles of 150 species and 33 families. In average 387 individuals hatched from 1 m^2 during a vegetation period.

During the year 2000 we were focussed onto hatching phenology of arthropod adults, especially insects (Hexapoda s.l.) near the Institute of Experimental Phytopathology and Entomology of SAS in Ivanka pri Dunaji, using a method of soil photoeclectors. We installed 2 POTs at the distance of 2 m. One of them was used as control, while the second one was sprayed by the Casoron G herbicide according to the instructions of the Uniroyal Chemical company – 100–150 kg.ha^{-1} or 10–15 gr. per 1 m^2. Casoron G is a barrier herbicide, applicable in spring and providing protection against weeds for a whole year. Chemically it is based on dichlobenile in granules (app. 6.7%).

The research on eclectorfauna brought data on 12,522 invertebrates of 20 groups. Total abundance reached a value of 10,244 ex.m^{-2} in the first POT and 2,278 ex.m^{-2} in the trap with the herbicide. Hence the chemical caused a 77.8% decrease in abundance of soil invertebrates. The values of abundance obtained in Germany (Funke 1991) correspond with our results. A producer of chemicals should include information on side effects of its product on environment.

Soil biocoenometers

They represent a certain modification of soil photoeclectors, isolating smaller area of a soil surface. Thus they can be marked as biocoenometers on basis of soil photoeclectors.

During the year 2001 we studied hatching phenology of arthropod adults (macrofauna, eclectorfauna), especially of insects (Hexapoda s.l.) (Majzlan, Fedor 2001b).

This type of POT was not stationary (in comparison with the stationary one used in the previous year) (Majzlan, Fedor 2000). However, a non-stationary POT possesses some advantages, for example it can provide more reliable data on hatching phenology of insect adults.

During our research we totally obtained 10,246 arthropods, with eudominant springtails (Collembola – 63.6%). 787 of them were classified as beetles of 103 species and 37 families. The species *Sericoderus lateralis* (16.6%) and *Psylliodes chrysocephala* (13.7%) were considered as eudominant species.

An average abundance of arthropods reached 2,561.5 individuals per 1 m^2. This value corresponds with the another one, found in the other biotope of the same site (Majzlan, Fedor 2001a).

The research was focussed onto changes in population density of *Cameraria ohridella*. Using a method of soil photoeclectors we obtained 119 specimens of this moth with an average abundance of 30 individuals per 1 m^2. The abundance peaked (122 ex. per 1 m^2) in May. The second maximum (98 ex. per 1 m^2) was observed in July. These peaks refer to the flight activity maximum of the moth. The research on the flight activity brought 21,303 specimens of the butterfly. The sex ratio (females to males = 2 : 1) according to the soil photoeclectors corresponds with the data obtained with the help of a Malaise trap.

Summary

The paper gives information on common as well as less frequent methods to study activity of arthropods in forest ecosystems. These methods help us to obtain data on structure and function of arthropod populations and communities. For more than 20 years we have been using various types of equipment to study activity of arthropods in forest ecosystems. They include Malaise traps, tree, soil and air photoeclectors as well as biocoenometers. Using these techniques we have obtained numerous faunistic and ecosozological data on beetles and other arthropods.

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AKTIVITA ČLÁNKONOŽCOV V LESNÝCH EKOSYSTÉMOCH

Súhrn

Štúdium aktivity článkonožcov, najmä však hmyzu si vyžaduje aplikáciu rôznych špeciálnych metód. Tie dokážu získať podrobné údaje o štruktúre a funkcii jednotlivých populácií v spoločenstve. Predkladaný príspevok sa venuje niektorým z týchto metód, poukazuje na ich špecifiká, klady aj nedostatky. Ide predovšetkým o využitie Malaiseho pasce, stromových, pôdnych aj vzdušných fotoeklektorov, ktoré autori vo svojom výskume využívajú už niekoľko rokov. Ich význam spočíva predovšetkým v pomerne spoľahlivých informáciach o populačnej dynamike jednotlivých druhov, z ktorých niektoré majú najmä v oblasti fytopatológie a ochrany lesa svoj veľký význam.

THE MOST SERIOUS FUNGAL PATHOGENS ON WOODY PLANTS IN URBAN GREENERY EVALUATED ON AN EXAMPLE – PEZINOK

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Abstract: *Juhásová, G., Ivanová, H., Bernadovičová, S., Kobza, M., Adamčíková, K.: The most serious fungal pathogens on woody plants in urban greenery evaluated on an example – Pezinok. In Folia oecologica. ISSN 1336-5266, 2003, vol. 30, no. 2, p. 239–244.*

In 2001, the health condition of woody plants in Pezinok – the castle park was evaluated with regard to incidence of parasitic fungi. The aim of this paper was to determine damage degree, damage cause and to propose suitable protective measures. For this purpose, all woody plants were classified according to a 6-point scale based on the damage degree. We evaluated 1203 woody plants. From them, 75 % tree species are suitable for further cultivation. We evaluated 34 genera of coniferous and broadleaved trees, from which 10 genera were healthy. On other genera, a relatively abundant spectrum of parasitic fungi was recorded. The most damaged were woody plants of the following genera: Acer, Aesculus, Fraxinus, Rosa, Tilia, Platanus, Robinia.

Key words: *health condition, methods of evaluation, method of treatment, parasitic fungi*

Introduction

In Slovakia, there exist several park objects, high valuable from the aspect of their tree-species composition. The maintenance of these woody plants is key-important for improvement of the quality of the life environment.

The castle park in Pezinok represents a precious collection of woody plants. The evaluation of the health condition of the woody plants at the site was realized with interest in preserving this subject of garden architecture.

The results acquired at the phytopathological evaluation in year 2001 can provide an background information for park reconstruction an for choice of appropriate protective measures.

Material and methods

The overall health condition was evaluated according to a 6-point scale, using the method of Juhásová (1997). Woody plants without symptoms of damage were labelled as healthy (H), the most damaged woody plant species obtained degree 5.

Phytopatological evaluation of woody plants, including the pathogen identification (1–96 signs) and determination of the treatment method (1–32 signs), was realized using the method of Juhásová and Serbinová (1997). The fungi were identified according to Bánhegyi (1985) and Brandenburger (1985).

Results and discussion

The health condition of woody plants was evaluated over the area of the castle park in Pezinok in year 2001. This area was divided into 11 sites.

We determined tree species composition on each site. For the individual trees, we determined damage degree, damage cause and method of treatment. Table 1 shows the results of the phytopathological evaluation of woody plant species at site number 5. The complete results from all sites are preserved at the author´s.

The data about the damage degree of the evaluated woody plant species are presented in Table 2.

From the total number of the evaluated trees (1203) more than 22% were healthy (without symptoms of damage), nearly 53% of trees were damaged at the 1st and 2nd degrees. More than 5% of the evaluated trees were assigned to the 4th degree an only 0.4% of trees were assigned to the 5th degree of damage. 85 trees, because a high degree of damage (possibly trees in life danger), were suggested for cutting.

The occurrence of parasitical microscopic and wood-destroying fungi on the broadleaved and coniferous woody plants in the evaluated locality is summarised in Table 3.

Species of the coniferous genera *Abies, Larix, Picea* and species of the broadleaved genera *Castanea, Evodia, Gymnocladus, Ilex, Magnolia, Rhus* and *Ulmus* showed no symptoms of damage (healthy). The majority of parasitic fungal species was recorded on the genus *Acer* (12), *Aesculus, Fraxinus* (9), *Rosa, Tilia* (7) and *Platanus, Robinia* (6).

Table 1. Results of phytopathological evaluation of woody plants in the castle park in Pezinok

Number of tree	Name of taxon	$d_{1,3}$ stem	Damage degree	Damage cause	Method of treatment
1	*Quercus robur*	72	1	1,2	1,2
2	*Pinus nigra*	78	1	36,37	0
3	*Fraxinus excelsior*	42	1	1	1
4	*Fraxinus excelsior*	52	1	1	1
5	*Robinia pseudoacacia*	56	3	3,4,20a	1,2
6	*Robinia pseudoacacia*	64	4	1,2,12(106x39x34cm),15,18,64,65,66,70	
				14(140x10cm),17,20a,27,30,49,55,59	13
7	*Quercus robur*	65	2	1,2	1,2
8	*Catalpa bignonioides*	62	3	1,2,3,4,12,14	1,2
9	*Robinia pseudoacacia*	6	H		0
10	*Quercus robur*	48	H		0
11	*Sophora japonica*	46	3	1,2,34,35	1,2
12	*Fraxinus excelsior*	86	H	81	0
13	*Robinia pseudoacacia*	46	1	1,2	1,2
		24	1	1,22,23	1
14	*Tilia platyphylla*	2	H		0
15	*Tilia platyphylla*	4	H		0
16	*Tilia platyphylla*	2	H		0

Continue Table 1.

17	*Tilia platyphylla*	2	H		0
18	*Tilia platyphylla*	2	H		0
19	*Tilia cordata*	80	H		0
20	*Tilia cordata*	72	H		0
21	*Fraxinus excelsior*	62	2	1,2	1,2
22	*Acer platanoides*	44	2	1,2,22a	3,6,14
23	*Fraxinus excelsior*	84	3	1,2	1,2
24	*Fraxinus excelsior*	58	3	1,2	1,2
25	*Acer platanoides*	42	1	1	1
26	*Acer platanoides*	44	2	1,2,22,23	1,2,6
27	*Fraxinus excelsior*	54	1	1,2	1,2
28	*Tilia europaea*	4	H		0
29	*Tilia europaea*	4	H		0
30	*Acer platanoides* Globosuth	24	1	1,2	1,2
31	*Tilia platyphylla*	82	2	1,2,47	1,2
32	*Tilia cordata*	74	H		0
		68	H		1
33	*Quercus robur*	82	3	1,2,22,23	1,2
34	*Fraxinus excelsior*	60	3	1,2,22	1,2
		24	1	1	1
35	*Acer platanoides*	52	4	1,2,12(300x40cm),32,33,68,70	1,2,22,13
36	*Fraxinus excelsior*	46	3	1,2,21,26c,65,66	1,2,21
37	*Quercus robur*	94	3	1,2,39	1,2,10
38	*Fraxinus excelsior*	38	3	1,2,3	1,2
39	*Fraxinus excelsior*	42	3	1,2,3,12,15,17	1,2
40	*Fraxinus excelsior*	44	3	1,2	1,2

Table 2. Total numbers of evaluated woody plants in castle park in Pezinok according to their damage degree (H – healthy trees)

Number of site	**Damage degree**						**Stump**	**Total**
	H	**1**	**2**	**3**	**4**	**5**		
1	21	19	8	20	3	1	2	74
2	22	59	23	16	10	0	9	139
3	46	24	19	22	7	0	4	122
4	37	66	30	33	12	1	9	188
5	13	10	10	7	2	0	1	43
6	25	33	11	20	6	0	8	103
7	49	65	54	26	11	1	3	209
8	12	60	28	13	6	0	3	122
9	17	29	21	16	8	0	2	93
10	15	21	10	11	1	0	0	58
11	8	20	14	5	1	2	2	52
Total	265	406	228	189	67	5	43	1203

Table 3. Parasitic fungi identified on woody plants in the castle park in Pezinok

Genus of woody plant	Damage originator
Abies	healthy
Acer	*Mycosphaerella aceris Woron*. *Mycosphaerella latebrosa (Ske.) Schröet*. *Cercosporella acerina* (Hartig.) Arn. *Marssonina truncatella* (Sacc.) Magn. *Gloeosporium acericolum* Allesch. *Ascochyta acericola* Massa *Phyllosticta aceris* Sacc. *Cylindrosporium acerellum* (Sacc.) Died. *Septoria acerinum* Pk. *Uncinula bicornis* (Wallr. ex Fr.) Fr. *Verticillium alboatrum* (Hartig) Arn. *Oxysporus* sp.
Aesculus	*Guignardia aesculi* (Peck) Steward *Mycosphaerella aesculi* (Cacc. ex Mor.) Tomilin *Valsa ambiens* Sacc. *Cytospora ambiens* Sacc. *Vuilleminia comedens* (Ness.) Maire *Nectria cinnabarina* (Tode ex Fr.) *Phellinus pomacearus* Tode *Ganoderma resinacearum* Boud. in Pat.
Alnus	*Phyllactinia guttata* (Wallr. ex Schlecht.) Lév. *Melampsoridium alni* (Thuem.) Diet.
Betula	*Marsonina betulae* (Lib.) Magn. *Phyllactinia guttata (Wallr. ex Schlecht.) Lév.* *Valsa sp.* *Cytospora betulicola* Fautr.
Buxus	*Ascochyta buxina Sacc.* *Phyllosticta auerswaldi* All.
Castanea	healthy
Catalpa	*Phytophthora parasitica* Rands
Evodia	healthy
Fagus	*Phyllactinia guttata* (Wallr. ex Schlecht.) Lév.
Fraxinus	*Phyllactinia guttata* (Wallr. ex Schlecht.) Lév. *Mycosphaerella fraxini* (Niesl.) Mig. *Cercospora fraxini* Desm. *Phyllosticta fraxinicola* Desm. *Giberella baccata* (Wallr.) Sacc. *Fusarium lateritium* Nees. *Ganoderma lipsiense* (Bats) Atk. *Ganoderma pheifferii* Bres. *Ganoderma carnosum* Pat.
Gleditsia	*Laetiporus suephureus* (Bull.) Hurvill
Gymnocladus	healthy
Juniperus	*Cladosporium glomerulosum* Sacc. *Hendersonia folucola* Berk *Gymnosporangium sabinae* (Dicks) Winter *Lophodermium juniperinum* (Fr.) de Not
Chamaecyparis	*Keithia chamaecyparisi Johnsonii* (Ell. et ev.) Rehm.
Ilex	healthy
Larix	healthy
Magnolia	healthy
Picea	healthy
Pinus	*Diplodia pinastri* Grove *Lophodermium pinastri* (Schrad.) Chev. *Cronartium ribicola* (Dietr.)
Platanus	*Gnomonia veneta* (Sacc. et Speg.) Kleb. *Gloeosporium platani* (Fckl.) Sacc. *Disculina platani* Sacc. *Gloeosporium nervisequum* (Fckl.) Sacc. *Cercospora platanifolia* (Ell.) Ev. *Mycosphaerella platanifolia* Cke.

Continue Table 3.

Genus of woody plant	Damage originator
Prunus	*Cytospora rubescens* Sacc.
Pseudotsuga	*Rhabdocline pseudotsugae* Syd.
Pyracantha	*Spilocea pyracanthae* (Otth) Arx
Quercus	*Microsphaera alphitoides* Griff. et Maubl.
Rhus	healthy
Robinia	*Ascochyta robiniaecola* Hollós *Phyllosticta advenae* Pass. *Nectria cinnabarina* (Tode) Fr. *Microsphaera coluteae* Kom. *Camarosporium robiniae* (West.) Sacc. *Cucurbitaria caraganae* Schultz
Rosa	*Phyllosticta rosarum* Pass. *Sphaerotheca pannosa* (Wollr.) Lév. *Oidium leucoconicum* Desm. *Marssonina rosae* (Lib.) Died. *Actinonema rosae* (Lib.) Fries. *Phragmidium subcorticum* (Schrank.) Wint. *Septoria rosae* Desm.
Sophora	*Fusarium lateritium* Ness.
Sorbus	*Cytospora rubescens* Fr.
Taxus	*Phoma hysterella* Desm.
Thuja	*Armillaria mellea* (Vahl. ex Fr.) Kumm. *Pestallozia funerea* Desm.
Tilia	*Cladosporium cladosporoides* (Fres) de Vries. *Pullularia pullulans* (de Bary et Loew.) Berkl. *Alternaria tenuis* Ness. *Mycosphaerella millegranna* Desm. *Gnomonia tiliae* Kleb. *Gloesporium tiliae* Oud. *Pyrenochaeta pubescens* Rostr.
Ulmus	healthy

Conclusion

The health condition of woody plant taxons in the castle park in Pezinok was evaluated in 2001. The object of our research was 9 genera of coniferous (14 taxons) and 25 genera of broad-leaved woody plants (35 taxons).

From the total number of the evaluated trees (1203), up to 75% of trees had suitable condition and satisfied the requirements on trees growing in parks and urban greenery. More than 5% of the evaluated trees were unsuitable from aspect of a next cultivation.

A relatively wide spectrum of parasitical fungi was recorded on 7 genera of trees from the total number 34 genera of coniferous and broadleaved trees (*Acer, Aesculus, Fraxinus, Rosa, Tilia, Platanus, Robinia*).

The obtained results serve as a suitable base for cultivation and maintenance of trees in urban greenery. The urgency of protective measures (cutting damaged branches, collecting and burning leaves as a possible source of infection at a tree cutting) follows from the phytopatological evaluation of the individual woody plants and consequent identification of the pathogens. These protective measures are important mainly in the woody plants evaluated by the 4^{th} and 5^{th} damage degrees. In the case of an insufficient effect of mechanical protection, chemical protection using recommended fungicides is necessary.

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NAJDÔLEŽITEJŠÍ PÔVODCOVIA HUBOVÝCH OCHORENÍ NA DREVINÁCH V MESTSKEJ ZELENI V PEZINKU

Súhrn

V roku 2001 sme zhodnotili v zámockom parku v Pezinku zdravotný stav vysadených drevín. Drevinové zloženie hodnotenej lokality bolo zastúpené 9 rodmi ihličnatých (14 taxónov) a 25 rodmi listnatých drevín (35 taxónov). Z celkového počtu hodnotených stromov (1203) až 75 % stromov má vyhovujúci stav, spĺňa požiadavky na dreviny rastúce v parkoch a mestských výsadbách. Viac ako 5 % hodnotených stromov je z hľadiska ďalšieho pestovania neperspektívnych.

Pomerne široké spektrum parazitických húb sme zaznamenali na 7 rodoch drevín z celkového počtu 34 rodov ihličnatých a listnatých drevín (*Acer, Aesculus, Fraxinus, Rosa, Tilia, Platanus, Robinia*).

Získané výsledky slúžia ako vhodný podklad pre pestovanie a údržbu drevín mestskej zelene. Z fytopatologického hodnotenia jednotlivých drevín a následnej identifikácie pôvodcov poškodenia vychádzajú aj navrhnuté ochranné opatrenia. Tieto je potrebné vykonať hlavne pri drevinách hodnotených 4. a 5. stupňom poškodenia (orez konárov, vyhrabávanie a pálenie listov ako možného zdroja infekcie až výrub dreviny). V prípade nedostatočného účinku mechanických opatrení je potrebné chemické ošetrenie odporúčanými fungicídnymi prípravkami.

OCCURRENCE OF HORSECHESTNUT LEAF BLOTCH AND CULTURAL CHARACTERISTICS OF ITS CAUSAL AGENT – FUNGUS *PHYLLOSTICTA SPHEAROPSOIDEA*, AN ANAMORPH OF *GUIGNARDIA AESCULI*

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Abstract: *Zimmermannová-Pastirčáková, K.: Occurrence of horsechestnut leaf blotch and cultural characteristics of its causal agent – fungus Phyllosticta spheаropsoidea, an anamorph of Guignardia aesculi. In Folia oecologica. ISSN 1336-5266, 2003, vol. 30, no. 2, p. 245–250.*

We observed the leaf blotch of horsechestnut on the collections from Belgium, the Czech Republic, the Netherlands, Croatia, Poland, Austria, Slovakia and USA. The aim of the study was to investigate in more details the pathogen Phyllosticta sphaeropsoidea (anamorph of Guignardia aesculi) causing the leaf blotch on the Aesculus species. The effect of different nutrient media, pH media and ultraviolet radiation on the mycelium growth and sporulation of Ph. sphaerospoidea isolates was studied. Carrot, malt agar with horsechestnut leaf extract, cornmeal and rice agar were the most suitable mediums for growth and sporulation of the tested fungus. Mycelium of Ph. sphaeropsoidea grew within the range of pH 3 to 12 on malt extract agar. The pH optimum for colony growth and sporulation ranged from 6 to 8. Ultraviolet radiation had a positive effect on production of microconidia. Phyllosticta produced less aerial mycelium and gave better sporulation after the exposure.

Key words: *Phyllosticta sphaeropsoidea, media, pH value of the medium, ultraviolet radiation, growth of mycelium, sporulation*

Introduction

The leaf blotch, caused by the fungus *Guignardia aesculi* (Peck) Stewart, a teleomorph of *Phyllosticta sphaeropsoidea* Ellis et Everh. is a well known and common disease in the majority of *Aesculus* species in Europe and North America (Stewart 1916; Neely 1971; Punithalingam 1993). Stewart (1916) pointed out that isolates from different *Aesculus* species are unable to attack other species than the original host plant. In Slovakia the leaf blotch on horsechestnut was recorded by Hrubík (1976) and Juhásová, Hamšíková (1996). Zimmermannová (2001) made a comprehensive study of occurrence of horsechestnut leaf blotch in Slovakia. Pastirčáková (2003) recorded the leaf blotch on the leaves of *Aesculus hippocastanum*, *A.* × *carnea* and *A. parviflora* at the Arboretum Mlyňany in 2001.

Stewart (1916) studied life history and morphology of *Guignardia aesculi*. The possibility of controlling the horsechestnut leaf blotch was frequently investigated (Zechini d´Aulerio et al. 1984; Anselmi et al. 1992; Plenk 1996), but the effect of various nutritional and environmental factors on the vegetative growth and sporulation of the fungus have not been studied yet. In the present study, the effect of pH, various media and ultraviolet radiation on the growth and sporulation of *Ph. sphaeropsoidea* in pure cultures is investigated.

Material and methods

Plant material

Fresh leaves of *Aesculus hippocastanum* with leaf blotch infections from Plankendaal (Belgium), Olomouc (Czech Republic), Wageningen (Netherlands), Zagreb (Croatia), Lublin (Poland), Tulln (Austria), Giraltovce (Slovakia) and Grove City (Pennsylvania, USA) were used for identification purposes and for morphological examinations of the pathogen by means of standard light microscopy.

Fungal isolation

Small fragments of necrotic tissue originating from attacked horsechestnut leaves were sown on malt extract agar. The twenty days old pure culture of the Slovak isolate of the fungus *Ph. sphaeropsoidea* isolated from the horsechestnut leaves was used at the next investigation. Germination of conidia (conc. 1.25 x 10^5 conidia per ml) was investigated on potato dextrose agar (pH 6.5) at 25 °C.

Nutrient media

The effects of ten media (Czapek-Dox agar, potato dextrose agar, cornmeal agar, special low nutrient agar, malt extract agar, oatmeal agar, rice agar, carrot agar, malt agar with horsechestnut leaf extract, water agar) on colonial growth and sporulation were investigated. The listed media were prepared according to Dhingra, Sinclair (1995) and Singleton et al. (1992). The experiment was carried out at 25 °C ± 2 °C. Fragments of the 20 days old colonies were placed by three replications on the separate media in Petri dishes. Mean colony diameter was measured every 48 hours during 30 days of incubation. The degree of the fungus fructification was determined visually on the basis of pycnidia formation after 30 days. The following scale was used: – negative appearance, + very poor fructification, + + poor, + + +medium, + + + + strong fructification.

pH value of the medium

For these investigations, malt extract agar with different pH values ranging from 1 to 13 was used. The pH value of the medium was achieved using 1 M HCl or 5 M HCl for pH values 1 to 6, and 1 M NaOH or 5 M NaOH for pH values 7 to 13. The sowing was carried out using 20-day-old colonial fragments (4 mm diameter). The experiment run in a thermostat at a temperature of 25 °C ± 2 °C. Colonial growth and sporulation were observed every 48 hours over 30 days of incubation.

Ultraviolet radiation

Plugs of mycelia (4 mm diameter) of isolate of *Ph. sphaeropsoidea* were transferred onto carrot agar in Petri dishes and exposed to light of two different wavelengths; 365 nm (UV-A) and 254 nm (UV-C) in the laboratory at a room temperature. The UV radiation was supplied by an ultraviolet lamp (Universal-UV-Lampe CAMAG, Muttenz–Schweiz) fixed over the Petri dishes. The exposure periods were 2, 5, 10, 15, 20, 40, 60, 80, 100 and 120 minutes and the distance from the lamp to the mycelia was 15 cm. The irradiated plates were incubated 30 days by daylight or in darkness conditions. Three replicates were used for each exposure period and each irradiation condition (with UV-A, UV-C and without UV). Colony diameters were measured every 48 hours.

Results and discussion

We observed the leaf blotch on horsechestnut on the collections from seven European countries (Belgium, Czech Republic, the Netherlands, Croatia, Poland, Austria, Slovakia) and North America (Pennsylvania, USA). Our results of morphometric measurements of the fungus *Ph. sphaeropsoidea* were in accordance with many studies (Stewart 1916; Van der Aa 1973; Bissett, Darbyshire 1984; Nag Raj 1993; Punithalingam 1993).

The fungal colonies were visible about 5 days after placing of necrotic tissue on malt extract agar. The colonies were growing slowly. According to Van der Aa (1973) the colonies of *Ph. sphaeropsoidea* attaining a diameter of about 5 cm on oatmeal and cornmeal agar and 6–7 cm on cherry-decoct agar in one month at 20 °C. Submerged mycelium was abundant, composed of brownish or greyish, septate, often densely guttulate hyphae; aerial mycelium was very scarce, more abundant in older strains, at first white, soon turning greyish with some shade of greenish-brown or even black in very old cultures. Stromata were usually cylindrical, at first white and composed of thin-walled, hyaline, subglobose cells, forming a soft pseudoparenchyma, later turning blackish, with 1–20 pycnidial and spermatial cavities in the upper part.

Germination of conidia

The average germinative activity of spores of *Ph. sphaeropsoidea* was 17.6 % and the germ tube length was 43.5 μm after 48 hours on potato dextrose agar. There are indications in the literature (Kuo, Hoch 1996; Caltrider 1961; Stewart 1916) that *Phyllosticta* conidia germinate poorly on commonly used culture media, yet they germinate readily on the host leaf surface. Germination of the conidia was reported to occur after 20 hours of cultivation. According to Caltrider (1961), the optimum temperature was 25 °C for growth and production of pycnidia and conidia of *Guignardia bidwellii* (*Phyllosticta ampelicida* anamorph).

Influence of nutrient media on colony growth and sporulation

The growth of *Ph. sphaeropsoidea* showed differences on different nutrient media. Data recorded after 30 days of incubation are given in Table 1. The carrot agar, malt agar with horsechestnut leaf extract and rice agar were the most suitable media for mycelium growth; the cornmeal and rice agar were the most suitable for sporulation of *Ph. sphaeropsoidea*. Colony growth was the poorest on special low nutrient agar and water agar. The fungus did not sporulate on the water agar.

Table 1. Effect of different nutrient media on the cultural features of *Ph. sphaeropsoidea*

Media	Growth rate in mm / day	Colony diameter in mm after 30 days	First day of sporulation	F
Czapek-Dox agar	1.0	30	14th	+ +
Potato dextrose agar	2.0	62	12th	+
cornmeal agar	1.9	56	10th	+ + +
special low nutrient agar	1.4	42	30th	+
malt extract agar	2.0	60	16th	+ +
oatmeal agar	2.1	64	20th	+ + +
rice agar	2.4	72	10th	+ + + +
carrot agar	3.0	90	26th	+ +
malt agar with leaf extract	2.6	78	20th	+ +
water agar	1.3	38	–	–

The effect of pH medium on colony development and sporulation

The effect of different pH values of the medium on growth of *Ph. sphaeropsoidea* colony is summarised in Table 2. Mycelium of the studied fungus grew on malt extract agar within the range of pH 3 to 12. The pH range for pycnidial production was narrower than that for vegetative growth of fungus. Radial growth rate and production of pycnidia by *Ph. sphaeropsoidea* isolate were greatest over the optimum pH range (6–8). Caltrider (1961) reported that the germination of *Phyllosticta* conidia is greatest at pH 4.5–5 at 30 °C.

Table 2. Effect of different pH levels on colony growth of *Ph. sphaeropsoidea* on malt extract agar at 25 °C ± 2 °C

pH levels	1	2	3	4	5	6	7	8	9	10	11	12	13
Growth rate in mm / day	0	0	0.8	4.2	4.5	5.7	7.5	7.9	7.7	6.9	4.6	0.3	0
First day of sporulation	–	–	30th	14th	12th	10th	10th	12th	14th	16th	–	–	–

Values are means of three replicates

Influence of ultraviolet radiation on the vegetative growth and sporulation

Ph. sphaeropsoidea produced less aerial mycelium and gave better sporulation after the exposure to ultraviolet radiation (UV) for a longer time than 40 minutes. According to Van der Aa (1973) diffuse daylight also had a positive effect on sporulation, although to a less extent. Pycnidia were formed in symmetric radial circles. Radial growth of colonies, exposured 2 to 20 minutes, incubated in the daylight were faster than the colonies incubated in dark conditions.

The growth and sporulation of the fungus *Ph. sphaeropsoidea* showed no differences in influence of different UV irradiation (UV-A / UV-C). The exposure to UV irradiation did not initiate production of perithecia of *Guignardia aesculi*. However, the UV light had a positive effect on production of microconidia. Caltrider (1961) observed increased production of spermatia (= microconidia) and pycnosclerotia of *Phyllosticta ampelicida* in cultures exposed to ultraviolet irradiation for 3 minutes and the effect of irradiation on production of conidia was less evident. Leach (1962) reported that exposure to UV-A increase the sporulation of *Phyllosticta* species.

Table 3. Effect of ultraviolet irradiation on colony growth and sporulation of *Ph. sphaeropsoidea* on carrot agar (pH 6.5)

Duration of exposure to UV (in minutes)	UV-A (365 nm)				UV-C (254 nm)			
	daylight		darkness		daylight		darkness	
	d	fr	d	fr	d	fr	d	fr
2	2.8	12th	1.8	14th	1.8	14th	2.1	14th
5	2.4	14th	1.3	14th	2.5	14th	2.3	14th
10	3.4	14th	1.4	14th	2.2	14th	1.8	14th
15	2.7	14th	1.0	14th	2.1	14th	2.4	14th
20	3.0	14th	1.5	14th	2.2	14th	1.7	14th
40	1.5	14th	1.0	14th	1.3	14th	1.3	14th
60	1.5	14th	1.3	14th	0.8	14th	1.9	14th
80	1.3	14th	1.2	14th	1.2	14th	1.1	14th
100	1.4	14th	1.1	14th	1.4	14th	1.8	14th
120	1.1	14th	1.1	14th	1.2	14th	1.5	14th
Control	2.3	12th	1.7	14th				

d – growth rate of mycelium in mm / day; values are means of three replicates; fr – first day of sporulation

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VÝSKYT LISTOVEJ ŠKVRNITOSTI PAGAŠTANOV A KULTURÁLNE VLASTNOSTI PÔVODCU *PHYLLOSTICTA SPHAEROPSOIDEA*, ANAMORFNÉ ŠTÁDIUM HUBY *GUIGNARDIA AESCULI*

Súhrn

Preskúmané vzorky listov pagaštana konského z Belgicka, Českej republiky, Holandska, Chorvátska, Poľska, Rakúska, Slovenska a USA potvrdili výskyt huby *Phyllosticta sphaerospoidea* (anamorfné štádium huby *Guignardia aesculi*) spôsobujúcej listovú škvrnitosť pagaštanov. Cieľom tejto štúdie bolo preskúmať kulturálne vlastnosti huby *Ph. sphaeropsoidea*. Študovali sme vplyv rôznych živných médií, pH kultivačného média a ultrafialového žiarenia na radiálny rast mycélia a sporuláciu huby *Ph. sphaerospoidea*. Mrkvový agar, sladinový agar s extraktom z pagaštanových listov, kukuričný a ryžový agar boli najvhodnejšie kultivačné média pre rast mycélia a sporuláciu skúmanej huby. Nevhodnou živnou pôdou bolo špeciálne nízkonutričné médium a vodný agar. Mycélium huby *Ph. sphaeropsoidea* rástlo v rozmedzí pH 3 až 12 na sladinovom agare. Optimálne pH média pre vegetatívny rast a sporuláciu huby bolo 6–8. Konídie *Ph. sphaeropsoidea* začali klíčiť na zemiakovo-dextrózovom agare pri teplote 25 °C po 20 hodinách. Ich priemerná klíčivosť po 48 hodinách kultivácie bola 17, 6 %. Ultrafialové žiarenie malo pozitívny účinok na produkciu mikrokonídií. Po expozícii ÚV žiarením huba produkovala menej vzdušného mycélia a lepšie sporulovala.

PROJECTION OF CULTURAL PHYTOCENOSES FOR URBANIZED ENVIRONMENT

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Abstract: *Tomaško, I.: Projection of cultural phytocenoses for urbanized environment. In Folia oecologica. ISSN 1336-5266, 2003, vol. 30, no. 2, p. 251–257.*

The urbanized environment is specific created by the anthropogenic system in a certain area conditions are very different, and usually worse, from the natural surroundings. The man – inhabitant experiences it and therefore the man not only creates the environment but he also changes it and preserves it for the benefit of keeping the health and good psychic condition. Vegetation, globally called the urban vegetation, is one of the factors influencing positively the urbanized environment. The cultural vegetation – greenery must fulfil not only the ecological but also environmental functions. The predominant part of functions are fulfilled by the park landscape only which is in form of closed massifs of high greenery, the cultural communities of plants. In principle there are communities of woody plants and herbs in question, it is necessary to project them, realize and subsequently maintain to fulfil their function and keep the aesthetic level. A new discipline arose – the urban dendrology.

Key words: *urbanization, urban vegetation, cultural phytocenoses, urban ecology environmentalistics*

Introduction

The social dominance of Homo sapiens resulted in disorders of balance, devastation and degradation of the urbanized as well as natural environment during the last stages of the development of society. Logically, there arose the inevitability to take care of the landscape, a discipline arose (the landscape architecture) to be engaged in problems connected with urbanism, planning of towns, rural landscape, development of travelling by cars, tourism and recreation , with nature protection as well as with making use of sustainable natural resources.

The consequence of the architectonic modern style and ecological post-modern style was that the ecological principles began to be preferred in the architectonic at detail also. The phytosociological principles began to be applied also in planning of town, not only of the landscape. The simulation of nature followed the historic continuity in the horticultural art at preserving the principles of region. More and more appeared the style less attractive design. The ecological movement arose as a consequence of development of the geobotany, sociology and plant ecology. The ecological movement asserted itself quickly not only in parks, landscape architecture but also in area planning and traffic system. The landscape architecture transformed gradually into a scientific-artistic profession, which gave preference besides the aesthetic values also to social and ecological viewpoints – it became multidisciplinary. Many problems become cosmopolitan which is naturally reflected also in the design and in choice of the used materials (building and biological ones).

Material and methods

Planning and project preparation are executive processes which act to fulfil the desired intent (Supuka 2000). The design of cultural phytocenoses is concretely aimed towards the realisation of vegetation arrangement in the urbanised surroundings. It starts from understanding the nature and functional relations in natural plant communities. There is a struggle for making the prominence of natural elements in urbanized landscape more important on the basis of draft of cultural phytocenoses on all levels (parterre, undergrowth formations and tree storey). There is a struggle for elimination of the effects of unfavourable factors in urbanized landscape on the inhabitant of the settlement or visitor of special recreation – rehabilitation areas.

The materials used (predominantly dendrotaxa) are autochthonous with clear priority of native ones divided according to the vegetation zoning, taking into account the specificity of the particular technosurroundings. The system of allelopathic relations and degree of phytoncid activities are used also. Influencing the micro-mesoclimate of the environment follows the amelioration of conditions for their positive influencing in accordance with the needs of human bioclimate. These are mainly the spans of temperatures and moisture of the air from the viewpoint of their comfort for the user – inhabitant of the settlement or visitor of the recreation area.

Directions which regulate the development of decisive factors are reflected in particular assortment composition and division of the space of the vegetation arrangement. This relates not only to the new realizations but also to the management of their maintenance. Natural mosaic of the particular region is used in an artistic shape which harmonizes with the surroundings, ecologization of arrangements give guarantee of stableness and functionality of cultural phytocenoses also within broader relations of the particular landscape surroundings.

Results and discussion

The anthropogenic pressure on natural landscape rises permanently, and it is reflected in threatening the stabilizing mechanism of the natural landscape (Demo 1999). The biological diversity in landscape as a guarantee of its ecological stability and balance is of great importance also from the viewpoint of landscape creation – formation the landscape image, its architecture (Supuka et al. 2000). The woody component of the vegetation is thanks to its longevity, mass and volume expressiveness of great importance and it has together with its seasonal and age dynamics also a great aesthetic and cultural value. Important woody plants are represented in forest stands (autochthonous taxa), whereas the foreign woody plants (the introduced taxa) are concentrated in parks and arboreta, or spa forests. The woody vegetation, forest and cultural vegetation in the anthropogenically changed landscape, mainly urbanized landscape, is the guarantee of the stability of the landscape but it is also of great environmental importance. The culture manifests itself in cultured manners of utilization, and further on also by the symbiosis with the works of architecture and civil engineering. Technical works in the landscape together with architectural view points create the image of the landscape and increase its aesthetic level.

The present assortment of woody plants used in the realization of the urban and lanscape greenery is rich and it is being permanently supplemented by new taxa and cultivars from the introduction and breeding practice. The assortment of allochthonous woody plants represents hundreds of introduced taxa from various regions on our globe. In the present cultivation and realization practice for the horticultural creation special attention is paid to the taxa suitable to be used in heavy anthropically changed conditions of our urbanized and industrial landscape. In our conditions create woody plants a substantial component of the phyto gene pool (COMBES 1996), long living and at the most effective one considering the biomass created by the woody plants. Over and above, the woody plants, as the most stable component of the ecosystems, create suitable conditions for the existence of many other plant species and they influence the shaping of the urban environment. The urbanized landscape, with its types of settlement landscape (urban and rural), production (industrial, agricultural), recreation and traffic landscapes, is in contrast with the natural landscape (forest and protected) damaged quite a lot, unbalanced and left to the melioration by means of cultural vegetation in form of park and horticultural arrangements and other functional greenery (CHUDÍK, TOMAŠKO 1987).

The causes of revision or addition to the criteria of the horticultural evaluation of woody plants are as follows:

– impacts and effects of the air and soil polluting components on woody plants and their ecosystems,
– effects of stress on woody plants and their ecosystems,
– regional consequences of global climatic changes which are demonstrated as: morphological manifestations,
– speed of taxa growing, and therefore there is necessary the plant breeding and selection for:
  stress tolerating species,
  resistance to pests.

The xerotermization of the climate results in:

– activation of synantrophs – ruderals and
– naturalization of introduced species and their adaptability, and even invasive behaviour.

If we understand the biodiversity also as a biological diversity of ecosystems (BRINDZA et al 1966) then we approach in such way also the proposal of cultural phytocenoses – the park ones, and their composition on the basis of natural ones is more prospective and resistant, which is naturally the purport of the park composition. The maintenance, if we understand it also as a continuous creation, is of great importance in regulation of changes in the composition of stands and in regulation of the general development of cultural communities of park plants. They differ by their composition, architecture, aims and ways of maintenance and protection. We apply the protection and preservation of biodiversity also to the cultural gene pool, and then there are opened greater possibilities just for the application of larger range of the introduced, resistant and prospective taxa. The changes of autochthonous gene pool take place more because of climatic changes, to which we place the increase of carbon dioxide, occurrence of acid rains and other pollution of the air along with the warming. When we compose the cultural park phytocenoses for the urbanized environment we must consider that the quantities and values of contaminants are much more higher and, of course, it will affect the composition of these phytocenoses.

If it is valid in the autochthonous communities that:

– the closed communities are more resistant, and that,
– the proportion of plant species rises with higher indication value of the temperature and tolerance to draught.

Then we use this knowledge in composing the cultural phytocenoses, making the changing relations between the individual components of the community more visible. There is expected the presence of invasive species and many neophytes out of the assortment of the introduced ones (*Negundo aceroides* MOENCH, *Ailanthus altissima* (MILL.) Swingle, and others). The richer biodiversity is caused by the variety of biotopes in Slovakia and the regionality is manifested not only in representation but also in composition of communities and this should be respected also in proposals of cultural park and fores-park phytocenoses, or phytocenoses in protective and isolation greenery. Compactness of the proposed phytocenoses is achieved also by the second layer or by undergrowth woody plants and of course by the wind mantle. Starting from these facts, we classify the broad assortment of woody plants from the viewpoint of their utilization as:

– Basic, park creating woody plants which shall be the skelet of the stands, it means they are used in stand, groups and as solitaires. The cenotic composition of natural forest communities (Quercetum, Fagetum, Picetum in a more precise cenological analysis) is substantial in the choice of a concrete assortment. If the allochthonous taxa are recommended the information about their origin and knowledge of their phytogeographic conditions of their origin are important. Their application is possible rather in conditions of extremely deteriorated areas.
– Secondary, park creating woody plants suitable mainly into groups and as underwood
– Supplementary woody plants are given priority as a part of park stands with quick effect (fast-growing and filling ones). It relates to shrubby stand also.

Knowledge of the biological material is matter of course for the activity of a horticultural architect because only a woody plant or herb which is correctly inserted and localized has all preconditions of correct growth, progress and development, of being healthy, functional and aesthetically effective during the time of its existence. The individual taxa and individuals in the community, besides the above mentioned, influence each other, namely they either support each other or they are indifferent or they can affect negatively each other. It means the knowledge of their allelopathic relations must not be depreciated in the interests of good prosperity and longevity of the designed stands.

Recommendations for practice

The global as well as local warming, mainly in the urban environment, increase of the glasshouse effect and unfavourable effects of the radiation affect not only the composition of allochthonous gene pool but also the representation and species composition of woody plant species planted for the horticultural activity, as well as activities to arrange the landscape. There opens an area for hybridization aimed at varieties tolerant of drought, salinity of soils and polluted environment. There increase demands for attractive flowering, variability of habitus, fruits, seeds and other parts of plants. The introduction is aimed at warmer and arid areas in the world, with salty soils, etc. The result of these processes and changes are new criteria necessary for the evaluation of woody plants for horticultural activity and for landscape creation.

Trees, and woody plants in general, are able to adapt themselves to a broad scale of site conditions, and it is important especially in the urbanized environment. Woody plants and their communities fulfill a range of functions in the system of greenery, from protective, isolating, melioration, through microclimatic, hygienic up to ornamental, in the system of greenery in settlements and lanscape (they create the image – picture of the landscape). The criteria for various extent of utilization shift more towards the sphere of ecological and organizational, and then follow the aesthetic criteria, and the growing and application criteria are at the end. Valorization of the criteria is of great importance mainly from the viewpoint of environmental changes as well as new knowledge in the sphere of protection and creation of landscape, and specially the cultural vegetation.

Conclusion

The intensively changing environmental conditions cause changes in the evaluation of woody plants for application in these changed conditions. The cultivation programmes in nurseries adapt naturally to the changed requirements of customers, and their breeding and scientific-theoretical activity is aimed at the new situation. Measures of legislative character cannot be neglected also. However, they should not restrict but help to solve the problems on conceptual levels of area planning and landscaping as a specific discipline at forming the qualities of the environment and landscape image of our country. The environment is changing, the requirements for woody plants are changing, and therefore the introduction, selection and hybridization aimed at stregthening the resistance in woody plants are necessary.

Ecology, urbanism, landscaping and architecture must give clearly formulated directions for the creation of not only healthy but also aesthetic environment. The greenery inside the towns is created predominantly by parks which must be logically connected with the greenery of forest parks and recreational forests of broader hinterland. The park and cultural greenery in general is in the present sense a complicated biologico-technical and artistic work, which is not only laid out but it is controlled and maintained during its development. It shall be a part of the system of greenery in towns or whole agglomerations.

Greenery is an inseparable phenomenon from the process of creation of the urban environment and it is of great environmental importance. The relation of man to the environment was and it remains very close and any negative intervention into the environment in which man lives can be negatively manifested on his health and activity. We know that man changes the environment to a better one, and he changes at the same time, too. The contact with nature was in the process of development of mankind at various degrees of intensity but it was and many natural processes were fixed also in feelings and healthy state of man.

Contemporary creation of architects, urbanists and landscapers must bring back the lost atmosphere to the public areas, parks and pedestrian zones, cleanliness and genuiness to our country. We must restore the contact zone in the town, to make it accessible, equip it and improve the image. The most suitable ground for the regionalistic diversity of opinions is the pluralistically democratic society which grants new areas and dimensions for the architectural and landscaping activities.

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PROJEKTOVANIE KULTÚRNYCH FYTOCENÓZ PRE URBANIZOVANÉ PROSTREDIE

Súhrn

V nevhodných urbanistických podmienkach zanikajú spoločenské kontakty, čo spôsobuje vznik duševných chorôb, frustrácie i mnohých protispoločenských a spoločensky nežiadúcich prejavov (vandalizmus, realizácia toxikománie a i.). Preto je potrebné venovať pozornosť človeku, prostrediu v ktorom prebýva, potrebám jeho vzťahu k prírode i dosiahnutiu rovnováhy medzi telesným a duševným rastom a formovaním osobnosti človeka. Prírodné prostredie pozitívne ovplyvňuje telesné a duševné zdravie, podporuje harmonický rast a urýchľuje obnovu životných síl. Urbanistické podmienky v sídlach sú už veľmi nevhodné z hľadiska vhodnosti pre človeka a preto je potrebné ich prestavať alebo budovať nové na nových ekologickejších princípoch. A v tomto smere nadobúda vegetácia a špeciálne urbánna vegetácia veľký význam. Zeleň ako kategória sa viaže najmä na vegetáciu kultúrnu, teda

na kultúrne spoločenstvá rastlín, tzv. kulturfytocenózy. Parkove upravená vegetácia predstavuje kompozíciu živých (stromy, kríky, byliny a trávniky včítane vody), neživých prvkov (drobná architektúra, vybavenosť, spevnené plochy, chodníková sieť, hygienické zariadenia) a terénu podľa princípov sledujúcich istý estetický a emocionálny účinok a v tomto duchu je aj udržiavaná.

Ideový zámer, myšlienka, ktorá je súčasne nositeľom koncepcie každej sadovej a krajinárskej úpravy si podriaďuje jednotlivé zložky diela z ktorých vegetácia, najmä dreviny majú podstatnú úlohu. Funkčnosť a funkcionalizmus hrali dlhú dobu dominantnú úlohu i v záhradnej architektúre i keď moderna sa prejavuje sporadicky, prípad od prípadu. Urbánna a vôbec aplikovaná dendrológia má svoje špecifiká, zohľadňuje predovšetkým ekológiu technoprostredia mesta a kultúrnej krajiny pri znalosti biologického materiálu pre návrh kultúrnych spoločenstiev parkových alebo lesoparkových. Rajonizácia využitia, poznania alelopatických vzťahov v spoločenstvách, estetické a biologické hodnotenie drevín, ich vlastností pre plnenie rôznych funkcií zelene v urbanizovanom prostredí sú podkladom pre správny výber a návrh skladby takýchto spoločenstiev. Kultúrne spoločenstvá rastlín parkových úprav majú byť stabilné a funkčne vysoko účinné i pri zohľadnení regionálnych predstáv o konkrétnom prostredí tvorby. Priestor (urbanizovaný, mestský a vidiecky) z hľadiska polohy, ako aj rozlohy, je často rozhodujúcim faktorom zdarnej existencie a teda aj maximálne účinnej pôsobnosti dielčích úprav v rámci konkrétneho systému.

Výsledkom negatívnych činností v krajine sú globálne environmentálne zmeny, ktoré je potrebné eliminovať, prípadne obmedziť. Tvoria sa nové disciplíny, ekologická architektúra, stvárňovanie priestoru (krajinotvorba) a urbánna ekológia, ktoré usmerňujú vývoj dendrológie do špeciálnej disciplíny – urbánnej dendrológie. Aplikovaná dendrológia pre formovanie kultúrnych spoločenstiev parkových rastlín sa orientuje na nové výsledky vied ekologických a v architektúre. Funkčnosť a teda i funkcionalizmus v záhradnej architektúre prakticky platí i naďalej pri zvýšených nárokoch na estetiku a kultúrnosť.