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Evaluation of two inorganic forms of nitrogen in water of the Nature Reserve Žitavský luh

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Abstract

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The water in the Nature Reserve Žitavský luh was examined to find concentrations of two inorganic forms of nitrogen (N-NO_3^-, N-NH_4^+). The evaluations were carried out over the whole year 2003. At all the sampling sites, both evaluated variables were found season-dependent on the environmental factors as well as mutually dependent on each other. The peaks of the mean N-NO_3^- concentrations were observed out of the vegetative season, in February (4.24 mg dm^{-3}) and November (3.80 mg dm^{-3}); probably reflecting the absence or only low rate of the uptake by autotrophic organisms in this time. According to the sampling sites, the highest mean N-NO_3^- concentrations were found in the Site No. 1 in January (3.40 mg dm^{-3}), February (8.70 mg dm^{-3}), May (2.50 mg dm^{-3}) and October (2.40 mg dm^{-3}). The Site No.1 presents the uptake spot for water transported by the Žitava River to the Reserve; therefore, the Žitava River can be considered as an important source of nitrate nitrogen for Žitavský luh. Decreasing tendency of N-NO_3^- was kept until summer, with the minimum in June (0.90 mg dm^{-3}), when the lowest N-NO_3^- concentrations were determined for the open water area in the sampling Sites No. 4 and 5. This can be connected with intensive N-NO_3^- drawing off by the phytocoenosis, especially by the phytoplankton, and also with absence of dissolved oxygen, resulting in inhibition of the nitrification process. The absence of dissolved oxygen in summer could also be the reason for increasing N-NH_4^+ levels in the sampling sites. The maximum mean N-NH_4^+ concentrations were observed in January (1.03 mg dm^{-3}) and February (0.79 mg dm^{-3}), which could be connected with the temperature conditions unfavourable for nitrification process. Based on the obtained mean N-NH_4^+ concentrations, it is possible to hypothesize that the main source of N-NH_4^+ was the decomposing organic matter in the sediments.

Key words

wetland, nitrate nitrogen, ammonium nitrogen

Introduction

Wetlands play an important role in effective transformation of nutrients and maintaining efficient biogeochemical cycles (Patten, 1990). Nitrogen compounds occurring in water can be found in organic and inorganic forms: ammonium, nitrite and nitrate (Noskovič, 1997). Concentrations of various forms of nitrogen in waters are dependent not only on its source, but also on biological processes running in the water medium – such as fixation of the atmospheric nitrogen, ammonisation, denitrification and nitrification (Štepánek, 1979).

Wetland ecosystems have properties of key importance for the biochemical nitrogen cycle. The permanently wet soil surface of many wetlands is a favourable environment for N fixation, particularly by blue-green algae (Patten, 1990). In terms of thermodynamics, the most stable and therefore most frequent form of inorganic nitrogen is the nitrate nitrogen, very well soluble in water and stable in aerobic conditions (Bűchlerová and Olejko, 2002).

Ammonium is the main inorganic nitrogen compound in natural wetland systems, with the values reaching up to 1–2 mg dm^{-3}, especially in summer (Patten, 1990). Under favourable conditions, ammonium can be transformed, by bacterial oxidation, to nitrites or nitrates (Štepánek et al., 1979).

Material and methods

The Nature Reserve was established in 1980, and originally it represented a wetland with an area of about 140 ha. The actual area is 74.69 ha, situated at an altitude of 132–133 m a. s. l. Geographic coordinates are: 48°12’ N and 18°19’ E. As for the climate, the territory belongs to the warm and dry region with mild winter and an average annual temperature of 9.5°C. The annual precipitation total represents 600 mm. The territory of the Reserve comprises parts of three cadastral zones belonging to the villages Maňa, Kmeťovo and Michal’ nad Žitavou (district Nové Zámky). The original side channel of Žitava crossing the southern and western part of the territory in 600 m long and belongs to the catchment area of the Žitava River, the training bank of the river represents the western boundary. The northern boundary is identical with the boundaries of the districts Nitra and Nové Zámky. The lowest parts on southeast of the considered wetland are typical marshes. The source of water is the surface water of the regulated Žitava River transported along an underground channel, from which the water periodically penetrates to the wetland surface. Until 1994, higher situated, periodically flooded meadows (cca 35 ha) were regularly mowed with machines.

The locality represents a significant habitat, especially because it serves as a foraging and breeding site for several endangered wetland bird species, both nesting and migratory. There have been confirmed 39 at-European-level endangered bird species occurring in this area: 7 critical endangered, 16 endangered and 4 migratory (Danko et al., 1995). Svobodová (1992) confirmed 262 upper plant species, 36 from them was being endangered species of the Slovak flora. The critically endangered taxon of high ecosozological value is *Adonis flammea,* endangered rare taxons: *Clematis integrifolia, Papaver albiflorus, and Viola pumila.* From the endangered we list here: *Adonis vernalis, Carex melanostachya, Carex paniculata, Catabrosa aquatica, Nepeta pannonica, Taraxacum palustre, Tithymalus salicifolius, Veronica longifolia.* The succession of the main vegetation formation of *Glyceria maxima, Typha latifolia* is in progress and has a significant impact on decrease in the nesting bird species. Wood vegetation in the southern part of the Reserve consists of associations and communities of *Salicion albae*, with expanding an invasive North American species – *Negundo aceroides*. At present, the riverine vegetation can only be found on the rest of original, non regulated flow of Žitava. The dominant woody plants are: *Salix alba*, *Salix fragilis*, *Salix cinera*, *Alnus glutinosa* and *Populus alba*. The shrubs are represented by *Crategus monogyna*, *Rosa canina* and *Rubus caesius*.

Sampling and processing of the material

The water from the wetland was sampled regularly, over the whole year 2003, monthly, always about the date of the 15-th. The layout of the sample sites system was proposed in such a way as to obtain the best possible data for evaluation the changes in concentrations of inorganic forms of nitrogen in dependence on space and time. We have established the following five sites:

1. The beginning of the old original bed of the Žitava River. It is the collection spot of the water transported from the Žitava River through the underground channel to the western part of the Reserve in spring and summer months.
2. Pursuing original bed of the Žitava River with the protective levee on the southern bank.
3. An open water area, with the water outfall regulated with a floodgate to control the flood water level in the southeastern part of the Reserve.
4. and 5. The sample sites situated on the open water area in the southeastern part of the wetland, with marshy character, adjacent to a road.

In the taken samples we have determined N-NO_3^- (colorimetric with phenoldisulphonic acid), and N-NH_4^+ (colorimetric with the Nessler's reagent).

Results and discussion

From the values of mean concentrations of nitrate and ammonium nitrogen it was evident that they were seasonal dependent, with a considerable range of variation (Fig. 1). The mean nitrate nitrogen concentration over the research period ranged from 0.90 mg dm^{-3} to 4.24 mg dm^{-3}, with the peaks found out of the growing season, in February (4.24 mg dm^{-3}) and November (3.80 mg dm^{-3}) – probably in connection with low or absence of any uptake by autotrophic organisms. The mean concentrations of nitrate nitrogen decreased from February to June, when the lowest concentration was determined (0.90 mg dm^{-3}). The second lowest mean concentration was found in July (0.94 mg dm^{-3}) and the third in August (1.12 mg dm^{-3}). Pitter (1990) also determined varying nitrate concentrations in natural waters over the vegetation period. The maximum concentrations of nitrate nitrogen were found in winter, i.e. out of growing period and minimum in summer, i.e. within the growing period, when nitrates are drawn from the water by the vegetation.

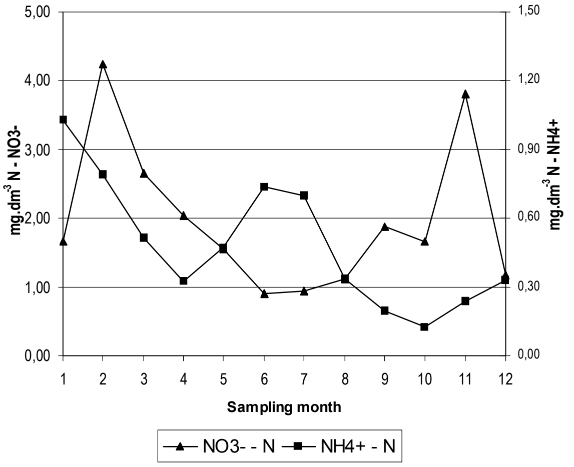

Fig. 1. The dynamics of N-NO_3^- and N-NH_4^+ concentrations over the year 2003

Considering the sampling site (Fig. 2), the highest mean N-NO_3^- concentration (8.70 mg dm^{-3}) was found in February for Site No.1, which is the collection spot for the water transported from the Žitava River to the Reserve. Therefore, Žitava can be considered as an important source of the nitrate nitrogen entering the Reserve. The lowest mean concentrations of N-NO_3^- 1.14 mg dm^{-3} and 1.51 mg dm^{-3} were determined in June for Sites No. 4 and 5, respectively, localized on the open water area on the southeast. This can be connected with intensive drawing off the N-NO_3^- by the phytocoenosis, especially by phytoplankton, and also with absence of dissolved oxygen; both factors inhibiting the nitrification process. Analogous effect of phytoplankton on the nitrate nitrogen concentrations was determined by Janda et al. (1998).

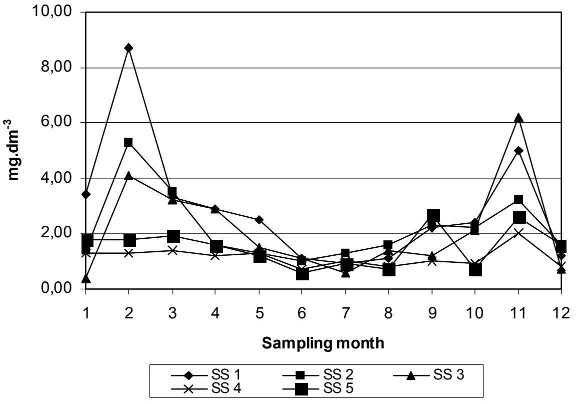

Fig. 2. N-NO_3^- concentrations in sampling sites depending on sampling time

The mean N-NO_3^- concentrations in the sample sites over the research period are demonstrated in Fig. 3. The highest value of mean N-NO_3^- concentration was found for Site No.1 where the water from the river Žitava enters the Reserve.

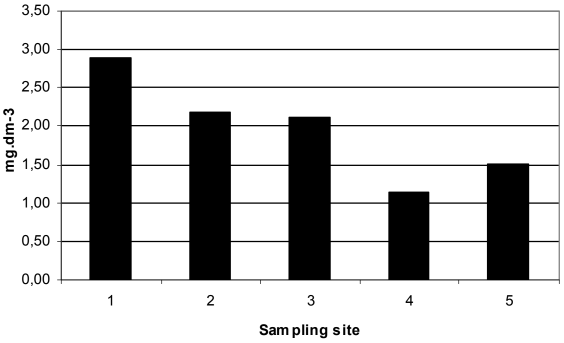

Fig. 3. The mean N-NO_3^- concentrations in sampling sites in the year 2003

Ammonium nitrogen is a precursor of nitrite nitrogen and nitrate nitrogen (Gábriš et al., 1996). This process was the main reason of the fact that the mean N-NH_4^+ concentrations (Fig. 1) over the research period were considerably lower compared to the N-NO_3^- concentrations. The highest mean N-NH_4^+ concentrations over the whole research period were determined in January (1.03 mg dm^{-3}) and February (0.79 mg dm^{-3}), following from unfavourable conditions for nitrification corresponding to the sampling time. The continual ice layer covering the water and prohibiting oxygen supply caused that the released ions N-NH_4^+ were not oxidized and cumulated in the water. Progressive warming of the water caused decreasing the N-NH_4^+ concentrations until April. In May, June and July, there were identified pronounced N-NH_4^+ concentrations resulting from accumulation. Similar tendency was described for other various eutrophic standing waters (Janda et al., 1998). The most significant increase was found in June for Sites No. 4 and 5 (Fig. 4), on the open water plot. The absence of dissolved oxygen in water in these sampling sites was the reason why the ammonium nitrogen released in the mineralising process of decomposing organic matter was not oxidized and cumulated in the water. The dynamic of the N-NH_4^+ concentrations in the sampling sites over the whole research period is summarised in Fig. 4.

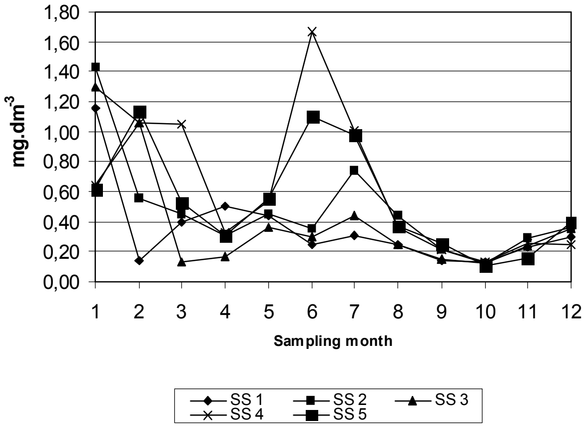

Fig. 4. N-NH_4^+ concentrations in sampling sites depending on sampling time

The mean ammonium nitrogen concentrations over the whole research period ranged from 0.35 mg dm^{-3} (Site No. 1) to 0.63 mg dm^{-3} (Site No. 4), (Fig. 5).

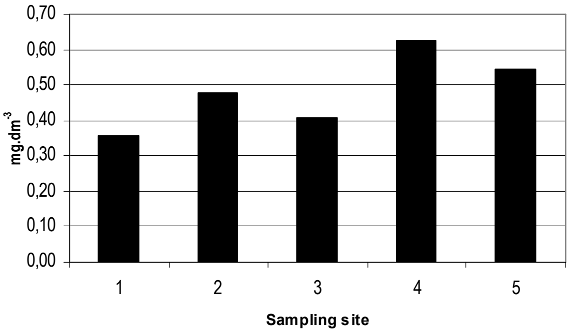

Fig. 5. The mean N-NH_4^+ concentrations in sampling sites in the year 2003

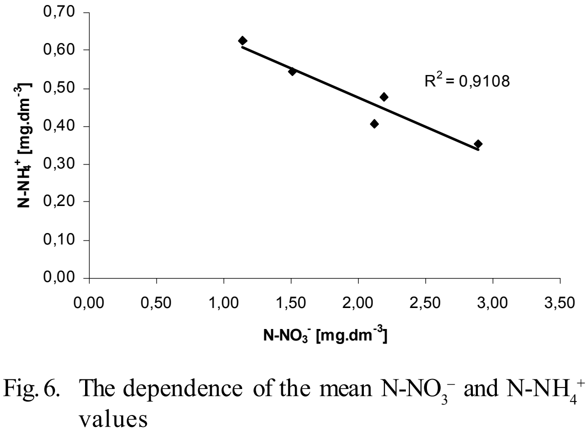

Fig. 6. The dependence of the mean N-NO_3^- and N-NH_4^+ values

Connection between the mean values of both inorganic forms of nitrogen for the individual sampling sites is expressed by a decreasing straight line, expressing their negative correlation (Fig. 6). The value of reliability ($R^2 = 0.9108$) points out a very high dependence between the concentrations of these two inorganic forms of nitrogen. However, the $N\text{-}NO_3^-$ concentration is always higher than the corresponding $N\text{-}NH_4^+$ concentration.

Conclusion

The results showed that the concentrations of both inorganic forms of nitrogen in the Nature Reserve Žitavský luh were changing over the whole research period in dependence on the sampling time and sampling site. Both inorganic forms of nitrogen revealed the seasonal dependence on the environmental factors (temperature, concentration of dissolved oxygen) as well as bilateral dependence on each other according to the sampling sites. The peaks of the mean $N\text{-}NO_3^-$ concentrations were identified out of the growing season in February and November, probably related with low or absence of any uptake by autotrophic organisms in this time. Considering the sampling site, the highest mean $N\text{-}NO_3^-$ concentration was found for Site No. 1 in January, February, May and October. The Site No. 1 presents the collection spot for water coming from the Žitava River to the Reserve; therefore Žitava can be considered an important source of nitrate nitrogen entering the Žitavský luh Reserve. Decreasing tendency of $N\text{-}NO_3^-$ until summer with the minimum in June was determined for sampling Sites No. 4 and No. 5 localized on the open water area. We can connect it with drawing off the $N\text{-}NO_3^-$ by the phytocoenosis, especially by phytoplankton and also with the absence of dissolved oxygen, both facts inhibiting the nitrification process. The absence of dissolved oxygen in summer was the reason of increasing $N\text{-}NH_4^+$ levels. Maximum mean $N\text{-}NH_4^+$ concentrations were found in January and February, which can be connected with unfavourable temperature conditions for nitrification process. Based on the obtained mean $N\text{-}NH_4^+$ concentrations, it is possible to state that the main source of $N\text{-}NH_4^+$ was the decomposing organic matter within the sediments. Ammonium nitrogen is a precursor of nitrite and nitrate nitrogen. This fact was probably the main reason why the mean $N\text{-}NH_4^+$ concentrations during the research period were markedly lower compared to the $N\text{-}NO_3^-$ concentrations, with exception of higher values found in June and July. We can conclude about higher releasing of $N\text{-}NH_4^+$ resulting from favourable conditions in the summer season.

Acknowledgement

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Hodnotenie koncentrácií vybraných foriem anorganického dusíka vo vode prírodnej rezervácie Žitavský luh

Súhrn

V priebehu roka 2003 sa vo vode prírodnej rezervácie Žitavský luh hodnotili koncentrácie vybraných foriem anorganického dusíka (NO_3^--N, NH_4^+-N). Získané výsledky ukázali, že koncentrácie oboch anorganických foriem dusíka v PR Žitavský luh sa menili v závislosti od času a miesta odberu. Obe formy anorganického dusíka prejavili sezónnu závislosť od faktorov prostredia ako aj vzájomnú negatívnu závislosť v odberových miestach. Kulminačné vrcholy priemerných koncentrácií NO_3^--N sa zistili v mimovegetačnom období v mesiacoch február (4,24 mg dm^{-3}) a november (3,80 mg dm^{-3}), čo súvisí pravdepodobne s tým, že jeho príjem autotrofnými organizmami je v tomto období veľmi nízky, resp. nie je vôbec prijímaný. Z hľadiska miesta odberu bola spravidla najvyššia koncentrácia NO_3^--N v 1. odberovom mieste, a to v mesiacoch január (3,40 mg dm^{-3}), február (8,70 mg dm^{-3}), máj (2,50 mg dm^{-3}) a október (2,40 mg dm^{-3}). Odberové miesto č. 1 je lokalizované v mieste vyústenia potrubia prívodného kanála, ktorým je voda do PR privádzaná z rieky Žitavy, preto rieku Žitavu možno považovať za významný zdroj NO_3^--N v Žitavskom luhu. Priemerná hodnota NO_3^--N od mesiaca február postupne klesala, pričom jej minimálna hodnota bola v mesiaci jún (0.90 mg dm^{-3}). V uvedenom mesiaci boli zistené najnižšie koncentrácie v 4. a 5. odberovom mieste, ktoré sú lokalizované v súvislej stojatej vodnej ploche. Predpokladáme, že to súvisí s jeho intenzívnym odčerpávaním fytocenózou, najmä fytoplanktónom ako aj s nedostatkom rozpusteného kyslíka vo vode, čím bol inhibovaný proces nitrifikácie. Nedostatok rozpusteného kyslíka vo vode v tomto období bol zrejme aj príčinou vzostupu koncentrácie NH_4^+-N v týchto odberových miestach. Maximálna priemerná koncentrácia NH_4^+-N bola v mesiacoch január (1,03 mg dm^{-3}) a február (0,79 mg dm^{-3}), čo možno spájať s nevhodnými termickými podmienkami pre priebeh nitrifikácie. Na základe získaných výsledkov koncentrácií NH_4^+-N možno konštatovať, že jeho hlavným zdrojom vo vode bola rozkladajúca sa organická hmota nachádzajúca sa v sedimentoch.

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Simulation study of the development of spatial genetic structure at the local scale during the colonization process. II. Relatedness

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Abstract

GÖMÖRY, D., SCHMIDTOVÁ, J. 2004. Simulation study of the development of spatial genetic structure at the local scale during the colonization process. II. Relatedness. *Folia oecol.*, 31 (2): 73–82.

Computer simulation was performed to assess the effects of seed dispersal, maternal fecundity and competition on spatial patterns of pairwise coancestry resulting from the expansion of a population to open area. A population consisting of 2.000 trees spatially distributed on an irregular square network with average distance among neighbours of 5 m was formed. Subsequently, expansion of this population was simulated over a period of 90 years, assuming overlapping generations (the age of reaching fertility of 30 years, established trees surviving until the end of the simulation), equal fertilities of maternal trees and exponential pollen and seed dispersal curves. Although the highest coancestry values were naturally found in the shortest distance classes, coancestry curves did not exhibit a smooth monotonous decrease with distance. In some cases (e.g., short seed dispersal), they even increased temporarily. This pattern is explained by the formation of dense clusters of half-sibs originating from seeds launched beyond the migration front, which are related to the half-sib relatives of their maternal trees. Maternal kin relationships are supposed to account for the formation of spatial genetic structure on the local scale, whereas paternal relationships do not seem to depend on distance.

Keywords

spatial genetic structure, local-scale colonization, population expansion, simulation

Introduction

Genetic aspects of the colonization process on the rangewide or regional scale have recently been an object of intensive research, mainly in association with the expansion of distribution ranges of tree species during the Holocene (TABERLET et al., 1998). The effects of colonization on genetic structures can be traced even after several generations and are of relevance for several practical issues like gene conservation, treatment of invasive plants, transfer of reproductive material of forest trees, etc.

In anemophilous and anemochorous plants, to which most economically important forest tree species belong, pollen and seed dispersal is never perfect. Isolation by distance is the consequence – the more are individuals (or populations) distant from each other, the more their genotypes (or gene pools) differ from each other. In an established population, isolation by distance over generations leads to an equilibrium level of differentiation among individuals and/or subpopulations. However, in an expanding population, the trees at the front edge have more possibilities to transmit their genes to offsprings than the more centrally located trees, since more "spatial niches" are available.

The hitherto studies mostly focused on the patterns of spatial organization of genes or gene frequencies, whereby the most frequently used instrument was spatial autocorrelation analysis (for review, see ESCUDERO et al., 2003). The course of the correlogram is subsequently used to estimate the parameters like neighbourhood size or mean dispersal distance (EPPERSON, 1995; HARDY and VEKEMANS, 1999). This approach relies on identity-in-state of genes, although it points towards identity by descent. A neighbourhood or seed dispersal are conceptually based on the common descent of genes rather than on similarity of genotypes. Naturally, there is a direct link between both concepts: a pair of relatives (i.e. a pair of individuals sharing genes descendant from a common ancestor) is expected to share more identical alleles than a pair of unrelated individuals. Nevertheless, even experimental studies allow a direct assessment of the levels and spatial arrangement of relatedness. Highly polymorphic DNA markers allow a relatively reliable reconstruction of kinship relationships (JONES and ARDREN, 2003; GERBER et al., 2003; GONZALEZ-MARTINEZ, 2002 etc.). In simulation studies, the complete reconstruction of whole pedigrees of offsprings can obviously be included.

Relatedness can be defined and described in various ways. An assessment of the spatial organization of consanguinity requires that it is quantified by a single number defining to what extent two individuals are related. Such a concept was developed by WRIGHT (1922) in the form of the coefficient of inbreeding. MALÉCOT (1948) redefined it in probabilistic terms employing the concept of identity by descent: the coancestry between two individuals is the probability that two alleles randomly sampled from their genotypes are identical by descent. To define the degree to which individuals within a group are related, COCKERHAM (1967) introduced the concept of group coancestry as an average of all pairwise coancestries, including self-coancestry and reciprocals. Again, group coancestry can be defined as a probability that two genes sampled with replacement from the gene pool are identical by descent. The concepts of inbreeding and coancestry are clearly related: in a random mating population, group coancestry in the adults quantifies the level of inbreeding in the offspring.

Computer simulation of genetic processes in a spatial context is a widely used approach (EPPERSON, 1995; DOLIGEZ et al., 1998 and others). It is also used for modeling of the colonization process, although emphasis is given to large-scale processes (AUSTERLITZ and GARNIER-GERE, 2003; LE CORRE and KREMER, 1997). Although models mostly oversimplify the biological reality, they allow to assess the effects of single factors, what is very difficult in manipulative experiments and almost impossible in observational biological experiments. Thus, they provide a better understanding of biological mechanisms, including colonization.

We studied the process of the colonization of an open area by Norway spruce at the research site Príslopy (Biosphere Reserve Poľana, Central Slovakia) within a research project financed by the Slovak Grant Agency for Science. At the current stage of the project, an ecologically explicit colonization model cannot be formulated yet. Therefore, we kept the simulation at a fairly general level. In a previous study (GÖMÖRY and SCHMIDTOVÁ, 2004), we investigated the effects of colonization on the formation of spatial genetic structure in the colonist population in terms of the spatial distribution of genes and genotypes. The presented study focuses on the assessment of the levels and spatial patterns of relatedness.

Material and methods

The simulation procedure essentially followed that described in GÖMÖRY and SCHMIDTOVÁ (2004): Initially, a tree population containing 2.000 individuals was simulated. The trees were distributed over an irregular square network with the average distance between neighbours of 5 m. The network was based on a square lattice with the distance between nodes of 5 m, with a random oscillation of tree positions around the nodes up to 5 m. Uniform random distribution was used to simulate the angle and the distance from the node. The area covered was thus approximately 216 × 216 m. The trees within the source population were considered non-related and non-inbred.

Subsequently, an unidirectional expansion of the population was simulated. The age, at which the trees were considered to be fertile (i.e., to bear male and female flowers or strobiles and to fructify) was set to 30 years in most simulations. Fertility variation or phenological asynchrony were not considered, each tree in the population aged over 30 years produced equal number of both pollen grains and seeds. In addition, we also tested the effect of a shorter generation turnover (15 and 7 years). To assess the effect of fecundity on the formation of the spatial structure, we simulated 1, 5, and 10 progenies per maternal tree. Although real fecundities are generally much higher in forest trees, only a small portion of offsprings survive until the fertile age.

The neighbourhood model (ADAMS and BIRKES, 1991; BURCZYK et al., 2002) was used to simulate mating:

$$\varphi_i = \frac{e^{-\beta d_i}}{\sum_k^n e^{-\beta d_k}}$$

where φ_i is the relative mating success of the i-th male partner at the distance d_i from the mother tree (seed parent), n is the number of all possible pollen parents. The whole adult population i.e. all trees of the source populations plus all progenies over 30 years of age were considered to belong to the neighbourhood. Distribution function of the mating success was then constructed by summing φ_i over the individuals, from which the pollen parent was chosen using a uniformly distributed random number.

For seed dispersal, the seed density $h(d)$ was assumed to decrease exponentially with distance ($h(d) = e^{-\beta d}$), based on which the distance of the seed drop from the mother tree can be simulated as $d = -\ln(u)/\beta$; where u is a uniformly distributed random number. The angle was simulated as a uniformly distributed random fraction of 2π. Polar coordinates of the seed were subsequently transformed to orthogonal ones. In both cases, we used the distance d_{50} as the dispersal parameter, i.e. the distance at which 50% of pollen grains reach the ovule and/or 50% of seeds drop (considering exponential dispersal function and infinite dispersal). Isotropic dispersal was modeled both for pollen and seeds.

In the case of anemophilous species, pollen is rather efficiently dispersed, so that mating in a wind-pollinating population may mostly be considered random or almost random. Therefore, we selected the pollen-dispersal parameter β_{pollen} = 0.01385, corresponding to d_{50} = 50 m, which is 10-fold average distance between the trees of the source population. This value was used in all simulations. For seed dispersal, the values of β_{seed} = 0.0346, 0.069, and 0.14 were used, corresponding to $d_{50(seed)}$ = 20 m, 10 m, and 5 m, respectively.

Since we were interested only in the expanding part of the population, seed dispersal within the source population was not considered. To make the model more realistic by inclusion of competition, only those seed were allowed to germinate and grow, which did not fall closer than a preset competition distance, which was set to 1 and 2 meters, respectively. After the progenies reached 30 years of age, they were included into the set of maternal trees, i.e., they produced further off springs. Simulation was stopped after 90 years, what means that the youngest seedlings may belong to the 3rd generation in most simulations.

The parameter combination d_{50} = 10 m, d_{comp} = 2 m, and n_{pro} = 5 was used as a standard for comparisons.

Within each simulation, the identity of parents was recorded for successful seeds. Subsequently, pedigrees over 3 generations were reconstructed for all progeny individuals. For all pairs of individuals, Euclidean distance was calculated as

$$d_{AB} = \sqrt{(x_A - x_B)^2 + (y_A - y_B)^2}$$

where $[x_A, y_A]$ and $[x_B, y_B]$ are orthogonal coordinates of the tree A and B, respectively. Further, types of relatedness were scored (Fig. 1) and the pair-coancestry was calculated as

$$\Theta_{AB} = \sum_i (0.5)^{n_{pi}+n_{mi}+1}$$

where i is the designation of a common ancestor of the individuals A and B, n_{mi} and n_{pi} is the number of generations between the common ancestor and the individuals A and B over maternal and paternal lineages, respectively (Ollivier, 2002). Self-coancestries and reciprocal relationships were not considered. To avoid possible edge effects, trees lying within a 50 m strip from the left and right margin were excluded from the assessment of relatedness. Average coancestries were then calculated over 1 m distance classes, as well as over the whole offspring population.

For the simulations of the population expansion, an *ad hoc* program based on the package sim (Gömöry, 1995) was used.

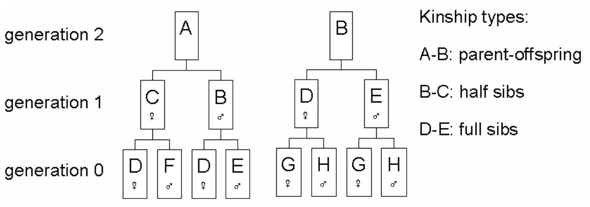

Fig. 1. Schematic representation of kinship types

Results

The formation of spatial patterns of relatedness in plant populations can be influenced by many factors. Our analysis was confined to seed-dispersal distance, maternal fecundity and competition. The farther seeds are dispersed, the higher is the potential for a tree to establish far beyond the migration front, and give rise to a group of half-sib offspring which will further be incorporated into a contiguous population when the front approaches it, what promotes a spatial genetic structure. On the other hand, also the spatial overlap of seeds dispersed from different mothers will be more extensive, having an effect on the spatial genetic structure. Concerning maternal fecundity, the more surviving offsprings per tree are produced, the quicker will the "spatial niches" be occupied and thus made unavailable for seeds coming later. Finally, competition distance determines how large the "spatial niches" are. In total, simulations for 7 different combinations of input parameters were accomplished.

The model allows a temporal and spatial overlap of different generations. The study focused only on the colonist population covering the open area. Neither the regeneration within the source population itself, nor the relatedness of the offspring to the trees of the source population were considered. The trees in the source population are considered non-inbred and non-related. This means that the trees of the 1st offspring generation may be related (half or full sibs) but not inbred. Starting from the 2nd offspring generation, various kinds of kinship and various levels of inbreeding may occur.

The colonization was limited by time (90 years), but not by space. Different combinations of input parameters resulted in different censuses, densities and distances of the migration front from the source population and, consequently, different numbers of pairs in individual 1 m distance classes. To avoid excessive random variation, we decided to omit estimates of average pairwise coancestry based on less than 500 pairs in the graphical presentations and the subsequent interpretation. For the calculation of the overall average coancestry, all tree pairs were included. The ancestor-descendant (e.g., parent-offspring) relationships are asymmetric, but no orientation can be assigned to sibling relationship or coancestry. Figures 2 to 4 should thus be interpreted as omnidirectional diagrams.

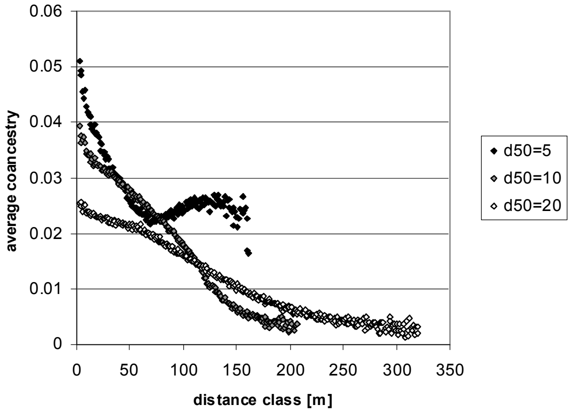

Fig. 2. Effect of the seed dispersal distance d_{50} on the spatial pattern of relatedness

For most input parameter variants, the decrease of the average coancestry with distance is monotonous but by far not linear. Adjustment of the simulated values to a regression curve would require higher-order polynomials, whereby regression coefficients would hardly be interpretable.

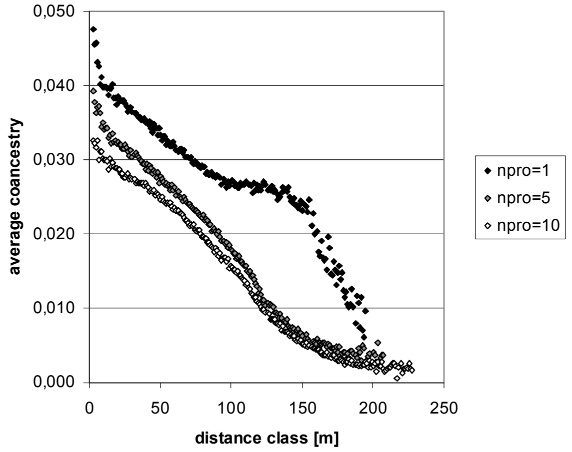

Fig. 3. Effect of the number of offsprings per maternal tree n_{pro} on the spatial pattern of relatedness

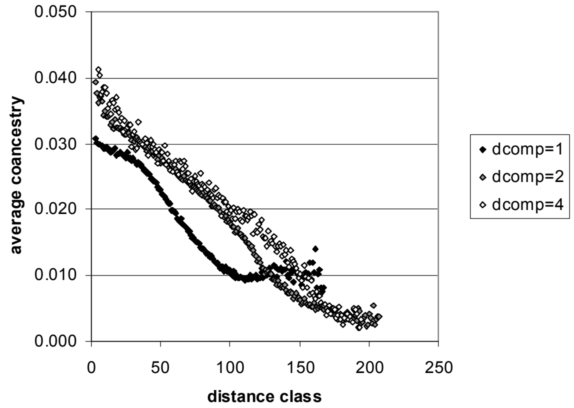

Fig. 4. Effect of the competition distance d_c on the spatial pattern of relatedness

Therefore, we decided to resign on regression and interpret the course of the respective coancestry values themselves.

Effects of seed dispersal distance

The choice of mean dispersal distances d_{50} used for simulations was determined by the tree distribution pattern in the source population. We selected d_{50} as an integer multiple of the average distance among trees: 5 m, 10 m and 20 m (Fig. 2). Average distance among neighbours should be regarded as a measure of the plant size. In a forest with closed canopy, it corresponds to crown diameter. Consequently, in the first variant, 50% of seeds fall beneath the crown, what corresponds almost to the gravity seed dispersal. On the other hand, at d_{50} of 20 m, the seed rain density is 16 times lower, what means a rather efficient seed dispersal. Wind dispersal of seeds follows the exponential dispersal curve. Other possible mechanisms (animal dispersal, animal caching, waterstream transport) were not modeled.

The variant with a restricted seed dispersal (d_{50} = 5 m) is just an exception from the rule. The decrease of coancestry with distance is not monotonous, the values decrease quite sharply up to the distance of approx. 70 m, but they increase then, and finally drop down at distances over approx. 130 m. We reconstructed the course of the population expansion to explain this pattern: with a restricted dispersal, trees tend to form rather compact groups of offsprings, but few seeds of every crop are dispersed far beyond the migration front. When the resulting trees start fructification, they form half-sib patches, which are dense because of a generally limited dispersal distance of seeds, and thus remain compact even when the migration front approaches them. The result is one half-sib group near the source and another one, 1 generation younger, near the front, with a common mother and grandmother, respectively. These “uncle-nephew” relationships are responsible for the temporary increase of coancestry at 70 m.

The same effect can be traced in the shape of average coancestry curves with higher seed dispersal rates. However, with the increasing mean dispersal distance, the half-sib patches become larger, less dense, thus more spatially overlapping. It is reflected in a more regular (almost linear for d_{50} = 20 m) decay of relatedness with distance. The overall average coancestry decreases with increasing d_{50} (Table 1).

Different kinship types do not contribute equally to the coancestry (Table 2). Full-sib relationships are extremely rare. Paternal kinships (half-sibs with a common father and father-offspring relationships) within the colonist population neither exhibit any spatial pattern. A slight decrease of frequencies of both kinship types with distance for d_{50} = 5 m is probably an artefact resulting from a smaller area covered by the colonist population as compared to the variants with larger d_{50}. Low and almost equal frequencies of paternal kinships in all distance classes indicate that a d_{50} of 50 m (as set for pollen dispersal) means that pollen flow is very efficient (effectively infinite), and thus the source population contributes massively to pollination during the whole colonization.

Table 1. Average coancestries for various combinations of input parameters

	Variants			Remaining input parameters
d_{50} [m]	5	10	20	$n_{pro} = 5$ $d_{comp} = 2$ m
Θ	0.027396	0.022010 1)	0.015924	
n_{pro}	1	5	10	$d_{50} = 10$ m $d_{comp} = 2$ m
Θ	0.030511	0.022010 1)	0.018322	
d_{comp} [m]	1	2	4	$d_{50} = 10$ m $n_{pro} = 5$
Θ	0.022171	0.022010 1)	0.021542	

1) standard variant

Table 2. Frequencies of selected kinship types under different seed dispersal distances

Distance class 1) [m]	Maternal half sibs	Paternal half sibs	Full sibs	Mother-offspring	Father-offspring
$d_{50(seed)} = 5$ m					
20	3.03E-2	6.38E-4	1.69E-5	6.15E-3	3.11E-4
40	5.17E-3	5.15E-4	2.38E-6	8.61E-4	3.58E-4
60	4.96E-4	3.94E-4	2.04E-6	1.55E-4	4.00E-4
80	4.01E-5	3.61E-4	0	9.44E-6	3.37E-4
100	0	3.35E-4	0	6.58E-6	2.37E-4
120	0	3.27E-4	0	0	1.69E-4
$d_{50(seed)} = 10$ m					
20	2.41E-2	4.30E-4	1.47E-5	4.25E-3	1.54E-4
40	8.17E-3	4.17E-4	0	8.67E-4	1.79E-4
60	2.41E-3	3.47E-4	1.09E-6	3.26E-4	2.01E-4
80	7.60E-4	3.33E-4	0	1.66E-4	2.17E-4
100	1.94E-4	2.48E-4	0	6.49E-5	2.31E-4
120	7.52E-5	2.00E-4	0	3.38E-5	2.89E-4
$d_{50(seed)} = 20$ m					
20	1.26E-2	4.51E-4	1.10E-5	2.56E-3	1.47E-4
40	7.17E-3	3.39E-4	1.50E-6	6.62E-4	1.29E-4
60	3.31E-3	3.73E-4	2.38E-6	3.09E-4	1.25E-4
80	1.67E-3	3.12E-4	1.25E-6	2.06E-4	1.39E-4
100	9.53E-4	2.66E-4	0	1.79E-4	1.81E-4
120	5.52E-4	2.08E-4	0	1.04E-4	2.14E-4

Competition distance 2 m, 5 offsprings per maternal tree

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1) upper limit

Maternal kinships (maternal half sibs and mother-offspring relationships) seem to be dominant contributions to coancestry. Note that with d_{50} = 5 m, there are almost no maternal kins in distance classes over 80 m, whereas coancestry temporary culminates at 130 m. This also indicates that the increase of coancestry between 70 and 130 m must be caused by other types of relatedness.

Effects of female fecundity

The variants tested represent the numbers of seeds produced by each maternal tree each year. The numbers of successful seeds are actually lower, because only seeds outside the competition range of older individuals were allowed by the model to germinate and produce a tree reaching the age of fertility. The fecundities considered in the model are unrealistically low, trees normally produce thousands of seeds. This parameter should actually be regarded as a composite effect of maternal fecundity, and the carrying capacity and heterogeneity of environment. The use of higher levels of fecundity would require modeling of mortality of seedlings and could introduce an artefact effect in the simulation, when seeds of a tree could not find a free spatial niche, because they would be occupied by seeds produced in the same year by its neighbour, which entered in the simulation earlier.

Although all coancestry curves decrease monotonously, low fecundity (n_{pro} = 1) produces a similar effect as a restricted seed dispersal. With a low fecundity, the progress of the migration front is slower, the colonist population remains at low density longer, what promotes the formation of half-sib families. With a higher fecundity, the available space becomes filled earlier, so that only seeds landing at larger distances can succeed. Larger and more overlapping families are the result.

Effects of the competition distance

Competition distance may be considered a rather simplistic tool for modeling interactions among trees. However, competition indices used in forestry include variables like tree height, crown size and shape, etc., so the tree growth process would have to be included in the model. In that case model would need to be fashioned for a particular tree species. Although this was not our goal at this stage, our approach to competition intuitively follows related logical assumptions: the density of trees reaching maturity and producing seeds cannot be infinitely high, and an older tree is supposed to be more successful in the competition than a younger one. Both assumptions are known to be broken in the nature (e.g., a younger tree can outcompete an older one, notably if the age difference is small), but they are valid in general.

While the overall average coancestries almost do not respond to the competition distance (Table 1), spatial patterns are rather different. For d_{comp} = 4 m, the density of the produced colonist population is very small. Consequently, there are less pairs and the variation among the coancestry estimates in distance classes is higher. Coancestries at short distances are the highest ones, and they decrease with distance almost linearly. For d_{comp} = 1 m, the course of the coancestry curve is more complicated, even with an increase between 110 m and approx. 140 m. A short competition distance allows a higher density and thus more spatial overlap of different families, so that average coancestries in lower distance classes are logically smaller.

Discussion

Spatial dispersal of plant propagules, its mechanisms and resulting patterns, belong to the key issues in plant population ecology. The effects of the dispersal of seeds and pollen on the spatial organization of genetic variation have been the object of both theoretical modeling and empirical studies. Spatially restricted gene flow generates genetic heterogeneity, since the other evolutionary mechanisms, like genetic drift, mutation and selection, may occur at different rates and act in different directions at different locations. This process is called isolation by distance. In plants with a fragmented range, the rate at which local subpopulations exchange genes decreases with increasing distance between them. In the case of a continuous range, it is the probability that two plants are relatives (i.e., have a common ancestor, share genes identical by descent) that depends on the distance.

Since the theoretical fundamentals were established by Wright (1946) and Malécot (1948), isolation by distance has been intensively studied. It is a dynamic spatial process, producing shifting patchworks of genotypes (Epperson and Li, 1993). Spatial autocorrelation analysis is therefore a preferred tool to study its effects on spatial genetic structures. The majority of theoretical studies rely on "lattice models", where plants are distributed over the nodes of a regular or irregular lattice. The results are derived from simulations (Epperson, 1995; Doligez et al., 1998; Hardy and Vekemans, 1999 and many others) and subsequently interpreted in terms of the isolation-by-distance theory. This is not an uncommon approach in population biology. In fact, any quantitative parameters refer to some kind of a model and should be understood as "effective quantities", i.e. numbers describing how a population or its part would behave if a defined set of assumptions is fulfilled. The problem is to what extent the assumptions of the model reflect biological reality. Shimatani (2002), who applied a stochastic point-process model, showed that spatial clumping of plants (which is quite common in nature, mainly in mixed communities) results in decreased spatial autocorrelations as compared to uniformly distributed populations. Consequently, spatial structure is not accumulated over generations, but just in opposite, it becomes more and more reduced. This is in contrast to the lattice models, which frequently yield unrealistically high degree of genetic clustering. The empirical observations in natural populations mostly do not confirm the existence of strong small-scale spatial genetic structures (for forest tree species, see the review in Geburek, 1993). Another problem is that the correlograms for different alleles may be very different. As pointed out by Slatkin and Arter (1991), different alleles may be subjected to different evolutionary forces, so under circumstances, computing an "average correlogram" may make no sense.

Hardy and Vekemans (1999) proved that spatial autocorrelation statistics are directly related to the parameters of kinship under the isolation-by-distance model. They argue that if there is a direct mathematical relationship between the estimators of kinship and autocorrelation statistics, using both of them to describe the spatial genetic structure is useless. This is true in an ideal population fulfilling the model assumptions (absence of selection, non-overlapping generations etc.). Interpreting spatial autocorrelation statistics in terms of kinship in real plant populations must therefore be very cautious.

Lattice models exhibit a tendency to equilibrium spatial structures after a number of generations, and most authors are interested just in the equilibrium state. In contrast, our study focused on genetic structures in the initial stages of the formation of the newly expanded part of a population. The phenomenon of colonization of an open area from the adjacent tree stand is by far not an exception in the nature. It occurs after severe natural disturbances, such as fires, windbreaks, etc., or may be human-induced by large-scale logging or expansion of forest on abandoned farmlands. There are large areas in Europe, which are considered natural forests now, but in fact they exist for few generations only. Even for true natural forests, their age if measured by generations need not be very high. The small ontogenetic cycle of Central-European primeval forest lasts, depending from species composition, from 150 to 250 years (Korpeľ, 1995).

Considering the fact, that most species appeared in Central Europe in Holocene some 8 to 10 ky BP, the number of generations may range from 30 to 65, whereby Hardy and Vekemans (1999) estimated that equilibrium is reached after approx. 250 generations.

Our previous study (Gömöry and Schmidtová, 2004) led to similar autocorrelation values as the simulation of Hardy and Vekemans (1999) in the early generations. However, we demonstrated that the identification of the spatial structure depends on the allele frequency. Rare alleles need not reveal a spatial structure even when it exists, because of sampling error. The comparison of correlograms with the coancestry curves presented in the current study does not allow to conclude about a direct relationship between the two concepts.

Compared to the spatial autocorrelation approach, a direct assessment of kinship and examination of its spatial structure is rare. Molecular markers allow the quantification of pairwise kinship in relation to distance (Loiselle et al., 1995).

The recent use of highly variable microsatellite markers allows a very reliable assessment of kinship for this purpose (KAMEYAMA et al., 2002).

BRUNEL and RODOLPHE (1985) used Bayesian approach to quantify half-sib and full-sib pairs in a Norway spruce population originated from natural regeneration. Like in our study, they found practically no full sibs, but the proportion of half sibs was excessively high as compared to our results (P_{HS} = 0.6). Although there might be some conceptual problems with the computation (linkage or epistatic effects among the loci used for the determination of kinship, deviations from the HW equilibrium etc.), a high level of coancestry can be due to the establishment history of stand (origin from a single seed crop of few widely spaced flowering seed trees, causing that most of offsprings are related either by mother or by father).

Our simulation study proved that the formation of a spatial kinship structure in an expanding population is affected by several parameters. The construction of a biologically credible model requires an empirical estimation of these parameters and its validation in a field study.

Acknowledgement

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Simulácia vývoja priestorovej genetickej štruktúry v lokálnej mierke počas procesu kolonizácie II. Príbuzenské vzťahy

Súhrn

Použili sme počítačovú simuláciu na určenie vplyvu rozptylu semien, plodnosti materských jedincov a konkurencie na priestorové rozdelenie príbuznosti medzi jedincami, ktoré vzniká pri expanzii rastlinnej populácie na voľnú plochu (napr. pri kolonizácii opustených pasienkov lesom). Simuláciou sme vytvorili rovnovekú populáciu pozostávajúcu z 2 000 jedincov priestorovo rozmiestnených v nepravidelnej štvorcovej sieti s priemernou vzdialenosťou medzi susednými stromami 5 m. Následne bola modelovaná expanzia tejto populácie po dobu 90 rokov. Stromy boli považované za plodné vo veku 30 rokov, s rovnakou produkciou samčích aj samičích gamét, a všetky jedince prežívali po celú dobu simulácie. Pre modelovanie rozptylu peľu a semien bola použitá exponenciálna krivka.

Aj keď najvyššie hodnoty príbuznosti boli samozrejme pozorované v najnižších triedach vzdialenosti, závislosť príbuznosti od vzdialenosti nevykazovala plynulý monotónny pokles. V niektorých prípadoch (napr. pri krátkej priemernej vzdialenosti rozptylu semien) krivka príbuznosti dokonca dočasne narastala. Toto priestorové rozdelenie možno vysvetliť vytváraním pomerne hustých polosesterských príbuzenských skupín, ktoré sú potomstvami jedincov vznikajúcich zo semien zanesených pred čelo migrácie, ktoré si zachovávajú integritu aj potom, ako ich migračný front dosiahne. Na vytváraní priestorovej štruktúry v lokálnej mierke (napr. mierke porastu) sa podieľajú predovšetkým príbuzenské vzťahy po materskom jedincovi. Vzťahy po otcovskom jedincovi nevykazujú závislosť od vzdialenosti.

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Gall-wasps (Hymenoptera, Cynipidae) associated with ten oak species in the “Quercetarium“ Čifáre

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Abstract

Kelbel, P. 2004. Gall-wasps (Hymenoptera, Cynipidae) associated with ten oak species in the “Quercetarium“ Čifáre. *Folia oecol.*, 31 (2): 83–90.

In the years 2001 and 2003 a study of gall-wasps (Cynipidae) was carried out in the experimental area of the “Quercetarium“ Čifáre. The area has been established with the aim to study nine autochtonous species of the Quercus genus. We performed our research on the following autochtonous oak species: *Quercus dalechampii* Ten., *Q. petraea* (Matt.) Liebl., *Q. polycarpa* Schur, *Q. pedunculiflora* C. Koch, *Q. robur* L., *Q. frainetto* Ten., *Q. pubescens* Willd., *Q. virgiliana* Ten. and *Q. cerris* L. Besides the autochtonous oaks, also *Q. rubra* L. was planted here, which was also included in our study. In the course of the research, in total 31 types of galls were detected, from which 20 types were galls on buds, two types of galls on fruit and 9 types of galls on leaves. From the investigated oaks, *Q. robur* was the most attacked by gall-wasps, with identified together 28 types of galls.

Key words

Cynipidae, *Quercus* spp., gall-wasps

Introduction

Up to present, in Slovakia there have been determined 9 autochthonous species belonging to the *Quercus* genus. The research was launched in the Arboretum Mlyňany in 1976, and in 1982 (Hrubík and Požgaj, 1988), there has been established a permanent research plot consisting of autochthonous oak species in Čifáre (Forest Enterprise Levice). The family of gall-wasps (Cynipidae, Hymenoptera) comprises numerous phytophagous insect species with relatively narrow range of food specialization. The females of phytophagous gall-wasps lay their eggs selectively – only into some particular plant organs. Their overall bionomy is rather complex and it has already been described in detail in other works (Kelbel, 2001, 2002).

Amid woody plants, oaks are the most attacked by gall-wasps. Pfeffer et al. (1961) present about 100 gall-wasp species developing in oak galls. In Slovakia, gall-wasps were dealt with, for example, in works by Červeňák (1955, 1958), Hrubík (1972, 1976, 1978), Křístek (1973), Kelbel (1994, 1995a, 1995b, 1996, 1997). During their entomofaunistic research in the experimental “Quercetarium“ Čifáre, Hrubík and Požgaj (1988) identified 16 Cynipidae species. In the years 1987–1992, Skuhravý et al. (1998) found out together 78 insect species feeding on oaks (*Quercus* spp.), the most frequent gall-wasp species (Cynipidae) were: *Andricus kollari* Htg., *A. lignicola* Htg., *A. lucida* Htg., *Neuroterus quercusbaccarum* L. and *Biorrhiza pallida* Oliv. We can suppose that the number of entomofauna species feeding on oaks in the "Quercetarium" Čifáre will increase not only because of increasing age of trees but also as a result of the beginning of the fructification developmental stage of these oaks. This hypothesis has already been confirmed by the study results (Hrubík, 1993; Skuhravý et al., 1998; Hrubík, 1999). The study on gall-wasps was not only focussed on their economic significance, but also included their development, study of hosts on both sexual and agamic gall-wasp generations, and a possible introduction of new species together with plant material – followed by the insect spreading over the European continent. Detailed analyses of their parasitoids resp. inquilines were accomplished, e.g. by Hails et al. (1990), Notton (1990), Stone and Sunnucks (1993), Schönrogge et al. (1998, 1999, 2000), Plantard et al. (1996), Plantard and Hochberg (1998), and others. Such detailed studies contribute to precising the systematics, understanding the developmental cycle and also the identification of new gall-wasp species, e.g. Lyon (1996), Melika and Abrahamson (1997), Melika et al. (1999), Stone et al. (2002), Atkinson et al. (2003), Stone and Schönrogge (2003), and others.

Up-to-date performed investigations into the entomofauna of the "Quercetarium" Čifáre have revealed numerous representatives of this insect group. Therefore, our work was focussed to obtain new, or to improve the existing information on the gall-wasp species currently present on the autochtonous Slovak oak species in the "Quercetarium", to compare the actual data with the results of the former research (Hrubík and Požgaj 1988; Hrubík, 1999), to assess the potential threat from gall-wasps to the individual oak species and to evaluate the economic importance of the studied insects.

Material and methods

In the years 2001 and 2003, we carried a study of gall-wasps (Cynipidae) in the experimental area of the "Quercetarium" Čifáre – an experimental plot of Slovak autochthonous oak species founded in 1982 by Ing. Jozef Požgaj, CSc. (The Institute of Forest Ecology of Slovak Academy of Sciences in Zvolen, Branch for Woody Plant Biology in Nitra). This experimental area was intended to gather all known original Slovak oak species and to enable observations on their ontogenesis, morphological variability, and fittness – e.g. resistence against biotic and abiotic harmful factors (Požgaj, 1986). The subject area is situated in south-western Slovakia, in the Pohronská pahorkatina upland, belonging to the Forest District Čifáre (Forest Enterprise Levice), (Požgaj, 1986), at 225–245 m a.s.l. The group of forest types at the site is Carpineto-Quercetum (hornbeam-oak forest, forest type 1308 – productive vetch-oak forest on loess (sensu Hančinský, 1972). The average annual temperature ranges from 9.0 to 9.5°C, average annual precipitation from 600 to 650 mm. The experiment was divided into two sections. The first represented the collection of all 9 native species of the genus *Quercus* (every species represented by 1 variant) in Slovakia. The experiment was arranged according to the system of Latin squares, with all of the variants repeated 3 times. The individual squares were originally 25 x 20 m in dimensions and each was provided with 250 to 300 seedlings, in spacing of 2 x 1 m (at the beginning, the trees were sed, then their number was gradually reduced by tending interventions). The area of this plot was 1.62 ha. The second part of the experiment represented an oak orchard, 1.40 ha in size (more details can be found in Požgaj, 1986). The assortment of the investigated autochthonous oak species was the following: *Quercus dalechampii* Ten., *Q. petraea* (Matt.) Liebl., *Q. polycarpa* Schur, *Q. pedunculiflora* C. Koch, *Q. robur* L., *Q. frainetto* Ten., *Q. pubescens* Willd., *Q. virgiliana* Ten. and *Q. cerris* L. Apart from the autochthonous species, there have also been planted individuals of *Q. rubra* L. which was also included into the research.

According to recommendation by Dr. Schönrogge (written communication), there is required to sample cca 150 twigs from one tree representing a specific site. If there are more trees of one oak species on the concerned site, it is possible to take twigs from cca 15 tree individuals to obtain the total number of 150 twigs. With respect to the age of the sampled trees, to the requirement to preserve their habitus and to ensuring possibility to check also other biometric characteristics, the radical sampling was compensated by detailed visual

Table 1. The presence of gall-wasps (Cynipidae) on oaks in the years 2001 and 2003

Species name and generation designation	Buds	Fruits	Leaves
Andricus caputmedusae (Hartig, 1843) ♀♀		1,2,3,4,5,6,7,9	
Andricus conglomeratus (Giraud, 1859)♀♀	2,3,4,5,6,7,8,		
Andricus conificus (Hartig, 1843) ♀♀	2,3,5		
Andricus coriarius (Hartig, 1843) ♀♀	1,5,6,7,8,9		
Andricus corruptrix (Schlechtendal, 1870) ♀♀	5,6		
Andricus curvator Hartig, 1840 ♀♂			5,6
Andricus foecundator (Hartig, 1840) ♀♀	3,6		
Andricus hungaricus (Hartig, 1843)	4,5,6,10		
Andricus inflator Hartig, 1840 ♀♂	6		
Andricus kollari (Hartig, 1843) ♀♀	1,2,3,4,5,6,7,8		
Andricus lignicola (Hartig, 1840) ♀♀	1,2,3,4,5,6,7,8,9		
Andricus lucidus (Hartig, 1843) ♀♀	6		
Andricus mayri (Wachtl , 1879) ♀♀	7		
Andricus nudus Adler, 1881 ♀♀	6		
Andricus ostrea (Hartig, 1840) ♀♀			6
Andricus quercuscalicis (Burgsdorf, 1783)♀♀		4,5,6	
Andricus quercusradicis (Fabricius, 1798) ♀♂	6		
Andricus quercus tozae (Bosc, 1792)♀♀	1		
Andricus tinctoriusnostrus Stefani-Perez ♀♀	2,3,5,6,7		
Andricus solitarius (Fonscolombe, 1832) ♀♀	6		
Biorhiza pallida (Olivier, 1791) ♀♂	5,6,8		
Cynips divisa Hartig, 1840 ♀♂			2,4,5,6
Cynips longiventris Hartig, 1840 ♀♀			5,6,7,8
Cynips quercusfolii Linnaeus, 1758 ♀♀			1,2,3,4,6,7
Cynips quercusfolii Linnaeus, 1758 ♀♂	6,7		
Chilaspis nitida (Giraud, 1859) ♀♀			6
Neuroterus fumipennis (Hartig, 1841) ♀♂			6
Neuroterus quercusbaccarum (Linnaeus, 1758) ♀♀			4,5,6
Neuroterus numismalis (Geoffroy, 1785) ♀♂			5,6
Trigonaspis megaptera (Panzer, 1801) ♀♂	2,5,6		
Trigonaspis synaspis (Hartig, 1841) ♀♂	2,5,6		

Explanations: ♀♀ – an agamic or asexual generation of the gall-wasp
♀♂ – a sexual generation of the gall-wasp
1 – *Q. virgiliana* Ten.
2 – *Q. dalechampii* Ten.
3 – *Q. polycarpa* Schur
4 – *Q. pedunculiflora* C. Koch
5 – *Q.* petraea Mattusch. (Liebl.).
6 – *Q. robur* L.
7 – *Q. frainetto* Ten.
8 – *Q. cerris* L.
9 – *Q. pubescens* Willd.
10 – *Q. rubra* L.

selection of the necessary number of branches and by searching of litter where the falling off galls was present. Considering the limited research conditions, the investigation was done in the autumn season (October) to cover the maximum range of the Cynipidae species, especially the species creating distinct visible non-falling off types of galls. Some disputable exemplars were determined in the laboratory. The determination was performed using the works by KIEFFER (1914), GUSEV and RIMSKIJ-KORSAKOV (1953) and BUHR (1965). Binomial nomenclature of the gall-wasps followed that by BUHR (1965).

Results and discussion

The results are summarised in Table 1, illustrating the occurence of individual gall-wasp species and their generations according to the host oak species – their assimilatory organs and fruits. We have confirmed occurrence of 31 gall types in total; from which there were found 20 on buds, 2 on fruits and 9 on leaves. In the case of the species *Cynips quercusfolii* L., there were recorded both sexual and agamic generations.

Buds

The bud galls were found the most frequent. The gall-wasps caused damage to terminal or lateral buds, promoted the drying of attacked twigs and constrained the growth of new shoots. This all has resulted in surface reduction of both the assimilatory and reproductive organs.

The most frequent was the agamic generation of the gall-wasp *Andricus lignicola* Htg. (9 oak taxons). HRUBÍK and POŽGAJ (1988) registered its occurence in the "Quercetarium" Čifáre on 5 native oak species (*Q. petraea*, *Q. robur*, *Q. dalechampii*, *Q. pedunculiflora* and *Q. virgiliana*). However, on the durmast (*Q. petraea)* oaks was this species only sporadic, and on the English (*Q. robur*) oaks was its occurence low.

The second in occurrence was found an agamic generation of *Andricus kollari* Htg. (8 taxons). Examining its spatial distribution, we observed that *Andricus kollari* Htg. mostly occurred in the middle and upper parts, i.e. sun parts of tree crowns. In the Arboretum Mlyňany, HRUBÍK (1976) observed the occurrence of this gall-wasp on oaks *Q. canariensis, Q. frainetto* and *Q. infectoria.* In the "Quercetarium" Čifáre, HRUBÍK and POŽGAJ (1988) recorded the highest average damage to the autochthonous oaks caused just by this gall-wasp species. According to these authors, there was recorded medium infestation of the durmast oak (*Q. petraea*) and only sporadic infestation of the English oak (*Q. robur*). A heavy infestation was diagnosed for *Q. frainetto*.

An agamic generation of *Andricus conglomeratus* Gir. (7 oak taxons) was found the third according to the frequency rank.

The finding of an agamic generation of the gall-wasp *Andricus hungaricus* Htg. at *Q. rubra* can be viewed as the latest information in the area.

Fruits

During our research in 2001 and 2003, there was a low seed production in the "Quercetarium" Čifáre. The acorns of sporadically fructifying oak trees were atacked by the gall-wasps *Andricus caputmedusae* Htg. (8 taxons) and *Andricus quercuscalicis* Burgsd. (3 taxons).

An agamic generation of the *Andricus quercuscalicis* Burgsd. creates galls of characteristic cup shape with a central hole inward. The gall surface is typical sticky. The gall cups about the acorn and causes its supression and deformation. Sometimes more galls can develope on one acorn and cause its total growth suppression or dwarfing. A little larva in a fallen-away fruit is able to diapause up to 3 years. The occurence of this gall-wasp was confirmed on fruits of *Q. pedunculiflora, Q. petraea* and *Q. robur.* The economic importance of this gall-wasp and its influence on premature fruit falling have already been described (KELBEL, 2001). According to BUHR (1965), this gall-wasp mainly feeds on *Q. robur*, rarely *Q. aegilops* L., *Q. petraea* and *Q. pubescens*. It has already been referred to by ČERVEŇÁK (1958), however the author did not reported precisely the extent of the injuries. HRUBÍK (1978) considers this gall-wasp species as an important pest – regarding to the acorn injury rating up to 87.6% at *Quercus turneri* var. '*Pseudoturneri'* in the Arboretum Mlyňany. At the same time, he assessed as negligible the infestation caused by two other gall-wasp species, namely *Andricus caputmedusae* Htg. and *Andricus foecundatrix* Htg. Čermák (1952) presented also other gall-wasp species occuring on acorns: namely *Cynips mayri* Kiefer, *Cynips kieferi* Cad., *Andricus superfetationis* Paszl., *Andricus seckendorffi* Wachtl. and *Andricus lucidus* Htg., but he did not provide any quantification of the injury range.

The occurence of an agamic generation of the gall-wasp *Andricus caputmedusae* Htg. was found on fruits of 8 native oak taxons (except *Q. cerris*), mainly in trees growing at stand edges, exposed to abundant solar radiation. However, the occurence of this species can be evaluated as sporadic, the economic importance of the species is low, even in the focus of the infestation area. Hrubík (1976) found out this species in *Q. canariensis, Q. frainetto* and Q. *infectoria.*

We suppose the abundance of gall-wasps on acorns will increase with proceeding tree age – to the fructification stage. In particular, we can expect increasing economic importance of *Andricus quercuscalicis* Burgsd. on the *Q. cerris* – both on trees within the collection of the autochthonous oaks and on the trees in the surrounding original oak stands because the sexual generations of this gall-wasp develop just on this oak species.

Leaves

These gall-wasp species also create numerous galls on leaves, both on the adaxial and abaxial sides. In the case of a heavy infestation, they can influence normal physiological processes in leaves (photosynthenic assimilation, transpiration, etc.). We studied their overall distribution over the native oak species in the study site. The results are summarised in Table 1.

From all of the investigated oak species, the most frequently attacked was *Q. robur* (28 gall types in total: 17 on buds, 2 on fruits and 9 on leaves); followed by *Q. petraea* (18 types of galls in total: 11 on buds, 2 on fruits and 5 on leaves) and *Q. frainetto* together with *Q. dalechampii* (both with 10 gall types in total – 7 on buds, 1 on fruits and 2 on leaves). The lowest number of leaf gall-wasps was found in *Q. pubescens* – 2 types on buds and 1 type on fruits.

The presented results agree, to a certain extent, with former findings by Hrubík, Požgaj (1988) who classified *Q. pubescens* and *Q. virgiliana* as the most resistant oak species; on the other hand, the oaks with the highest number of insect pests, according to these authors, were *Q. cerris*, *Q. pedunculiflora*, *Q. polycarpa* and *Q. robur*. A more recent information (Hrubík, 1999) shows that the most numerous entomofauna is living on *Q. robur* (42 species), *Q. petraea* (40 species), *Q. polycarpa* (37 species), *Q. cerris, Q. frainetto* (35 species), *Q. pedunculiflora* (33 species), *Q. dalechampii* (30 species), *Q. virgiliana* (24 species) and *Q. pubescens* (22 species). The last results must be interpreted with regard to the fact that the research subject was the whole entomofauna, whereas we only focussed on the gall-wasp group (Cynipidae). According to Hrubík (1999), the most frequent insect species from our target group were *Biorhiza pallida* Oliv., *Andricus kollari* Htg., *Neuroterus quercusbaccarum* L., *Andricus conglomeratus* Gir., *Andricus lignicola* Htg., *Cynips glutinosus* Gir. and *Cynips divisa* Htg..

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Hrčiarkovité (Hymenoptera, Cynipidae) spojené s desiatimi druhmi duba v „Quercetáriu“ Čifáre

Súhrn

V rokoch 2001 a 2003 sa vykonal výskum hrčiarkovitých (Cynipidae) na experimentálnej ploche „Quercetária“ v Čifároch, ktorá je zameraná na výskum deviatich pôvodných druhov rodu *Quercus*. Počas prieskumu sa zistilo celkom 31 typov hrčiek, z toho 20 typov na púčikoch, dva typy na plodoch a 9 typov na listoch.

Druhy poškodzujúce púčiky tvorili najpočetnejšiu skupinu hrčiarok, z nich boli najčastejšie zastúpené druhy *Andricus lignicola* Htg, *Andricus kollari* Htg. a *Andricus conglomeratus* Gir. Naše doterajšie poznatky vedú k názoru, že uvedené druhy hrčiarok spôsobujú poškodenie terminálnych alebo postranných púčikov, môžu spôsobovať postupné usychanie napadnutých konárikov a obmedzovať vývoj nových výhonkov. Dochádza tým k redukcii asimilačnej plochy, ale aj reprodukčných orgánov dubov.

V prípade premnoženia môžu byť lokálne hospodársky významné. Ako nový poznatok hodnotíme nález hrčiarky *Andricus hungaricus* Htg. na dube červenom (*Q. rubra*).

V čase nášho prieskumu v rokoch 2001 a 2003 bola v „Quercetáriu“ Čifáre semenná neúroda. Na sporadicky plodiacich jedincoch niektorých druhov dubov sa zistilo napadnutie hrčiarkami *Andricus caputmedusae* Burgsd. a *Andricus quercuscalicis* Burgsd. Predpokladáme vyššie zastúpenie druhov v čase nástupu stromov do štádia fruktifikácie. Je predpoklad vzrastu hospodárskej významnosti hlavne hrčiarky *Andricus quercuscalicis* Burgsd., a to vzhľadom na zastúpenie duba cerového (*Quercus cerris*) v zbierke autochtónnych dubov, ale aj v pôvodných okolitých dubových porastoch okolo experimentálnej plochy. Práve na tomto druhu duba sa vyvíja sexuálna generácia hrčiarky.

Hospodársky význam hrčiarok na listoch môžeme hodnotiť ako zanedbateľný.

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Dendro-climatic analysis of annual rings in Austrian pine (*Pinus nigra* Arnold)

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Abstract

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The aim of our work was dendroclimatic analysis of tree-ring indexes in Austrian pine, detailed description of dependence of radial increment on climatic factors (mean monthly temperature and monthly precipitation total). Our basic empiric material was a set of increment cores sampled from Austrian pine trees in November 2003. We obtained tree ring curves of Austrian pine, covering periods of 79–96 years. Dendroclimatic analysis revealed the positive influence of temperature at the beginning of vegetation period and also positive influence of temperature in the vegetation period. Mean monthly temperatures in July and September of the preceding year and April, July and August of the current year have negative influence on increment creation. The precipitation at the beginning of diameter growth (March, April, May) and at the end of diameter growth in the current year (June, July, August) has positive influence on the width of annual rings.

Key words

black pine, dendroclimatology, tree ring, air temperature, precipitation

Introduction

The Austrian pine is a much-promising woody plant introduced to Slovak forests thanks to its high production capacity and low ecological demands. Compared to the Scotch pine (*Pinus sylvestris* L.), it seems to be more resistant against particular matter and sulphur, consequently, it can be considered an appropriate species for planting in immission-loaded regions (ŠÁLY and FIEDLER, 1998). This fact has also been confirmed by PETRÁŠ et al. (2004) who observed – under the same immission load – higher losses in diameter increment in Austrian pine (*Pinus sylvestris* L.) than in Scotch pine (*Pinus nigra* Arnold). In such a way, besides the well-known ability of Austrian pine to grow in extreme conditions, also its better resistance against immission load has been confirmed. We have focussed our research on Austrian pine in a stand in Lefantovce, since 2002 considerably damaged by noxious agents (phyto-pathogenic fungi). JANKOVSKÝ and PALOVČÍKOVÁ (2003) proposed a hypothesis that an important precursor of the damage to Austrian pine in Southern Moravia in 2002 was the impact of extreme climate events, primarily drought that was, besides others, also reflected on the diameter increment. The dynamics of radial growth reflects also a complex influence of a wide range of climate factors (Bitvinskans, 1976). This paper is aimed at dendroclimatic analysis of relation between the width of annual rings in Austrian pine trees and climate characteristics, namely the mean monthly temperature and monthly precipitation total over the period of the growing up 1921–2003. Škvarenina et al. (2003), mean that precipitation and temperature are the most important factors determining the climate pattern of a landscape.

Material

Empirical material

The permanent research plot (PRP) with a stand of Austrian pine in Horné Lefantovce was established in 1987 by Prof. F. Tokár with the aim to study growth, leaf area index, aboveground wood mass production, and stand structure in this introduced woody plant. The plot with dimensions 50 x 50 m is grown with an Austrian pine monoculture and is situated in the stand No. 1.114 belonging to the Forest District Nitrianska Streda. According to the Forest Management Plan for year 2000, the stand age is 85 years, stocking 0.8, exposure S. The Austrian pine stand at the site belongs to the forest type 2.307 – beech oak stands on loess loams and loess (80%) and 2.306 – blue grass beech-oak forest with wood rush (20%).

The basic empiric material was a set of increment cores sampled from Austrian pine trees in November 2003. The samples were bored with Pressler´s increment borer from dominant and codominant trees at 1.3 m above the ground. The bored samples were processed using dendrochronological methods. Annual radial increments (i_r) were obtained by measuring annual ring width with a Digital positiometer with an accuracy of ±0.01 mm. The obtained tree ring curves were synchronised using the cross-dating method provided by the Programme DAS (Dendrochronological analysis system), (Janíček, 1997) at the Department of Forest Management and Geodesy, Faculty of Forestry of the Technical University in Zvolen.

Climate conditions

The village of Horné Lefantovce is situated in warm climatic region; subregion T4, moderately dry with mild winters (Landscape Atlas of the Slovak Republic, sheet 27, climatic regions 1961–1990). The prevailing winds are NW-N. The mean number of days with snow cover in a year is 38. The annual course of temperature is typical for Central Europe and for the given altitude, with maximum in July (19.2°C) and minimum in January (–2.1°C). The annual course of precipitation totals is characterised by a double-wave with the main minimum in March (29 mm) and a secondary in October (37 mm). The main maximum is in June (73 mm), a secondary in November (57 mm) – following from the sensitivity of this region to weather events connected with the transport of moist Mediterranean air to our territory (Table 1). The precipitation sum in the warm half of year (April–September) covers about 60% of the year's total.

The atmospheric precipitation is very variable over the territory in terms of monthly totals too.

Table 1. Mean monthly temperature (T) and mean monthly precipitation totals (P) in Horné Lefantovce for the period 1961–1990

Month	1	2	3	4	5	6	7	8	9	10	11	12	Year
T (°C)	–2.1	0.6	4.7	9.9	14.7	17.6	19.2	18.7	14.9	9.9	4.2	–0.1	9.3
P (mm)	35	34	29	41	61	73	57	65	41	37	57	45	575

The time series of the monthly totals was used directly from Horné Lefantovce rain gauge station pursuing high-confident observations during the whole period 1921–2003. A temperature series that is to be input in the model must have guaranteed data homogeneity. This requirement was not possible to reach with the data provided by meteorological stations in the neighbourhood (Nitra, Nemčice).The computing model also requires high-confident data about the air temperature with guaranteed fluctuation in this characteristic between the months and the maximum possible consistence in the data ranking within the months. This requirement was sufficiently matched by a series of mean monthly temperature data from the meteorological station in Hurbanovo. The temperature in Horné Lefantovce is lower by 0.3–0.6°C in months of cold half-year and by 0.7–1.1°C in months of warm half-year; however, Hurbanovo is situated in the same climatic region and both the stations belong to a territory characterised with the same impact of air circulation on temperature conditions and their variability. This is also evident on the correlation coefficient between the mean monthly temperatures of the series obtained in Hurbanovo and Nitra, with a value of 0.98 for the period 1961–1990.

Methods

Dendroclimatic model belongs to the category of empirical models that are based on statistical evaluation of empirically derived relations between the time series of annual rings parameters and the time series of monthly climate characteristics. The background for the statistical evaluation is the linear regression model (Fritts, 1976; Cook and Kairiukštis, 1990):

$$\hat{y}_i = \sum_{k=0}^{K} x_{i,k} \cdot \beta_k + a + \varepsilon_i \qquad (1)$$

where:

$\hat{y}_t$ – estimation of parameters of the radial increment (width of annual rings),

$x_{i,k}$ – k-th independent variable representing monthly climate characteristics in the i-th year,

β_k – regression coefficient,

a – constant,

ε_i – residuum after the estimation by regression.

The design of our dendroclimatic model was as follows: studied period 1921–2003, focussed on single trees, independent variables ($x_{i,k}$) – standardised mean monthly temperatures ($T_1 \ldots T_{14}$) and standardised monthly precipitation totals ($P_1 \ldots P_{14}$), beginning with July of the preceding to August of the current year, which was in total 28 climate describing variables.

Dendrochronological series (dependent variable – $\hat{y}_t$) consisted of relativised and standardised values of the measured radial increment in the individual trees. The relativisation of the radial increment was made by calculation of annual ring indexes and by determining the growth trend according to the best-fitting increment function. We have found the best these functions: Hugershoff's function (Šmelko, 2000) and polynomials of the 3-rd and 4-th degree. The annual ring index was obtained from the relation:

$$I_t = \frac{y_t}{\hat{y}_t} \qquad (2)$$

where:

I_t – index of radial increment,

y_t – actual increment,

$\hat{y}_t$ – smoothed value corresponding to the age trend.

Consequently, autocorrelation was filtered from the time series of annual rings provided by the programme DAS (Dendrochronological analysis system), (Janíček, 1991). Relativisation and standardisation complied with an important requirement of dendroclimatic modelling – stationarity of the relevant time series.

Results and discussion

We obtained tree ring curves of Austrian pine, covering periods of 79–96 years. The mean extent of the curves was 90 years. By cross dating we obtained synchronised annual ring curves (Fig. 1). The mean correlation coefficient between tree ring curves is 0.454, a sign test of interval trends resulted in 69%. Sensitivity of the individual annual ring series ranges between 0.275–0.382 around a mean value of 0.318. Sensitivity reflects the fluctuation of annual ring width and the response of trees to external environmental influences (Eckstein et al., 1984). The value of population signal providing information that the tree ring curves are related to the same population has a value of 0.917 (maximum is 1.00).

Generalised course of radial increment on the PRP is illustrated with the average tree ring series in Fig. 2. The figure also contains information about the 95% confidence interval, about the number of values necessary for calculation of an average tree ring curve (No) and about occurrence of so called significant years connected with such a change that can be, based on statistical testing of internal variability, labelled as significant or high significant (level 5% or 1%). Positive changes (+) in the increment were recorded in 1965 (void circle), high significant in years 1934, 1948, 1951, and 1994 (black circles). Significant negative changes (–) were recorded in 1929, 1967, 1968 and 1993 (void squares).

The influence of climatic factors on increment creation was studied using the method "response function" (Fritts, 1976). The multi correlation coefficients of the individual models ranged between 0.40–0.74. The average relative tree ring series for the given plot: actual and model are in Fig 3.

The impact of the individual climatic factors was expressed by means of mean standardised

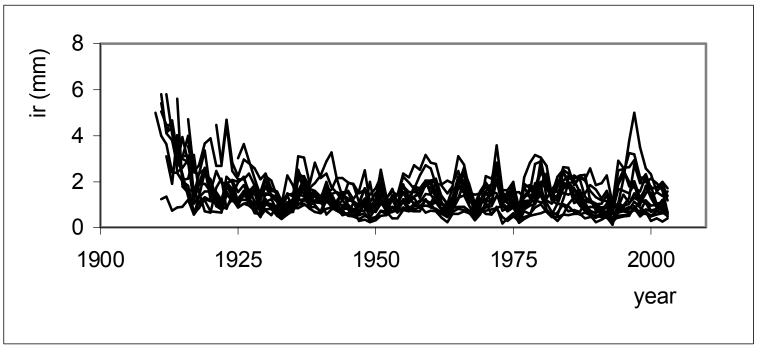

Fig. 1. Course of synchronised indexes of annual rings in the studied Austrian pine trees

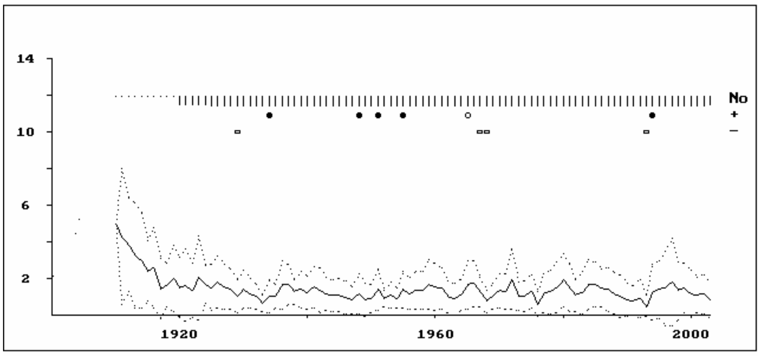

Fig. 2. Average tree ring series in the studied Austrian pine (*Pinus nigra* L.) trees

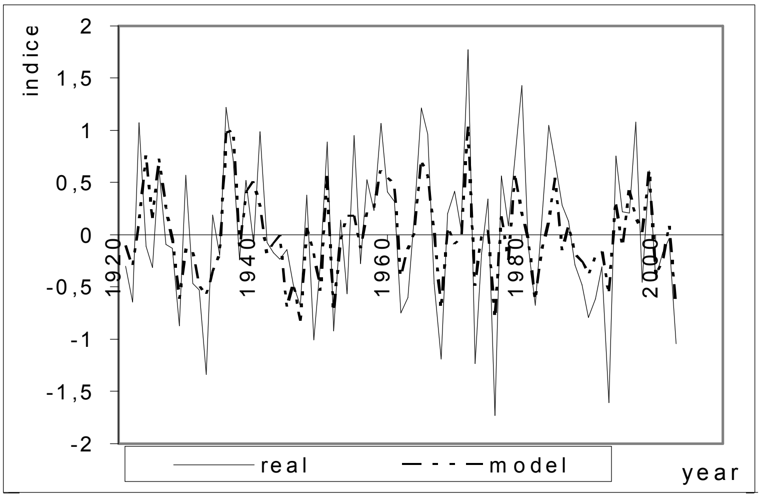

Fig. 3. Actual and model mean relative increment on PRP

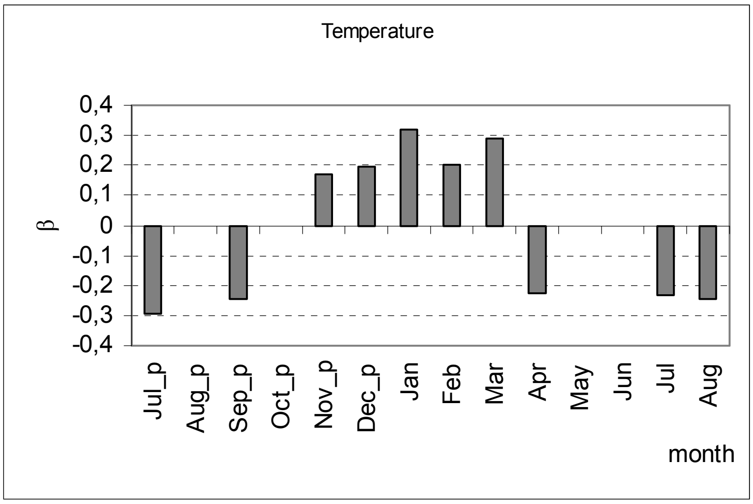

Fig. 4. Standardised partial regression coefficients expressing influence of monthly mean temperature on increment

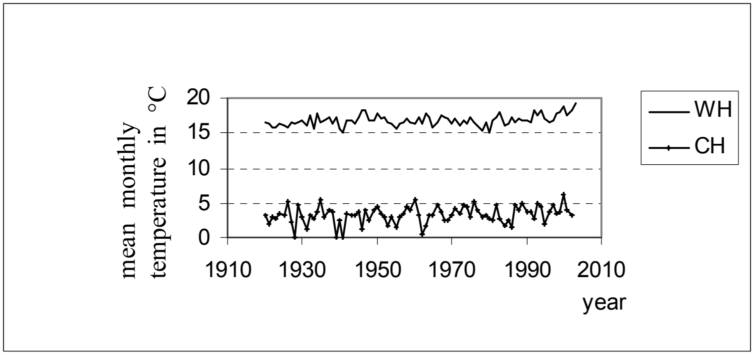

Fig. 5. Mean temperature of air (Hurbanovo) in cold (CH) and warm (WH) half of year

partial regression coefficients. Their average values are summarised in Figs 4 and 5.

The influence of mean monthly temperatures from July of the preceding year to August of the current year over the period 1921–2003 is in Fig. 4. We can see that the temperature influence on diameter growth in Austrian pine trees was positive from November of the preceding year to March of the current year (especially January and March). Negative influence was found in July and September of the preceding year, in April of the current year and at the end of the current vegetation period (July, August).

The temperature course in the Hurbanovo series shows higher variability over the cold half of year (October–March), which is characteristic for the temperature conditions in Slovakia (Fig. 5). The warm half-years were in general colder to the beginning of the period. Longer, continuous periods of the warm half-years were recorded from the end of 40s to the beginning of 50s of the last century and from the beginning of 90s up to the year 2003. The coldest was year 1941; conspicuously cold were also the years 1955, 1978, and 1980. The warmest warm half-year was in 2003; significantly warm were warm half-years 1946 and 1947, 1982 and five half-years within the period 1992–2003.

Cold half-years were colder in the first half of the studied period, the most frequent were at the beginning of the 40s, at the beginning of the 60s and at the end of the 80s years of the last century. Milder cold half-years were characteristic in the 70s years and from the beginning of the 90s up to the present time. The coldest cold half-year was in 1941/42, extreme cold were also 1928/29, 1939/40 and 1962/63, from the last twenty years 1984/85 and 1987/88. The warmest cold half-year was 2000/2001. Since the beginning of the 90s there can be observed permanent increase in temperature in both halves of year.

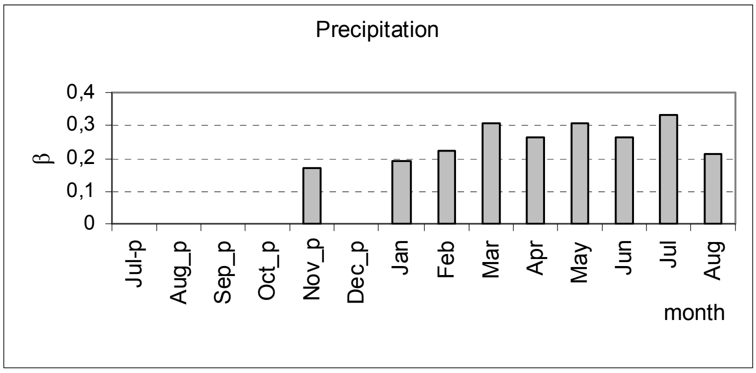

Fig. 6. Standardised partial regression coefficients of influence of monthly precipitation totals on increment in Austrian pine trees

Positive influence of precipitation on diameter increment in Austrian pine trees was observed in November of the preceding year (secondary maximum in the annual course) and in January and February of the current year (Fig. 6). The precipitation collected in these months practically provides reserves for the subsequent vegetation period and, consequently, is key-important for the development of diameter increment in the following vegetation period and for prevention of damage to trees. There has been observed positive influence of precipitation on diameter increment in Austrian pine trees from the beginning on March to August of the current year. So it is evident that a regular water supply in the vegetation period is high important. Correlation coefficient between the annual precipitation total and the mean index annual ring curve from all the sampled trees was 0.47.

Wet warm half-years were prevailing at the beginning of the studied period, at the end of the 50s, at the beginning of the 60s and at the beginning of the 90s years of the last century; the maximum was reached in 1972 (Fig. 7). Dry warm half-years were mainly observed in the 40s, 70s and 80s, with the minimum in 1971. Wet cold half-years were frequent in the first half of the studied period, with precipitation maximum in 1950, dry were found in the second half of the studied period, with the minimum in 1947.

As we can see in Fig. 2, negative years were 1929, 1967, 1968, 1993 (void squares), positive 1934, 1948, 1951, 1994 (black circles). The cold winter 1928/29 reported by HOLUBČÍK (1968) for the Arboretum Kysihýbel followed by a dry summer 1928 could also negatively affect the width of annual ring in the vegetation period 1929. Dry period from February to July 1968 can be identified based on a narrow annual ring in the vegetation period 1968. The dry and cold winter 1992/93 and atmospheric precipitation deficiency in spring 1993 could

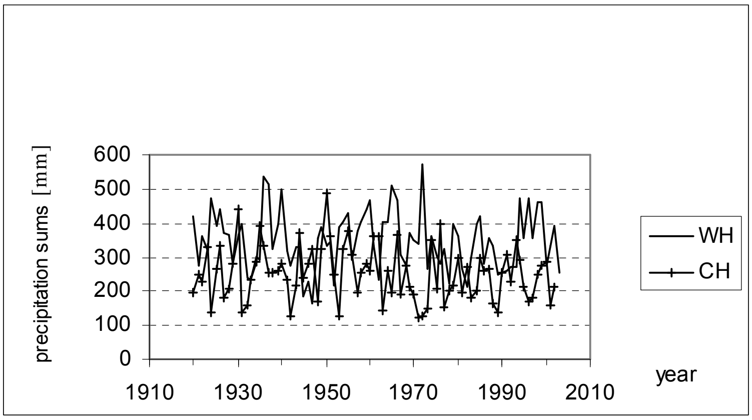

Fig. 7. Precipitation totals in warm half-year (WH) and cold half-year (CH) (Horné Lefantovce)

also be reflected on very narrow width of tree rings in all the studied Austrian pine sample trees.

The dry and warm summer 1947 followed by a wet winter 1948 could have a positive influence on tree ring width in the vegetation period 1948. Very mild winter 1993/94, warm spring and summer 1994, wet spring and autumn 1994, had possible positive impact on the minimum tree ring width in 1993 and on improved increment trend in 1994 (increasing trend in tree-ring curve).

There have been confirmed research results obtained by Fiedler and Wenk (1973) according to whom meteorological factors (temperature, precipitation) have different impact on tree diameter growth in the individual months of vegetation period. These results are also dependent on the woody plant species, age, situation, soil and stand closure density. The author mean that at the beginning of the diameter growth is important the temperature in April but also in March. In May are equally important temperature and precipitation (high temperature in this period can cause the diameter growth culmination). In June is the controlling factor again temperature – unlike in July (primarily dry July) and in August when precipitation is governing the increment creation process. A precipitation deficiency in this period can have a negative impact on diameter increment because the ground water reserves have in general been abstracted. According to experience and literature, the Austrian pine well tolerates hot and dry summers. This might also be deduced from the width of tree rings created in 2003 where, after a decrease in 2002, a new slow increase was recorded. Faško, Šťastný et al. (2003) mean that from autumn 2002 up to the beginning of February 2003 was precipitation in Slovakia above the normal and the situation in the following months up to August was just opposite – with a severe precipitation shortage.

Growth parameters and biomass creation are to a considerable extent dependent on bio-meteorological conditions (Tužinský, 1995). The distribution range of the Austrian pine is in zone characteristic with dry and hot summer months and cold winter months with abundant precipitation (Pagan, 1996). Consequently, this woody plant has high demands on summer temperatures and also tolerates low winter temperatures. The demands on soil moisture are low – thanks to a long tap root reaching to the water reserves in deeper forest layers.

Gruber (2001a) means that the potential and nutrient storage for the increment created in the current year is key-dependent on weather conditions in the preceding year.

According to Schneider et al. (1986) up to 73% and according to Ashy and Fritts (1972) up to 59% of the woody plant growth is possible to explain by climate variability – events as short-term climate changes, competitions and seed year outweigh the permanent climate influence and are reflected in the character of the individual tree rings (ex Pelzmann, 1989). Our results explaining the influence of the studied climate factors on diameter growth of Austrian pine trees in Horné Lefantovce well-correspond to the results of Gruber (2001b) demonstrating the known close correlation between climate and tree diameter growth. However, the author points out that under the changing conditions in the environment, dendroclimatic methods could serve for making first drafts of biological and ecological prognoses necessary for support and preventive protection of artificially established forest stands.

Conclusions

In this work we studied the influence of climate factors on diameter growth in Austrian pine (*Pinus nigra* Arnold) in Horné Lefantovce. Dendroclimatic analysis revealed the positive influence of temperature at the beginning of vegetation period and also positive influence of temperature in the vegetation period. The positive influence on diameter increment was also found in temperature, beginning with November of the preceding year to March of the current year, that means in the so called cold half-year (from October to March). Mean monthly temperatures in July and September of the preceding year and April, July and August of the current year have negative influence on increment creation. The precipitation at the beginning of diameter growth (March, April, May) and at the end of diameter growth in the current year (June, July, August) has positive influence on the width of annual rings.

It is necessary to complete the research with a study into dependence of annual ring width in

Austrian pine on other environmental factors and to pursue a research into eco-physiology enabling a more detailed description of the relation increment – environment. This could contribute to correct diagnosing of the recently recognised attack to this woody plant by phyto-pathogenic fungi (identification of course and causes of fungal attacks). The last work assigns to the climate 30% impact on the radial increment creation. That means that the growth in Austrian pine in this territory is also influenced by other factors, apart from the considered climatic (mean monthly temperature and monthly precipitation total). We can conclude that the Austrian pine is growing in its optimum growth conditions with limiting factors different from temperature and precipitation. It is necessary to pursue further research to find out whether the Austrian pine – a wood species with low water demands and well tolerating dry extreme site conditions has also prerequisites to resist against climate change.

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Dendroklimatická analýza letokruhov borovice čiernej

Súhrn

V predloženej práci sme sledovali vplyv klimatických faktorov na hrúbkový rast borovice čiernej *Pinus nigra* (Arnold) v Horných Lefantovciach. 15 vývrtov bolo odobraných a spracovaných podľa zásad dendrochronológie. Podstatou štatistického hodnotenia je viacnásobný lineárny regresný model (FRITTS, 1976; COOK a KAIRIUKŠTIS, 1990). V našom prípade bol dendroklimatický model zostavený pre roky 1921–2003 ako jednotlivo-stromový, do ktorého ako nezávislé premenné ($x_{i,k}$) vstupovali štandardizované priemerné mesačné teploty ($T_1 \ldots T_{14}$) a štandardizované mesačné úhrny zrážok ($Z_1 \ldots Z_{14}$) od júla predchádzajúceho roku do augusta bežného roku, teda celkom 28 klimatických premenných. Získané letokruhové diagramy borovice čiernej mali dĺžku 79 až 96 rokov. Priemerný korelačný koeficient medzi letokruhovými krivkami je 0,454 a súbežnosť intervalových trendov je 69 %. Senzitivita jednotlivých letokruhových radov sa pohybuje v rozpätí od 0,275 do 0,382 a jej priemerná hodnota je 0,318. Hodnota populačného signálu, ktorý vyjadruje pravdepodobnosť, že letokruhové diagramy pochádzajú z jednej populácie, je 0,917 (maximum je 1,00). Dendroklimatickou analýzou sa zistil pozitívny vplyv teplôt na začiatku vegetačného obdobia, ako aj pozitívny vplyv zrážok vo vegetačnom období. Priemerné mesačné teploty júla a septembra predchádzajúceho roka a apríla, júla, augusta bežného roka majú záporný vplyv na tvorbu letokruhov. Zrážky majú na začiatku hrúbkového rastu (marec, apríl, máj) a na konci hrúbkového rastu bežného roku (jún, júl, august) pozitívny vplyv na šírku letokruhov. Touto prácou sa dokázal vysvetliť vplyv klímy na radiálny rast borovice čiernej na 30 %.

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Influence of site conditions on physiological status of black walnut (*Juglans nigra* L.) stands

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Abstract

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The work presents the results of a study focused to the eco-physiology of the black walnut (*Juglans nigra* L.) in Slovakia. The research was realised on the permanent research plots (PRP) in Ivanka pri Nitre under different site conditions (on an open plot and on the shaded plot) in the years 2000–2002. The concentration of assimilation pigments (chlorophyll *a, b, a* + *b*) and the content of carbohydrates were determined spectrophotometrically. The results point out different eco-physiological responses of black walnut trees corresponding to the site conditions. Statistically significant influence of the plot and date of sampling on all studied physiological characteristics was confirmed.

Key words
chlorophylls, carbohydrates, *Juglans nigra* L.

Introduction

Exotic woody plants play an important role in Slovak forest management. Their introduction is justified primarily due to their biological, ecological and production properties compared to our autochthonous species. A necessary condition for the introduction is an overall assessment of the final effects, mainly in association with the desired increase of timber production. Šindelářová (1973) supposed that the introduction of exotic woody plants is economically effective only if the increase of timber yield and quality is at least 30 to 40% compared with the yield of autochthonous species. We focussed our research on black walnut (*Juglans nigra* L.), an important and promising broadleaved exotic woody plant that is recommended for cultivation in forest stands in Central, South and South -East Europe. The commercial interest in this species is in the very precious wood, high-valued fruits and fast growth rate on favourable sites (Holubčík, 1968; Tokár, 1984a). According to the above mentioned knowledges, black walnut trees were introduced to Europe from North America at the beginning of the 17th century. Due to its outstanding aesthetic value (leaves, bark, fruits), this woody plant has become a frequent component of our parks. The records about walnut trees in Slovak parks reach back as far as to 1770 (Benčať, 1982). A more intensive introduction into forest stands has started mainly in Germany and in France since the last century. The tree exhibits outstanding growth abilities in the southern parts of Europe. However, several authors (Benčať, 1982;

Holubčík, 1968; Tokár 1984), recommend a more extensive use of this species (which started in the 1950s and 1960s) in the Slovak silviculture, as well.

The issues concerning the structure, yield, silvicultural treatment and tending of the stands of this species have been elaborated quite sufficiently (Tokár, 1996, 1998). On the other hand, studies analysing the influence of site factors on physiological processes in walnut trees under our ecological conditions are lacking. Considering these facts, we focussed our investigations on the measurement of selected physiological characteristics in walnut trees (analysis of chlorophylls and carbohydrates) and subsequent evaluation of physiological status of the stands of black walnut (*Juglans nigra* L.) growing under different site conditions.

Material and methods

The physiological status of black walnut trees growing under different site conditions (stand shelter and open plot) was observed on two permanent research plots (PRP) in Ivánka pri Nitre (Forest District Nitra, Forest Enterprise Palárikovo). The shaded walnut trees were grown on partial plot I with dimensions of 50 × 50 m established in a stand with the predominance of black walnut (80%) with the admixture of red oak (20%). The open plot with selected isolated walnut trees is situated near the studied stand.

The research was realised during the growing seasons 2000 to 2002. On each trial plot, five sample trees aged about 15 years were selected. During each growing season, we sampled leaves for quantitative analysis of chlorophyll content that was performed using disk method. The discs were cut directly at the site and saved for transport in an 80% acetone solution in a vacuum flask with ice. In the laboratory, the leaves were homogenized in a grinding bowl and analysed to determine their chlorophyll contents. Chlorophyll absorbance was measured spectrophotometrically (Spekol-211, Germany) and the concentrations of chlorophylls *a, b* were calculated according to Lichtenthaler (1987). Chlorophyll *a, b, a + b* contents were expressed per dry mass unit (mg g^{-1}). Simultaneously with sample separation we also determined gravimetrically the dry mass content.

Saccharides in the assimilatory organs were determined using the colorimetric method according to Somogyi-Nelson, based on the reduction of cupric salts ($CuSO_4$) with poly-acetal groups of mono-saccharides to Cu_2O. The method takes into consideration that biological materials contain, apart from saccharides, also other reducing materials, such as proteins, whose presence could have disturbing effects on saccharides identification. Therefore, proteins were removed from the extracts prior to analysis. Extracts were obtained from the fresh plant material and the content of reducing saccharides as well as the total content of all saccharides were determined spectrophotometrically. The content of non-reducing saccharides was obtained subtracting the reducing saccharides from the total content of saccharides. The values were expressed in mg substances per g of leaf dry mass.

The obtained results were statistically evaluated by analysis of variance (ANOVA) using the SAS 6.03 statistical package (SAS Institute 1988). Variance components were compared with the residual variance using an F-test.

Results

The values of chlorophyll *a, b, a + b* concentrations and chlorophyll *a : b* ratio in assimilatory organs of black walnut trees on the open plot and under the stand shelter in growing seasons 2000 to 2002 are presented in Tables 1–4.

In general, higher chlorophyll *a* concentrations were determined in leaves of shaded trees (Table 1). On the open plot, mean chlorophyll *a* concentration during the whole observation period was 2.90 mg g^{-1}, whereby the maximum of 5.06 mg g^{-1} was recorded on August 14, 2001 (sample tree V3), what may be associated with the formation of assimilation organs. The minimum of 1.22 mg g^{-1} was observed on September 26, 2000 (sample tree V3), corresponding to the decrease of assimilatory pigments during the autumn.

Mean chlorophyll *a* concentration in walnut trees growing under the stand shelter was 4.78 mg g^{-1}, while the annual averages during 2000–2002 ranged from 2.76 to 7.09 mg g^{-1}. The highest value of this parameter (8.82 mg g^{-1}) was measured on August 15, 2000 (sample tree P1), the lowest

Table 1. Values of chlorophyll *a* concentration (mg g^{-1}d.m.) in black walnut leaves in the years 2000–2002

Date of measurement	Chlorophyll a (mg g^{-1} d.m)											
	open plot						shaded plot					
	V1*	V2	V3	V4	V5	mean	P1**	P2	P3	P4	P5	mean
24. 5 .2000	2.73	2.54	2.26	2.17	1.98	**2.34**	3.26	4.72	4.50	4.07	6.49	**4.61**
28. 6. 2000	3.39	4.32	2.78	3.10	3.80	**3.48**	6.99	4.63	6.19	3.78	5.59	**5.44**
15. 8. 2000	4.99	4.12	3.36	3.60	4.39	**4.09**	8.82	6.20	5.99	7.36	7.08	**7.09**
26. 9. 2000	2.18	1.90	1.22	2.22	2.39	**1.98**	3.94	3.67	2.51	3.88	3.56	**3.51**
24. 5. 2001	2.80	3.20	2.82	2.71	2.50	**2.81**	3.78	4.41	4.06	5.00	4.40	**4.33**
26. 6. 2001	3.98	2.72	2.06	2.33	2.76	**2.77**	7.08	4.46	4.21	4.88	5.87	**5.30**
14. 8. 2001	4.23	4.68	5.06	3.36	4.10	**4.29**	7.65	6.38	7.40	5.87	8.01	**7.06**
2. 10. 2001	2.29	3.02	2.96	2.05	2.24	**2.51**	4.08	2.98	2.92	0.00	5.05	**3.01**
24. 6. 2002	2.66	3.08	4.46	1.76	3.46	**3.08**	4.38	6.28	4.46	4.82	3.56	**4.70**
24. 7. 2002	1.44	2.08	1.71	1.34	1.69	**1.65**	2.58	2.69	2.80	2.61	3.13	**2.76**

* *number of tree (1–5) on an open plot*
** *number of tree (1–5) on the shaded plot*

one (2.51 mg g^{-1}) on September 26, 2000 (sample tree P3).

The seasonal dynamic of chlorophyll *b* concentrations (Table 2) showed similar tendency than chlorophyll *a*, which means that the mean values were obtained from the leaves of sample trees growing under the stand shelter. The values of chlorophyll *b* concentration were lower, reaching approx. one third of the chlorophyll *a* concentrations, what corresponds to the published data. The mean value of chlorophyll *b* concentration on the plot under stand shelter was 1.76 mg g^{-1}, the maximum value (3.20 mg g^{-1}) was determined on June 24, 2002 (sample tree P2) and the minimum was 1.21 mg g^{-1} (sample tree P4). On the open plot, the values of chlorophyll *b* concentrations ranged from 0.70 mg g^{-1} to 1.69 mg g^{-1}, the mean was 1.07 mg g^{-1}. The highest value (1.65 mg g^{-1}) was estimated on June 28, 2000 (sample tree V2), the lowest one (0.41 mg g^{-1}) on September 26, 2000 (sample tree V3).

The assessment of the chlorophyll *a* : *b* ratio (Table 3) confirmed that in growing season 2000–2002, the values slightly fluctuated around 3. The total mean value of the chlorophyll *a* : *b* ratio was somewhat higher (2.82) on the open plot compared to the trees under the stand shelter (2.69). The annual averages of the *a* : *b* ratio ranged from 1.82 to 3.51 and from 1.60 to 3.69 on the open plot and under the stand shelter, respectively.

The data of the chlorophyll *a* and chlorophyll *b* concentrations suggested that the chlorophyll *a* + *b* concentrations (Table 4) would be higher under the stand shelter, as well. This assumption was confirmed: the mean value of chlorophyll *a* + *b* in 2000–2002 under the stand shelter was 6.54 mg g^{-1}, on the open plot 3.96 mg g^{-1}. The highest value under the stand shelter (11.36 mg g^{-1}) was measured on August 15, 2000 (sample tree P1), the lowest one (3.75 mg g^{-1}) on September 26, 2000 (sample tree P3). The maximum value on the open plot (6.64 mg g^{-1}) was recorded on August 14, 2001, the minimum (1.63 mg g^{-1}) on September 26, 2000 (sample tree V3).

The photosynthetic pigments were evaluated by analysis of variance (Table 5). *F*-test revealed highly significant differences between the plots (P > 99.9%), which was also confirmed of high values

Table 2. Values of chlorophyll *b* concentration (mg g^{-1}d m.) in black walnut leaves in the years 2000–2002

Date of measurement	Chlorophyll *b* (mg g^{-1} d.m.)											
	open plot						shaded plot					
	V1*	V2	V3	V4	V5	mean	P1**	P2	P3	P4	P5	mean
24. 5. 2000	0.79	0.73	0.69	0.70	0.58	**0.70**	1.32	1.65	1.53	1.45	2.16	**1.62**
28. 6. 2000	1.24	1.65	0.98	1.26	1.35	**1.30**	2.77	2.00	2.27	1.65	2.19	**2.18**
15. 8. 2000	1.42	1.22	0.73	1.20	1.43	**1.20**	2.54	1.68	1.46	2.02	2.01	**1.94**
26. 9. 2000	0.73	0.75	0.41	0.79	0.87	**0.71**	1.39	1.71	1.24	1.84	1.70	**1.58**
24. 5. 2001	0.83	0.95	0.80	0.84	0.73	**0.83**	1.30	1.55	1.52	1.84	1.58	**1.56**
26. 6. 2001	1.38	0.84	0.61	0.72	0.77	**0.86**	2.14	1.31	1.32	1.27	1.34	**1.47**
14. 8. 2001	1.38	1.50	1.59	1.01	1.26	**1.35**	2.10	1.76	2.31	1.53	2.27	**2.00**
2. 10. 2001	1.15	0.83	1.41	1.00	1.12	**1.10**	2.55	1.31	1.64	0.00	2.15	**1.53**
24. 6. 2002	2.13	1.54	2.04	1.01	1.72	**1.69**	2.29	3.20	2.18	2.29	1.67	**2.33**
24. 7. 2002	1.11	1.15	0.85	0.75	0.76	**0.93**	1.31	1.34	1.39	1.21	1.49	**1.35**

Table 3. Values of chlorophyll *a* : *b* ratio in black walnut leaves in the years 2000–2002

Date of measurement	Chlorophyll *a* : *b* (mg g^{-1} d.m.)											
	open plot						shaded plot					
	V1*	V2	V3	V4	V5	mean	P1**	P2	P3	P4	P5	mean
24. 5. 2000	3.46	3.48	3.28	3.10	3.41	**3.34**	2.47	2.86	2.94	2.81	3.00	**2.82**
28. 6. 2000	2.73	2.62	2.84	2.46	2.81	**2.69**	2.52	2.32	2.73	2.29	2.55	**2.48**
15. 8. 2000	3.51	3.38	4.60	3.00	3.07	**3.51**	3.47	3.69	4.10	3.64	3.52	**3.69**
26. 9. 2000	2.99	2.53	2.98	2.81	2.75	**2.81**	2.83	2.15	2.02	2.11	2.09	**2.24**
24. 5. 2001	3.36	3.36	3.51	3.23	3.45	**3.38**	2.90	2.84	2.68	2.72	2.78	**2.78**
26. 6. 2001	2.88	3.23	3.36	3.25	3.59	**3.26**	3.31	3.41	3.20	3.84	4.40	**3.63**
14. 8. 2001	3.06	3.12	3.19	3.33	3.24	**3.19**	3.64	3.62	3.20	3.84	3.53	**3.56**
2. 10. 2001	1.99	3.63	2.10	2.04	2.01	**2.35**	1.60	2.27	1.78	0.00	2.35	**1.60**
24. 6. 2002	1.25	2.00	2.19	1.74	2.01	**1.84**	1.91	1.96	2.04	2.10	2.13	**2.03**
24. 7. 2002	1.29	1.80	2.01	1.79	2.21	**1.82**	1.97	2.00	2.01	2.16	2.10	**2.05**

Table 4. Values of chlorophyll $a + b$ (mg g^{-1}d m.) concentration in black walnut leaves in the years 2000–2002

Date of measurement	Chlorophyll $a + b$ (mg g^{-1} d.m)											
	open plot						shaded plot					
	V1*	V2	V3	V4	V5	mean	P1**	P2	P3	P4	P5	mean
24. 5. 2000	3.52	3.27	2.95	2.87	2.56	**3.03**	4.58	6.37	6.03	5.52	8.65	**6.23**
28. 6. 2000	4.63	5.97	3.76	4.36	5.15	**4.77**	9.76	6.63	8.46	5.43	7.78	**7.61**
15. 8. 2000	6.41	5.34	4.09	4.80	5.82	**5.29**	11.36	7.88	7.45	9.38	9.09	**9.03**
26. 9. 2000	2.91	2.65	1.63	3.01	3.26	**2.69**	5.33	5.38	3.75	5.72	5.26	**5.09**
24. 5. 2001	3.64	4.16	3.63	3.56	3.23	**3.64**	5.08	5.97	5.57	6.83	5.98	**5.89**
26. 6. 2001	5.36	3.56	2.67	3.05	3.53	**3.63**	9.22	5.77	5.53	6.15	7.20	**6.78**
14. 8. 2001	5.61	6.18	6.64	4.37	5.37	**5.63**	9.76	8.14	9.71	7.40	10.27	**9.06**
2. 10. 2001	3.44	3.85	4.38	3.05	3.36	**3.61**	6.62	4.29	4.56	0.00	7.20	**4.54**
24. 6. 2002	4.78	4.62	6.50	2.77	5.18	**4.77**	6.67	9.48	6.64	7.11	5.23	**7.03**
24. 7. 2002	2.55	3.23	2.57	2.09	2.45	**2.58**	3.89	4.04	4.19	3.82	4.63	**4.11**

Table 5. Analysis of variance of the chlorophyll *a, b, a + b* concentrations and *a : b* ratio in black walnut leaves ($p < 0.05^{*}$, $p < 0.01^{**}$, $p < 0.001^{***}$)

Source of variability	Degrees of freedom	Chlorophyll a (mg g^{-1} d.m.)		Chlorophyll b (mg g^{-1} d.m.)		Chlorophyll a : b		Chlorophyll a + b (mg g^{-1} d.m.)	
		F-test	Components of variance (%)	F-test	Components of variance (%)	F-test	Components of variance (%)	F-test	Components of variance (%)
Plot	1	82.41^{***}	48.06	121.79^{***}	56.71	4.46	2.10	93.69^{***}	53.04
Sample tree	8	1.74	1.30	1.11	0.43	0.52	0.00	1.72	1.28
Year	2	0.66	0.00	0.27	0.00	8.6^{*}	23.41	0.28	0.00
Sampling	7	20.69***	34.74	11.51^{***}	22.44	2.79^{*}	20.03	18.86^{***}	30.04
Residual	80		15.90		20.42		54.45		15.64

among-plot variation components for chlorophyll *a* (48.06%), chlorophyll *b* (56.71%) and chlorophyll *a* + *b* (53.04%). Highly significant differences ($P > 99.9\%$) were also found between individual samplings over the year, in all studied parameters (chlorophyll *a, b, a* + *b*). Residual variance components were low, ranging between 15.64% and 20.42%.

Carbohydrates are the main product of photosynthetic processes, and, at the same time, they are one of main indicators of plant physiological status. Consequently, we determined their content in assimilatory organs of black walnut trees growing under different site conditions, during the growing seasons 2000 to 2002.

The mean values of content of total, reducing and non-reducing carbohydrates in mg g^{-1} in leaves of black walnut trees growing on the studied open plot and under the stand shelter are presented in Figs 1, 2.

Based on these results it could be concluded that generally higher carbohydrates contents were found on the open plot, what is consistent with the published data. The mean value of total carbohydrate contents (in mg g^{-1}) on the open plot (Fig. 1) during 2000 to 2002 was 51.07 mg g^{-1}, whereby the highest value (87.53 mg g^{-1}) was measured on May 24, 2000, the lowest one (20.16 mg g^{-1}) on June 24, 2002.

The mean values of reducing carbohydrates were always lower compared to non-reducing carbohydrates. The mean values of this parameter on the open plot ranged from 6.73 mg g^{-1} (June 24, 2002) to 29.29 mg g^{-1} (June 28, 2000). The total mean value of reducing carbohydrates was 17.88 mg g^{-1}. The mean values of non-reducing carbohydrates ranged from 13.43 mg g^{-1} to 62.43 mg g^{-1}, with the total mean of 33.99 mg g^{-1}.

The data on the carbohydrates content in leaves of black walnut trees growing on the open plot do not allow to specify the course of accumulation of carbohydrates during the growing season. However, from Fig. 1 we can conclude that relatively high values of total carbohydrates were in general observed at the beginning of the growing season during the study years.

The mean values of contents of total, reducing and non-reducing carbohydrates in leaves of black walnut trees under the stand shelter are presented in Fig. 2.

Table 6. Analysis of variance of carbohydrate concentrations (mg g^{-1}d m.) in black walnut leaves ($p < 0.05^{*}$, $p < 0.01^{**}$, $p < 0.001^{***}$)

Source of variability	Degrees of freedom	Total carbohydrates F-test	Total carbohydrates Components of variance (%)	Reducing carbohydrates F-test	Reducing carbohydrates Components of variance (%)	Irreducing carbohydrates F-test	Irreducing carbohydrates Components of variance (%)
Plot	1	53.93^{***}	19.58	82.88^{***}	23.51	33.29	12.70
Sample tree	8	0.58	0.00	0.50	0.00	0.64	0.00
Year	2	0.27	0.00	1.81	12.58	0.07	0.00
Sampling	7	16.82***	49.49	14.15^{***}	36.21	19.71^{***}	57.34
Residual	80		30.93		27.42		29.95

The contents of total carbohydrates ranged between 22.94 mg g^{-1} and 61.38 mg g^{-1}, with an average of 35.52 mg g^{-1}. The maximum value was measured on July 24, 2002. In the case of reducing carbohydrates we found a mean value of 17.35 mg g^{-1}, in the case of non-reducing carbohydrates it was 24.55 mg g^{-1}.

Analysis of variance (Table 6) confirmed highly significant differences ($p < 0.001$) between plots in all the studied parameters (total, reducing and non-reducing carbohydrates). The effect of the sampling date within the current year was also found to be highly significant ($p < 0.001$). Consequently, the content of carbohydrates in assimilation organs of black walnut trees and other forest woody plants is closely correlated with the changes of both, ontogenetical development and site condition.

Discussion

Within ecophysiological research, many studies can be encountered dealing with the influence of stress factors on physiological functions of assimilation apparatus of forest woody plants, based on the analysis of their assimilation pigments. However, the majority of these papers focused on the physiology of coniferous species growing in stress conditions (e.g. Kmeť and Blaho, 1995; Polle et al., 1992; Pfanz et al., 1994). Considerably less studies is devoted to the problems of physiology of broadleaved species including exotics, on which our study was oriented.

As was reported by Haspelová-Horvatovičová (1981), pigment analyses are generally accepted as a suitable bioindication method for the asses-

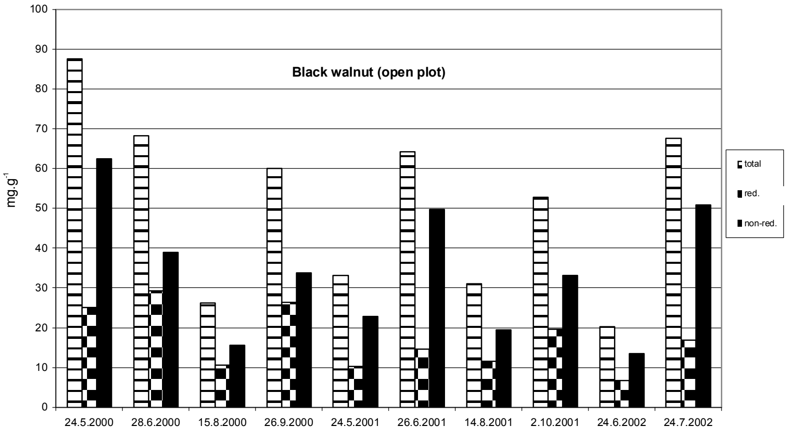

Fig. 1. Mean values of the total, reducing and non-reducing carbohydrate concentrations (mg g^{-1} d.m) in black walnut leaves (open plot) in the years 2000–2002

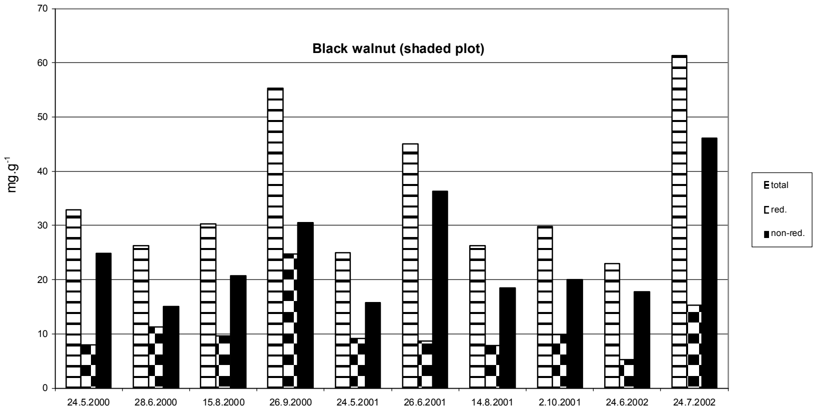

Fig. 2. Mean values of the total, reducing and non-reducing carbohydrate concentrations (mg g^{-1} d.m) in black walnut leaves (shaded plot) in the years 2000–2002

sment of the health condition of forest woody plants. However, they cannot be considered to be a specific indicator of environment because they are influenced by a number of biotic and abiotic environmental factors (seasonal fluctuations in assimilation pigment contents, differences between sun and shade leaves, etc.). Therefore Kmeť (1998) suggested that the use of pigment analyses for diagnostic purposes is only reasonable in combination with the other physiological and biochemical methods (measuring parameters of chlorophyll *a* fluorescence, mineral nutrient content, etc.).

The contents of assimilation pigments in leaves can considerably change depending on internal and external factors. Many studies documented that the plastids in plants are subjected to changes during the plant growth and development. This is mainly true for the state of the chlorophylls *in vivo* and the ratios between their active and inactive, stable and instable forms. These changes are then reflected in the photosynthetic activity of the whole photosynthetic apparatus. As the content of pigments is influenced by much many factors, it is not easy to achieve the unambiguous conclusions, what explains frequent contradictions in the published results, not only in association with assimilation pigment concentrations but also their ratios (Amundson et al., 1993; Lippert et al., 1996). Haspelová-Horvatovičová (1981) considered that the study into changes in plant chlorophyll should take into consideration the reference unit to which the pigment content determined by the analysis is related. As a matter of fact, shade assimilation organs have higher chlorophyll contents per dry mass unit compared to sun organs. Sun leaves are thicker, have more chlorophylls per leaf area and their morphology differs from that of shade leaves. This is consistent with the conclusions obtained, by e.g. Masarovičová and Minarčic (1985), Masarovičová and Štefančík (1990), Gratani and Foti (1998). Our results (presented in Tables 1, 2) also confirmed this observation. However, influence of irradiance on photosynthetic processes and pigments distribution in plants may sometimes be destructive. The destruction of chlorophylls can also occur in case of excessive irradiation by high values of PhAR, which is an important natural stress factor to production activities in forest woody plants (Šprtová and Marek, 1996).

To study the changes in photo-synthetic pigments in the course of growing season, we need to take into consideration all factors entailing these changes. Concerning seasonal changes of pigment contents in deciduous woody plants, several peaks were observed. The first maximum may be associated with the budset, the following one, preceding the autumn yellowing, occurs in August to September and is associated with the accumulation of winter reserves (Haspelová-Horvatovičová, 1981; Gratani and Moriconi, 1989). Based on our results of the assessment of chlorophyll *a, b, a + b* concentrations during the growing seasons 2000 to 2002, we can conclude that the concentrations of these chlorophylls increased with progressing development of assimilation organs. A decrease of chlorophyll contents was observed in the autumn and was followed by natural depigmentation process. The variability in seasonal dynamics of changes in the chlorophyll components *a, b* is also reflected in the seasonal variability of their ratio which can show very different courses (Duda and Masarovičová, 1976). The ratio between chlorophyll *a* and chlorophyll *b* is not constant. The amount of chlorophyll *a* is in general three times higher that the amount of chlorophyll *b*. Our results are consistent with these data. According to Kmeť and Ditmarová (1997), woody plants with disturbed assimilation apparatus exhibited higher values of this ratio. Although our results indicate that the ratio *a : b* on the open plot was only slightly higher than under the stand shelter, we observed a rapid worsening of the physiological state followed by leaf fall on trees growing under the parent stand shelter. We have not observed a similar phenomenon in other exotic woody plants studied (red oak, European chestnut).

The results of a similar research on red oak (*Quercus rubra* L.) and European chestnut (*Castanea sativa* Mill.) can also be found in Kmeť and Šalgovičová (2000), Kmeť et al. (2001), Šalgovičová (2004).

According to Jamrich (1980) carbohydrates are a basic primary metabolites supporting the plant resistance against drought and frost. Involved are primarily the simplest saccharides (fructose, glucose and saccharose), which are most common in plants and provide a skeleton for the synthesis of more complex ones, finishing with starch and cellulose. Plant resistance against frost displays seasonal fluctuations in dependence on the carbohydrates accumulation and transformation of starch to saccharides preventing the proteins from coagulation. Bláha et al. (2003) also reported that the frost-resistance in plants is season-dependent, operating in annual cycles. It is connected with the ability of plants to prevent the ice formation inside the cells on the background of presence of osmotic-active compounds – among others namely saccharides and amino acids. Woody plants start to adapt to low temperatures already in the late summer, by lowering their growth rate. The gradually decreasing daily temperature continually increases the resistance – up to the first winter frosts. The issue of frost resistance is of key importance namely in the case of introduced woody plants. At present, however, there is a lack of studies dealing with the saccharide content and dynamics in exotic woody plants including black walnut (*Juglans nigra* L.) in our conditions.

Lichtenthaler (1981) concluded, that the metabolic processes in sunny leaves result in a higher accumulation of lipids, starch, soluble carbohydrates and a lower accumulation of proteins compared to shade leaves, which accumulate lower amounts of lipids and saccharides but higher amounts of proteins. This was also confirmed by our findings: we determined a higher content of carbohydrates in leaves of sample trees growing on the open plot in comparison with the plot under the stand shelter.

The contents of carbohydrates and chlorophylls in various genotypes of European chestnut (*Castanea sativa* Mill.) were also evaluated by Proietti et al. (1999), who studied the influence of leaf position, presence of fruits and light supply on the photosynthetic rate. He observed that the presence of fruits increased the photosynthetic rate (Pn) in leaves on shoots; on the other hand, no significant influence was observed for chlorophylls and saccharides.

Sarivildiz and Anderson (2003) compared chemical composition of sunny and shade leaves in three broadleaved species (*Castanea sativa* Mill., *Quercus robur* L., *Fagus sylvatica* L.).The authors also analyzed the contents of nitrogen, lignin and polysaccharides (hemicellulose). The results revealed differences in the chemical composition corresponding to the different categories of leaf type classification.

Conclusions

The aim of this work was to evaluate the physiological status of black walnut (*Juglans nigra* L.) stands under different site conditions. The research was conducted over the period 2000–2002. The physiological status of the examined trees was evaluated through the values of chlorophylls concentrations and carbohydrates contents in the assimilation organs. The values of chlorophylls *a, b, a + b* (in mg g^{-1} leaf dry mass) concentrations were always higher in trees growing under the stand shelter in comparison with trees growing in open area. There were found highly significant differences in photosynthetic pigments contents between the plots and also between the sampling times in the studied year. In general, higher bulk contents of carbohydrates were determined in the assimilation organs of trees on the open plot.

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Vplyv podmienok prostredia na fyziologický stav porastov orecha čierneho (*Juglans nigra* L.)

Súhrn

Práca predkladá výsledky z ekofyziologického výskumu orecha čierneho (*Juglans nigra* L.) rastúceho v rozdielnych stanovištných podmienkach (pod clonou porastu a na voľnej ploche).Výskum sa realizoval na trvalých výskumných plochách (TVP) v Ivánke pri Nitre počas vegetačného obdobia rokov 2000–2002. Fyziologický stav porastov sa hodnotil na základe analýz fotosyntetických pigmentov, ako i obsahu sacharidov v asimilačných orgánoch orecha čierneho (*Juglans nigra* L.), ktoré boli stanovené spektrofotometricky. Hodnoty koncentrácie chlorofylov a, b, $a + b$ (v mg g^{-1} suchej hmotnosti listov) boli celkovo vyššie v listoch vzorníkov rastúcich pod clonou porastu, na rozdiel od sacharidov (celkové, redukujúce, neredukujúce), kde priemerné hodnoty boli celkove vyššie v asimilačných orgánoch stromov rastúcich na voľnej ploche. Práca potvrdila štatisticky vysokopreukazný vplyv plochy (na hladine významnosti 99,9 %) i jednotlivých odberov v rámci roka na všetky sledované fyziologické parametre.

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Leaf area index (LAI), production and silvicultural practice in European chestnut (*Castanea sativa* Mill.) monocultures

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Abstract

TOKÁR, F. 2004. Leaf area index (LAI), production and silvicultural practice in European chestnut (*Castanea sativa* Mill.) monocultures. *Folia oecol.*, 31 (2): 111–121.

The work evaluates the influence of over 30 years (1971–2001) repeated thinning from above (positive selection, various degrees, various intervals) on the dynamics of leaf area index (LAI) in tended European chestnut (*Castanea sativa* Mill.) monocultures on the PRP series (7 partial permanent research plots) Žirany (Forest Enterprise Topoľčianky, Forest District Zobor). Over the whole stand development period, the highest LAI values were reached in tended stands treated through heavy thinning from above applied at 10-year intervals (PRP III, V, VII). At the stand age of 46 years, the highest LAI value was reached on PRP III (6.96 ha ha^{-1}). The highest growing stock and the highest total production of aboveground biomass was reached on the PRPs tended through heavy thinning from above with positive selection and 10-year interval of repetition (PRP III, V, VII). On these plots, we also reached the highest values of both mean periodical increment and total mean increment. Also in connection to the LAI were the highest values of mean periodical increment reached on the PRP treated with heavy thinning from above repeated at 10-year intervals (5.05, 4.27 and 4.61 g dm^{-2} year^{-1}). The stands tended with heavy thinning from above repeated at 10-year intervals provided their promising trees with the most favourable conditions for the above-ground biomass development.

Key words

Castanea sativa Mill., silvicultural practice, monocultures, leaf area index, biomass production

Introduction

Biomass production in woody plants is dependent on leaf area index (LAI), expressing the total area of leaf blades converted per unit area of the ground, and on net assimilation expressing the photosynthetic intensity per leaf area unit. Both LAI and net assimilation are dependent on the surrounding environment and on the developmental stage and density (spacing) of the individual trees. In forest stands, LAI and production are dependent on the stand composition, developmental stage and silvicultural practice (KORPEĽ et al., 1991; OSZLÁNYI, 1995; TOKÁR, 1985, 1989a, 1995, 1997; VYSKOT et al., 1971).

This work evaluates the 30-year (1971–2001) influence of thinning from above (positive selection, various degrees, various intervals of repetition) on the dynamics of leaf area index (LAI) in tended European chestnut (*Castanea sativa* Mill.) monocultures on the series of permanent research plots (PRP) (7 partial PRP) Žirany (Forest Enterprise Topoľčianky, Forest District Zobor).

Material and methods

We studied the influence of thinning on dynamics of both qualitative and quantitative characteristics of European chestnut monocultures on the series of seven permanent research plots Žirany (Forest Enterprise Topoľčianky, Forest District Zobor). We established the PRPs in 1971, in a 16-year old chestnut monoculture – in consistency with the site conditions and in consistency with all the requirements met in establishment of PRPs in the case of the native species.

In terms of site conditions, the PRPs belong to the nutrient rank, oak forest vegetation tier, forest type group Carpineto-Quercetum. The stand was established with cordon-planted, one-year old chestnut seedlings of provenience from Jelenec, in triangular spacing with 1m distances between the rows and 1m distances between the trees in a row. The stand was even-aged and also the tree composition was homogeneous. In 1971 we established in this stand 7 partial PRP with the aim to evaluate the structure, dynamics and quality of chestnut monocultures and to study the influence of thinning from above of various degrees applied at various time intervals on the changes in both quantitative and qualitative characteristics of the examined stands (Table 1). All the trees on the PRPs were numbered. In 1971, 1976, 1981, 1986, 1991, 1996 and 2001, always at the end of the vegetation season, the PRPs were subjected to an inventory with forest mensuration (HALAJ, 1963; ŠMELKO, 2000). We assessed the tree bio-sociological status, evaluated the quality of stems and crowns (Table 2).

According to a long-term thinning plan, the plots were subjected to thinning from above with positive selection (qualitative thinning according to Schädelin) aimed to tend promising trees. The promising trees were selected as trees with proper quantitative and qualitative characteristics (with larger diameter and higher then the mean stem, of the 1st and 2nd quality classes in terms of stem and crown). The numbers of the selected trees were 250–300 ha^{-1} (TOKÁR, 1998). We assessed the influence of thinning based on the trends in volume production and yield of the stands, crown and stem quality and the development of promising trees. The results of this work are summarised in TOKÁR

Table 1. Thinning plan on the PRPs Žirany (monocultures of *Castanea sativa* Mill.)

Partial PRP	Thinning method	Intervention	Thinning intensity	Thinning interval (years)	1971	1976	1981	1986	1991	1996	2001
								Stand age			
					16 years	21 years	26 years	31 years	36 years	41 years	46 years
I	From above	Positive selection	heavy	5	first intervention	second intervention	third intervention	fourth intervention	fifth intervention	sixth intervention	seventh intervention
II			moderate	5	first intervention	second intervention	third intervention	fourth intervention	fifth intervention	sixth intervention	seventh intervention
III			heavy	10	without intervention	first intervention	without intervention	second intervention	without intervention	third intervention	without intervention
IV			moderate	10	first intervention	without intervention	second intervention	without intervention	third intervention	without intervention	fourth intervention
V			heavy	10	first intervention	without intervention	second intervention	without intervention	third intervention	without intervention	fourth intervention
VII			heavy	10	without intervention	first intervention	without intervention	second intervention	without intervention	third intervention	without intervention
VI	Control plot										

Table 2. Height position of trees, stem and crown quality

Classification Degree	Evaluated hight position of trees	Stem quality	Crown quality crown size	crown density	crown shape
1	codominant trees	hight-quality stem	medium	medium	regular
2	dominant trees	average-quality stem	big	dense	fork-like
3	suppressed trees	low-quality stem	small	thin	bouquet-like
4	overtopped trees	–	–	–	strongly deformed

(1976, 1982, 1984a, b, 1987a, b, 1990a, b, 1998, 1999a, b).

The photo-synthetically active leaf area and the aboveground biomass amount were evaluated using the destructive method (sample trees).

We determined number and type of sample trees following the fact that the tree biomass (weight) is directly dependent on the basal area and that this dependence is best-fitted with a 2nd degree (quadratic) parabola (Tokár, 1989a, b). The number of the sample trees in the stand was determined using stratified selection according to the presence of the individual basal area proportions corresponding to the individual diameter classes, with a precision of 10% (Šmelko, 1963). In young stands (aged less than or equal to 25 years), with rather high diameter range, was the total number of sample trees determined to be 30, in older stands 15 (Tokár, 1984a, b, 1990a). This number was distributed over the individual diameter classes according to their percentage share in the stand diameter structure (Tokár, 1982, 1984a, b, 1990a, 1993).

We measured in sample trees the following dimensions: diameter $d_{1,3}$, tree height, crown height and diameter. For each sample tree we determined the weight of the stem, branches (both vital and dry), annual shoots and leaves. We used a scale Kamor with a capacity up to 50 kg and an accuracy of 0.01 kg. From each third of stems, branches, annual shoots and leaves of four trees representing the tree classes we took samples. In the laboratory, these samples were dried at a temperature of 105°C and, consequently, their dry matter content was determined.

The converted values of the individual aboveground biomass components were explored in relation to the diameter $d_{1,3}$ and, in the sense of Tokár (1989b) they were fitted with a quadratic parabola. The fitted values were multiplied by numbers of trees in the individual diameter classes identified in the stand diameter structure. In such a way, we obtained the values of the aboveground biomass growing stock on the individual partial PRPs.

We determined the leaf area, using a photoplanimeter EIJKELKAMP. For each plot we examined three representative samples (3 x 100 leaves) mixed from all the sample trees. Based on the samples we calculated conversion coefficients (fresh leaves weight in kg divided by the fresh leaves area in m^2), which was consequently used for the calculations in all the sample trees. The converted values of leaf area were examined in relation to the diameter $d_{1,3}$ and the calculation of the active leaf area – leaf area index (LAI) was done using the parabola-fitted values multiplied by the tree numbers in the individual diameter classes. The leaf area index (LAI) was expressed in ha ha^{-1}. The dependence of LAI on tree age were fitted with power functions. Here we give a graphical representation of the obtained results.

Results

Leaf area index (LAI)

The highest LAI (Table 3) values were over the whole stand development reached in chestnut monocultures tended through heavy thinning from

Table 3. Leaf area index (LAI) of European chestnut monocultures (*Castanea sativa* Mill.) on the PRP-series Žirany in 1971–2001

Partial PRP	1971	1976	1981	1986	1991	1996	2001
				Age of stand			
	16 yr	21 yr	26 yr	31 yr	36 yr	41 yr	46 yr
				Leaf area index (LAI)			
	ha ha^{-1}	ha ha^{-1}	ha ha^{-1}	ha ha^{-1}	ha ha^{-1}	ha ha^{-1}	ha ha^{-1}
I	2.06	2.46	3.11	3.41	3.11	4.22	5.21
II	2.12	2.34	3.02	3.30	2.75	3.88	4.58
III	2.40	3.02	3.89	4.52	4.18	5.86	6.96
IV	2.18	2.76	3.32	3.88	3.98	4.60	5.49
V	2.60	3.12	3.76	4.00	4.34	6.26	6.39
VI	2.24	2.70	3.40	3.89	4.17	5.28	5.75
VII	2.21	2.62	3.26	3.68	3.44	4.64	6.15

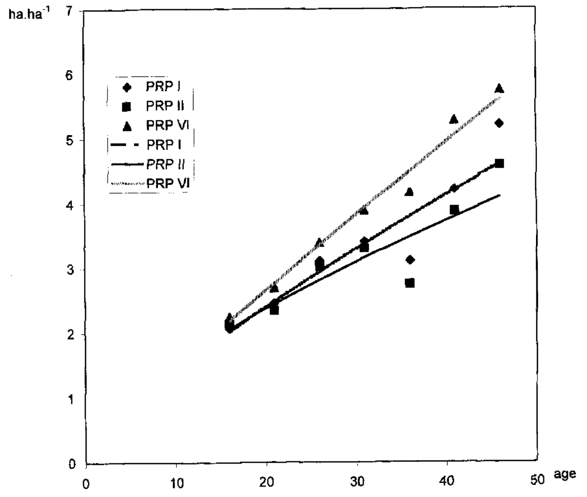

Fig. 1. LAI for tended pure stands of *Castanea sativa* Mill. in PRP I, II and VI in Žirany at different age, $y_I = 0.2296x^{0.7831}$ ($R^2 = 0.8984$), $y_{II} = 0.3359x^{0.6527}$, ($R^2 = 0.8209$), $y_V = 0.1812x^{0.8961}$ ($R^2 = 0.9853$)

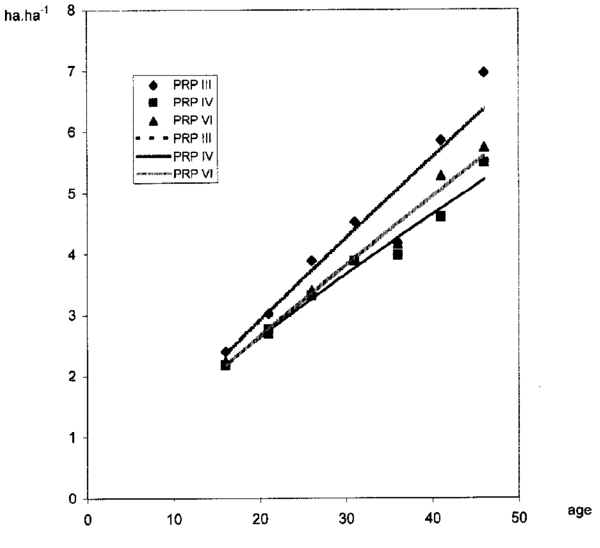

Fig. 2. LAI for tended pure stands of *Castanea sativa* Mill. in PRP III, IV and VI in Žirany at different age, $y_{III} = 0.1753x^{0.9382}$ ($R^2 = 0.9401$), $y_{IV} = 0.226x^{0.8196}$, ($R^2 = 0.9836$), $y_{VI} = 0.1812x^{0.8961}$ ($R^2 = 0.9853$)

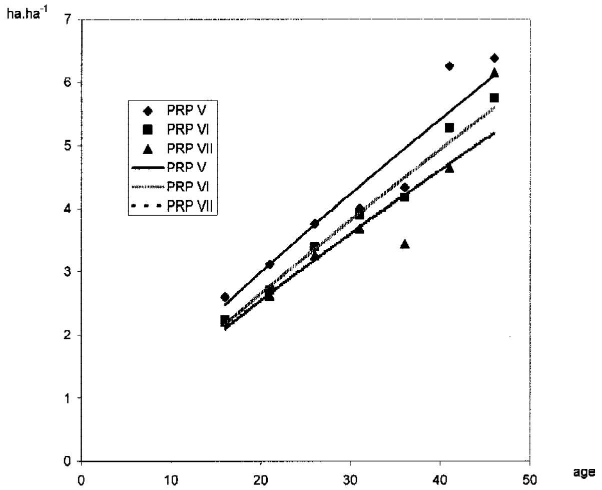

Fig. 3. LAI for tended pure stands of *Castanea sativa* Mill. in PRP V, VI and VII in Žirany at different age, $y_V = 0.2312x^{0.8552}$ ($R^2 = 0.9336$), $y_{VI} = 0.1812x^{0.8961}$ ($R^2 = 0.9853$), $y_{VII} = 0.1952x^{0.8573}$ ($R^2 = 0.896$)

above applied at 10-year intervals (PRP III and V). The stands on these plots reached at the age of 46 years the LAI values of 6.96 and 6.39 ha ha^{-1}, respectively. The lowest LAI were reached in chestnut monocultures tended through moderate thinning from above applied at 5-year (PRP II, 4.58 ha ha^{-1}) and 10-year intervals (PRP IV, 5.49 ha ha^{-1}).

We fitted the age-dependence of the empirical LAI values with a power function (Figs 1–3). This dependence has been found close or even very close (R^2 = 0.8209–0.9853).

Aboveground biomass stock

Table 4 shows that the highest aboveground biomass stock was reached in chestnut monocultures tended through heavy thinning from above applied at 10-year intervals (PRP III and V), the lowest in chestnut monocultures tended through moderate thinning from above applied at 5-year intervals (PRP II).

In 2001, at the stand age of 46 years, was the highest aboveground biomass stock found on PRP V (384.16 t ha^{-1}) and TVP III (372.48 t ha^{-1}), the lowest on PRP II (260.04 t ha^{-1}).

From the results we can see that the biomass production in the stands is dependent on the degree (strength) and interval of thinning (the higher degree and the longer interval, the higher final production). This finding has also been confirmed with the results in the mean periodical increment (Table 6), because the highest values of this parameter were reached on PRPs V and III (10.88 and 10.68 t ha^{-1} year^{-1}, respectively), what is by +21.02% and +18.80% more compared to the control.

Table 4. Aboveground dry biomass stock in European chestnut (*Castanea sativa* Mill.) monocultures on the PRP-series Žirany in 1971–2001

Partial PRP	Aboveground biomass in dry matter t ha^{-1}						
	1971	1976	1981	1986	1991	1996	2001
	Age of stands (years)						
	16	21	26	31	36	41	46
I	60.31	87.70	113.43	186.09	191.26	239.94	271.42
II	41.07	76.40	106.71	181.20	186.76	236.55	260.04
III	52.15	102.59	132.55	246.64	255.18	342.57	372.48
IV	46.60	77.04	122.09	200.07	222.04	272.05	291.64
V	71.89	95.11	132.87	218.32	265.02	358.71	384.16
VI	54.89	89.72	126.58	211.03	249.95	305.59	324.63
VII	52.97	90.03	116.52	201.31	215.76	269.86	330.55

Total biomass production

Also in the case of the total aboveground biomass production (thinnings + mortality + other losses), the best results over the all stand development were reached in the stands tended through heavy thinning from above applied at 10-year intervals (PRP III, V, VII). The highest aboveground biomass production was reached (Table 5) in 2001 at the stand age of 46 years in the stand on PRP III (612.29 t ha^{-1}). This stand has also reached the highest total mean increment (13.31 t ha^{-1} year^{-1}), what was by +26.76 % more than on the control (Table 6).

Mean periodical aboveground biomass increment

Over the long-term and regularly evaluated development of the aboveground biomass production on the studied PRPs (Table 7), we identified two outstanding periods when the mean periodical aboveground biomass increment reached the peaks (1982–1986 and 1992–1996). The highest values were reached on PRP III and V tended through heavy thinning from above repeated at 10-year intervals (22.82 and 17.09 t ha^{-1} year^{-1}, respectively, in 1982–1986 and 17.48 and 18.74 in 1992–1996).

In dependence on LAI, the highest values of mean periodical increment converted per leaf area unit (Table 8) were again reached on the same partial plots (III, V and VII), tended applying heavy thinning from above (5.05, 4.27 and 4.61 g dm^{-2} year^{-1} in 1982–1986; 2.98, 2.99 and 2.33 g dm^{-2} year^{-1} in 1992–1996); the lowest were reached on the plots tended through moderate thinning from above.

For the forest management practice, there follows an important consequence – the direct dependence of biomass production on the thinning intensity and leaf area index. Besides these factors, which can directly be influenced by the forest manager, is the aboveground biomass production also influenced by a sequence of other ecological factors as are soil conditions and, first of all, climatic factors governing at the site in the relevant period and genetic properties of the grown woody plant.

Table 5. Total aboveground biomass in dry matter in European chestnut (*Castanea sativa* Mill.) monocultures on the PRP-series Žirany in 1971–2001

Partial PRP	Total aboveground biomass supply in dry matter t ha^{-1}						
	1971	1976	1981	1986	1991	1996	2001
	Age of stands (years)						
	16	21	26	31	36	41	46
I	60.31	121.92	186.72	283.96	327.60	414.51	492.82
II	41.07	105.32	171.34	276.59	324.25	418.06	486.38
III	52.15	170.05	240.48	394.87	433.84	521.89	612.29
IV	46.60	111.33	176.86	283.41	344.96	450.76	486.72
V	71.89	121.57	192.47	300.71	376.16	526.26	597.35
VI	54.89	135.71	218.14	364.76	376.56	458.63	483.14
VII	52.97	135.71	180.53	308.94	361.00	430.84	541.19

Table 6. Trends in growing stock and total aboveground biomass production in European chestnut (*Castanea sativa* Mill.) monocultures on PRP-series Žirany in 1971–2001

PRP	Growing stock 1971 after thinning	Growing stock 2001 before thinning	Mean periodical increment (MPI)	Index MPI to PRPVI	Total aboveground biomass	Total mean increment (TMI)	Index TMI to PRPVI
	t.ha^{-1}		t ha^{-1} year^{-1}		t ha^{-1}	t ha^{-1} year^{-1}	
I	47.11	271.42	7.48	83.20	492.82	10.71	102.00
II	33.63	260.04	7.55	83.98	486.38	10.57	100.67
III	52.15	372.48	10.68	118.80	612.29	13.31	126.76
IV	40.79	291.64	8.36	92.99	486.72	10.58	100.76
V	57.71	384.16	10.88	121.02	597.35	12.98	123.62
VI	54.89	324.63	8.99	100.00	483.14	10.50	100.00
VII	52.97	330.55	9.25	102.89	541.19	11.76	112.00

Table 7. Mean periodical increment of dry aboveground biomass in European chestnut (*Castanea sativa* Mill.) monocultures on the PRP-series Žirany in 1971–2001

Partial PRP	Mean periodical increment (t ha^{-1} year^{-1})						
	1956–1971	1972–1976	1977–1981	1982–1986	1987–1991	1992–1996	1997–2001
I	3.77	5.48	5.15	14.53	1.03	9.74	6.30
II	2.57	7.07	6.06	14.90	1.11	9.96	4.70
III	3.26	10.09	5.99	22.82	1.71	17.48	5.98
IV	2.91	6.09	9.01	15.60	4.39	10.00	3.92
V	4.49	4.64	7.55	17.09	9.34	18.74	5.09
VI	3.43	6.97	7.37	16.89	7.78	11.13	3.81
VII	3.31	7.41	5.30	16.96	2.89	10.82	12.14

Table 8. Mean periodical increment of dry aboveground biomass in European chestnut (*Castanea sativa* Mill.) monocultures on the PRP-series Žirany in 1971–2001

Partial PRP	Mean periodical increment (g dm^{-2} year^{-1})						
	1956–1971	1972–1976	1977–1981	1982–1986	1987–1991	1992–1996	1997–2001
I	1.89	2.23	1.65	4.26	0.96	2.31	1.21
II	1.21	3.02	2.01	4.51	0.40	2.51	1.03
III	1.36	3.34	1.54	5.05	0.41	2.98	0.86
IV	1.33	2.21	2.71	4.02	1.10	2.17	0.71
V	1.73	1.49	2.01	4.27	2.15	2.99	0.80
VI	1.53	2.58	2.17	4.34	1.86	2.11	0.66
VII	1.50	2.83	1.62	4.61	0.84	2.33	2.02

Table 9. Aboveground biomass stock in promising trees of European chestnut (Castanea sativa Mill.*)* on the PRP-series Žirany in 1971–2001

1971	1976	1981	1986	1991	1996	2001	
Stand age (yr)							Index to PRP VI
16	21	26	31	36	41	46	
Aboveground biomass stock in t ha^{-1}							
16.49	29.13	44.94	75.30	98.98	98.30	114.28	102.02
14.63	34.30	50.30	62.64	73.51	99.77	114.11	101.87
17.04	36.58	52.85	82.91	104.58	134.54	152.57	136.20
14.08	29.38	47.89	63.66	73.76	94.39	113.49	101.31
23.47	39.41	55.67	70.94	93.17	115.21	128.06	114.32
10.25	19.58	31.26	58.09	71.71	96.01	112.02	100.00
8.54	23.08	35.07	67.56	89.69	137.27	138.93	124.02

This finding has also been confirmed with the results on the development of growing stock and the total aboveground biomass production over the entire studied period (Table 6).

The highest values of the mean periodical increment (MPI) and the total mean increment (TMI) were reached on the PRP treated through heavy thinning from above repeated at 10-year intervals (III, V and VII), what means in the first parameter by 2.89 and 18.80–21.02% more than on the control plot (VI), and in the second parameter by 12.00, and 23.62–26.76% more compared to the control.

Aboveground biomass production in promising trees

In consistency with the requirements imposed on promising trees, we selected at the beginning of the experiment (1971) from 873 (VI) to 1,758 (II) promising trees representing a stock of 8.54 t ha^{-1} (VII)–23.47 t ha^{-1} (V). The development of these trees was promoted through targeted management – thinning interventions. The number of promising trees decreases with increasing stand age. In 2001, ranged the promising trees numbers from 292 (I) to 404 (VII), what represented only 22.71% and 43.27%, respectively, of the original numbers stated in 1971.

From the obtained results on the aboveground biomass production in promising trees we can see (Table 9) that the thinned PRPs provided the promising trees with more favourable growing conditions than the control plot. The highest values of the growth index of the aboveground biomass in promising trees were reached on the partial plots tended applying heavy thinning from above (PRP III, V a VII).

Discussion

The assimilatory surface of tree crowns expressed as leaf area index (LAI) is one of key factors determining the production fitness of the given woody plant (Oszlányi, 1995; Tokár, 1982, 1984a, b, 1985, 1987b, 1989a, b, 1990a, b, 1993, 1995, 1998, 1999a, b, c). However, the biomass production in stands is also dependent on other ecological conditions provided at the stand management (soil fertility, stand type, composition, age, climatic conditions) and on genetic and physiological properties of the relevant trees (Tokár, 1980, 1989a, b, 1995, 1998).

The results obtained in the biomass production and LAI confirm the former results obtained by Tokár (1987a, 1998, 2002a), that the highest values were obtained in homogeneous European chestnut monocultures in the stands tended through heavy thinning from above applied at 10-year intervals. From this fact there follows a practical finding that the applied silvicultural practice (thinning) can influence the active leaf surface in tree crowns – the parameter strongly controlling the aboveground biomass creation in the whole stands and also in the separate promising trees.

As for the European chestnut stands mixed with another tree species, in the case of moderate tending from above applied at 5-year intervals, the mixed stands, namely those with admixture of small-leaved linden and those with admixture of forest pine, were more productive than the European chestnut monocultures. Beginning with the age of 35 years, higher production was reached in the tended stands than in the stands growing without tending. The causes of higher weight production reached in the mixed stands are at favourable alelopatic and soil conditions in such types of stands (Tokár, 1985a, b, 1993, 1998, 1999b, c, 2002b).

In the abroad literature, the biomass production in European chestnut trees has been documented with a rather small piece of data. Ovington (1962) refers a value of 117 t ha^{-1} for the aboveground biomass of a 47-year old chestnut monoculture.

Comparing this figure with the data obtained in Slovakia, we can see that in our conditions is the biomass production higher in both chestnut monocultures and stands mixed with other woody plants. This fact has also been confirmed with the data about mean periodical increment – converted per stand area unit and converted per leaf area unit.

The annual production of dry mass per leaf area unit was studied by Walter (1964, sec. Vyskot et al., 1971). The author gives for the European chestnut a value of 1.15 g dm^{-2} year^{-1}. Comparing this value with our results, it is evident that in our conditions reach chestnut trees higher annual biomass production per leaf area unit both in monocultures and in mixed stands. However, this value is considerably influenced with climatic conditions in the current year and also with ecological and physiological properties of the grown taxon.

In mean periodical increment two periods of its culmination (1982–1986 and 1992–1996) and one period of its decline (1987–1991) were observed. Reasons have to be sought in effect of the mean climatic factors (air temperature and rainfalls) on ecological-production characteristics of European chestnut stands. By nearly the same mean annual air temperature (10°C) during the periods studied, annual sum of rainfall (decrease under 500 mm) showed to be the limiting factor. This interesting problem requires however a more detailed climatic and production evaluation, namely with regard to stand phytotechnique and leaf area index. Results of our studies in pure stands of European chestnut are in an accord with our previous results (Tokár, 1987a, 1998, 1999a, b, c, 2002a, b), which demonstrate that the best growth characteristics were observed in the stands tended by the strong crown thinnings with frequency 10 years.

The European chestnut has been classified by Beran and Šindelář (1996) and Tokár (1999d) as a woody plant with favourable properties for intensive growing in conditions changed because the global warming. At the same time, the authors point at the up-to-present lacking experience in silvicultural practice connected with growing stands of this species.

Today is also in Slovakia hot the problem of protection of the European chestnut against the fungus *Cryphonectria parasitica* (Murill.) Barr. Studied and verified are methods of so-called biological defence (Juhásová, 1992; Juhásová et al., 1992; Juhásová et al., 1997) and hybridisation (Bolvanský, 1997).

Conclusion

This work evaluates a 30-year (yrs. 1971–2001) influence of repeated thinning (positive selection, various degrees, various intervals) on the dynamics of leaf area index (LAI), growing stock and the total aboveground biomass production in European chestnut (*Castanea sativa* Mill.) monocultures and in their promising trees on the PRP series (7 partial plots) Žirany (Forest Enterprise Topoľčianky, Forest District Zobor). Over the whole development period, the highest values of LAI, growing stock, total aboveground biomass production both in whole stands and in promising trees were found on plots treated through heavy thinning from above with positive selection repeated at 10-year intervals (PRP III, V and VII).

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Index listovej plochy (LAI), produkcia a fytotechnika nezmiešaných porastov gaštana jedlého (*Castanea sativa* Mill.)

Súhrn

Práca zhodnocuje 30-ročný vplyv (r. 1971–2001) úrovňových prebierok (pozitívny výber, rôzna sila, rôzny interval opakovania) na vývoj indexu listovej plochy (LAI) vychovávaných nezmiešaných porastov gaštana jedlého (*Castanea sativa* Mill.) na sérii TVP (7 čiastkových TVP) Žirany (Lesný závod Topoľčianky, Lesná správa Zobor). Počas celého vývoja najvyššie hodnoty LAI dosahujú prebierkové TVP vychovávané silnými úrovňovými prebierkami a intervalom opakovania 10 rokov (TVP III, V, VII). Pri veku 46 rokov najvyššiu hodnotu LAI dosiahla TVP III (6,96 ha ha^{-1}). Najvyššiu zásobu a celkovú produkciu nadzemnej dendromasy dosahujú TVP vychovávané silnými úrovňovými prebierkami s pozitívnym výberom a intervalom opakovania 10 rokov (TVP III, V, VII). Na týchto TVP sa dosiahli aj najvyššie hodnoty priemerného periodického prírastku a celkového priemerného prírastku. Aj vo vzťahu k LAI sa najvyššie hodnoty priemerného periodického prírastku dosiahli opäť na TVP so silnými úrovňovými prebierkami a intervalom opakovania 10 rokov (5,05, 4,27 a 4,61 g dm^2 rok^{-1}). Jeho hodnota je počas vývoja porastov ovplyvnená aj klimatickými charakteristikami. Limitujúcimi sa ukázali byť ročné zrážky pod 500 mm. Porasty vychovávané silnými úrovňovými prebierkami a intervalom opakovania 10 rokov poskytli pre vývoj nadzemnej dendromasy nádejných stromov najpriaznivejšie podmienky.

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Tree species composition of natural geobiocoenoses in forest types in Slovakia

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Abstract

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The proposal of the target tree species composition for forest types in Slovakia suggested by HANČINSKÝ (1972) is mainly based on commercial aspects of forest management. As a result, spruce is supported as a dominant woody plant in a number of forest types where this species is not autochthonous. Up to present, this proposal has been used as the general basis for all forest categories concerned in forest management. From the scientific point of view, however, it is not suitable for management of protection forests and special purpose forests situated in national parks and nature reserves. We present here a proposal of nature-closed target composition consisting of indigenous tree species – founded on the author's authentic first-hand experience from survey of natural conditions and on the data provided by bibliographical resources. The proposal takes into account diverse habitat conditions in geobiocoenoses of forest types occurring in the territory of Slovakia, and is applicable to management of protection forests and special purpose forests. It can also serve as a methodical tool for determining ecological stability for all forest categories.

Key words

species composition, natural geobiocoenosis, forest type, ecological stability

Introduction

The contemporary species composition of Slovak forests (as part of the Carpathian range complex) is a result of natural processes in the post-glacial period, mutual interaction between woodland organisms and human influence.

The late glacial – early Holocene period (following the period of later Dryas with habitats of open formations ranging from cold-climate grasslands to cold-climate tundra; about 12,000 years ago) was in the Carpathians characterized by massive re-spreading of forests. The changes in the species composition were determined by a number of factors. The climatic factors were connected with changes in solar radiation affecting the temperature and precipitation. Consequences also followed from soil development, from distance between refuges where isolated forest communities survived the ice age and from genetic habits of the concerned tree species.

From the pre-boreal period (about 10,000 years ago) to Atlanticum period (about 6,000 years ago) the Carpathian nature wasn't significantly affected by human influence. The natural (autochthonous) species composition depended on the climatic and soil conditions only. Fir and beech had became natural components of our woodlands by the end of the Atlanticum period.

Succession cycle of these two shade-preferring tree species continues about 350–400 years. During the Epiatlanticum period (6,000–3,200 years ago) beech and fir gradually penetrated from the Balkan glacial refuges and invaded the zones of mixed oak woods and spruce forests. Oak and spruce had formed semi-shaded stands perfectly suitable for distribution of fir and beech. Within the following two thousand years a stable belt of fir and beech woods had been formed, wedged between the oak and spruce zones, pushing the mixed oak woods into lower altitudes, the spruce zone, on the other hand, was pushed up into higher sites.

In the early Sub-Boreal period (3.200 years ago), and even more intensively in the Sub-Atlanticum period (2.700 years ago), the human influence more and more affected the natural woodland succession. In the Sub-Atlanticum period (2.700–1.400 years ago), the indigenous local differentiation of altitudinal vegetation zones became stabilized (according to LOŽEK, 1973; MÍCHAL, 1992). Compact farming and settlement areas appeared in the countryside. Due to soil cultivation and due to increasing precipitation, severe soil erosion was frequent. As a result of agricultural cultivation practices (and livestock husbandry in particular), the natural indigenous forest complexes were gradually suppressed and replaced by expanding alternative communities. In such a way, a secondary cultural landscape was formed, which, in comparison with the original ecosystems, had a higher secondary biodiversity. The Slavic tribes, settling in the Carpathians in the 5th and 6th centuries, kept on the cultivation practices by further deforestation and farming, increasingly suppressing the original primeval forests. Each newly occurring form of forest utilization affected the natural ecotope as an alternative ecological factor, entailing specific changes in the plant species composition (including tree species) and wildlife distribution.

The impact of traditional farming on the natural life of animals and plants has pursued up to the modern times. Occurrence of cultural ecosystems reflected the small-scale land utilization practices. Since the 19th century, the industrial development, however, was connected with further intensification of the human influence on the natural surroundings. The persistent increase of the large-scale human impact on the nature resulted in decreased biodiversity of the landscape and its biotic subsystems. The most severe changes in forest species composition in the sub-montane and montane forest zones occurred in the period between the 13th and 17th century, following the mining boom and subsequent German colonization of the mining areas; and later the development of sheep farming introduced into the Slovak territory by the Walachian shepherds.

At the turn of the century, in the late 1890s and early 1900s, the European scientific and academic communities started to be more and more interested by the fragmented examples of the natural environment, especially virgin forests. In our country, at that time the “spruce-mania“, imported from Germany, was gradually fading away. The economically profitable spruce was given precendence against nature – which severely affected the original beech woods, fir-beech woods and partly also oak-beech woods, by replacing these with spruce monocultures. The large-scale replacement of the original tree species caused severe deterioration of ecological stability of the woodland ecosystems, turning them vulnerable to harmful biotic and abiotic agents. Surviving fragments of natural forest communities were put under protection as nature monuments in the 19th century and as nature reserves and national parks in the 20th century, mainly thanks to the effort of scientists and forestry specialists.

The study research conducted on these natural forest ecosystems, situated in protected areas, provides tools and ideas for development of nature-oriented principles of forest management.

Material and methods

In the years 1995–1996, our team, involved in the project VEGA No. 95-5305/372 (carried out at the Institute of Forest Ecology, Slovak Academy of Sciences in Zvolen), was dealing with the chorology of autochthonous tree species of Slovakia. The forest typological investigation database of the Institute LESOPROJEKT Zvolen was used as a source for reconstruction of a pattern of the original tree species distribution. The research has been stopped due to lack of financial support. The problems, however, were got on again in 1999, within the partial project VEGA No. 1/6273/99, carried out at the Department of Applied Ecology of the Faculty of Ecology and Environmental Sciences in Banská Štiavnica, Technical University in Zvolen.

Focusing on the question of existence of the most original primeval ecosystems in our nature reserves, we concentrated our effort on investigation of the ecological stability of forest ecosystems situated in the Slovak nature reserves and national parks.

To specify the indigenous tree species distribution in the natural woodland habitats, we used the results of our own previous research, data from the forest typological survey carried out over 1958–1974 and published materials. The most detailed analysis of natural woodland species composition according to the forest type groups was performed and published by ZLATNÍK (1935, 1956, 1959a, 1959b, 1975, 1976 and 1978).

In former years, the tree species composition of forests in the Hungarian Monarchy was surveyed by FEKETE and BLATTNY (1913). The natural tree species distribution in Slovakia was later studied and published by BLATTNY and ŠŤASTNÝ (1959). The possibility to estimate and control the species composition of forest stands for management goals was studied by GRÉK (1966). The works of RANDUŠKA (1955) and RANDUŠKA et al. (1986) dealt with species composition based on the forest typology results. The paper of FAITH et al. (1974) is concerned with the calculation of the target species composition according to the forest type groups in the spruce, fir and beech vegetation zones.

The species composition in selected typological units and the issue of forest ecosystem stability were treated by VLADOVIČ et al. (1998), VLADOVIČ et al. (1999) and VOLOŠČUK (1966, 1968, 1973a, 1973b, 2000, 2001).

The presented summary of original tree species composition of natural geobiocoenoses in Slovak forest types enables us to calculate the degree of similarity between the currently existing and original species composition of these forest types. The degree of similarity is also a methodological tool for assessment of woodland ecosystem stability (according to VOLOŠČUK, 2000). The forest types and their numbering were adopted from the work by HANČINSKÝ (1972), however, we have objections against specification of some forest types. This issue will be dealt with later in the text.

The original tree species composition in natural forest habitats is a common result of many-hundred-year forest development in the post-glacial period, influence of climatic, soil and site ecological conditions, and competitions between the tree species. The proposal of the species composition in the Slovak forest types, presented by the author (VOLOŠČUK, 2000, 2001) has been in this paper partly modified in accordance with specific forest management approach required in the special purpose and protection forests.

“**Available species composition**“ is a term used in forestry, denoting the species composition of currently existing production stands at felling age. This term comprises the following items: target species composition of the concerned management groups of forest types, difference between the current state of the forest stand and the corresponding model, as well as possible changes (regulation) by means of stand regeneration and tending measures carried out with regard to the principles of rational forest management. The target is to be achieved by the end of the current felling period of the stand. Sustainable production and sustainable development have also important place in the design of the available species composition (VLADOVIČ et al., 1998).

The regeneration species composition means the resulting tree species composition in a stand that is being regenerated. It is determined with regard to the current and target species composition as well as to the condition of the parent (regenerated) stand. Due to the influence of natural regeneration and the influence of external factors, the current figures characterising regeneration species composition may be modified during the regeneration period, if necessary.

Forest type groups and forest types are classified according to the ecological trophical series/interseries and hydric orders (by ZLATNÍK, 1959a). Their titles and numbering are assumed from HANČINSKÝ (1972). The bioclimatic line is adopted from ZLATNÍK (1959a).

Results

Oligotrophic (acidic) ecological series

Pineto-Quercetum
1101 : sp 40, so 55, bsp 5
1102 : sp 30, so 65, bsp 5
1103 : sp 25, so 60, sl 5, hb 5, bsp 5
1104 : sp 20, so 70, sl 5, hb 5

Quercetum
1111 : so 75, sp 15, bsp 5, ea 5
1112 : so 70, sp 10, hb 5, bsp 5, sl 5, ea 5
1113 : so 60, sp 10, hb 20, bsp 5, sl 5
1114 : so 50, sp 30, sl 10, bsp 5, hb 5
1115 : so 60, sp 20, sl 10, hb 10

Fagetum quercinum inferiora
2101 : poo+do 70, be 20, ba 10
2102 : poo+do 60, be 20, hb 10, ba 10
2103 : poo+do 60, be 25, hb 5, nm 5, sl 5

Fagetum quercinum superiora
3101 : be 50, so 35, ba 10, bsp 5
3102 : be 60, so 35, ba 5
3103 : be 65, so 30, ba 5

Querceto-Pinetum
4101 : sp 80, so 10, bsp 10
4102 : sp 75, so 15, bsp 10
4103 : sp 70, so 15, bsp 5, ba 10

Fagetum quercino-abietinum
4111 : be 60, so 20, sf 15, ba 5
4112 : be 60, so 15, sf 20, ba 5
4113 : be 55, so 20, sf 20, ba 5
4114 : be 65, so 15, sf 15, ba 5

Fagetum abietinum
4121 : be 80, sf 15, ba 5
4122 : be 75, sf 20, ba 5

Fagetum abietino-piceosum inferiora
The tree species distribution to the south of the bioclimatic line and that of the montane areas not included in the spruce altitudinal vegetation zone is given in the brackets.
5101 : be 40, sf 35, ns 20, ba 5 (be 50, sf 40, ns 5, ba 5)
5102 : be 35, sf 25, ns 20, sm 15, ba 5(be 55, sf 30, ns 5, sm 10)
5103 : be 35, sf 30, ns 20, sm 10, ba 5 (be 40, sf 45, ns 5, sm 10)
5104 : be 40, sf 30, ns 20, sm 5, ba 5 (be 60, sf 35, ns 5)
5105 : be 40, sf 35, ns 20, sm 5 (be 50, sf 35, ns 10, ba 5)

Fagetum abietino-piceosum superiora
The tree species distribution to the south of the bioclimatic line and that of the montane areas not included in the spruce altitudinal vegetation zone is given in the brackets.
6101 : ns 40, be 30, sf 15, el 5, ba 10 (be 35, sf 35, ns 15, ba 15)
6102 : ns 40, be 35, sf 20, ba 5 (be 40, sf 40, ns 5, ns 15)
6103 : ns 40, be 30, sf 15, sm 5, ba 5, el 5
(be 30, sf 40, ns 15, ns 5, ba 10)
6104 : ns 35, be 30, sf 25, sm 10 (be 45, sf 45, ns 10)
6105 : ns 40, be 25, sf 25, sm 10 (be 50, sf 45, ns +, ba 5)
6106 : ns 35, be 35, sf 20, el 5, ba 5 (be 40, sf 35, el 10, ba 10, ns 5)
6107 : ns 40, be 40, sf 20 (be 45, sf 30, ns 15, ba 10)

Pineto-Piceetum inferiora
5111 : ns 80, sp 10, sf 10
5112 : ns 75, sp 10, sf 15

Pineto-Piceetum superiora
6111 : ns 80, sp 5, el 5, sf 5, ba 5
6112 : ns 70, sp 5, el 10, sf 10, ba 5
6113 : ns 75, sp 5, el 5, sf 10, ba 5

Piceetum abietinum
6121 : ns 80, sp 10, sf 10
6122 : ns 75, sp 5, sf 10, el 5, ba 5
6123 : ns 80, sp 5, sf 10, ba 5, el +
6124 : ns 80, sp 5, sf 10, ba 5
6125 : ns 70, sp 5, sf 15, sm 5, el 5

Fagetum acidiphilum inferiora
5131 : be 70, sf 20, sm 5, se 5
5132 : be 70, sf 30

Fagetum acidiphilum superiora
6131 : be 80, sf 20
6132 : be 75, sf 15, ns 5, ba 5

Sorbeto-Piceetum
7101 : ns 95, ba 5
7102 : ns 90, ba 10
7103 : ns 85, ba 15
7104 : ns 80, ba 10, sm 10
7105 : ns 90, ba 10
7106 : ns 75, sm 15, ba 10

Lariceto-Piceetum
7110 : ns 80, el 10, cp 5, ba 5
in High Tatras: 11s 60, el 35, ba 5

Mughetum acidiphilum
8101 : mp 85, ba 10, siw 5
8102 : mp 75, ns 10, ba 5, cb 5, siw 5
8103 : mp 80, cb 10, ba 5, siw 5

Oligo-mesotrophic ecological interseries A/B

Fageto-Abietum inferiora
5201 : sf 55, be 35, sm 5, ns 5
5202 : sf 55, be 40, sm 5
5203 : sf 60, be 35, sm 5
5204 : sf 55, be 35, sm 5, se 5
5205 : sf 55, be 35, sm 5, se 5
5206 : sf 55, be 35, sm 5, se 5
5207 : sf 60, be 35, sm 5
5208 : sf 60, be 40
5209 : sf 60, be 35, sm 5
5210 : sf 50, be 35, sm 10, se 5

Fageto-Abietum superiora
The tree species distribution to the south of the bioclimatic line and that of the montane areas not included in the spruce altitudinal vegetation zone is given in the brackets.
6201 : ns 40, sf 40, be 20 (sf 60, be 40)
6202 : ns 40, sf 35, be 20, sm 5 (sf 50, be 35, sm 10, ba 5)
6203 : ns 35, sf 35, be 25, sm 5 (sf 50, be 40, sm 10)
6204 : ns 35, sf 35, be 25, sm 5 (sf 45, be 40, sm 10, se 5)
6205 : ns 35, sf 30, be 25, sm 10 (sf 50, be 30, sm 15, se 5)
6206 : ns 35, sf 35, be 30 (sf 60, be 30, sm 10)
6207 : ns 35, sf 30, be 20, sm 10, se 5 (sf 50, be 40, sm 10)
6208 : ns 35, sf 25, be 15, sm 15, se 10 (sf 40, be 40, sm 15, se 5)

Fagetum humile
6221 : be 90, sm 5, ba 5

Piceeto-Abietum inferiora
5231 : sf 75, ns 20, el 5
5232 : sf 70, ns 20, sm 5, se 5

Piceeto-Abietum superiora
6231 : ns 50, sf 50
6232 : ns 40, sf 45, sm 10, ba 5

Mesotrophic (nutritive) ecological series B

Carpineto-Quercetum
1301, 1302, 1303 : so 75, eo 5, hb 10, sl 5, asp 5
1304, 1305, 1306, 1307, 1308, 1309 : so 65, to 10, hb 5, nm 5, fm 5, sl 5
1310, 1311, 1312, 1313 : so 55, to 20, hb 5, nm 5, fm 5, sl 5, asp 5

Fageto-Quercetum
2301 : poo+do 55, be 15, nm 5, sl 5, hb 5, asp 5, sp 10
2302 : poo+do 50, to 5, be 15, hb 10, nm 10, sp 10
2303 : poo+do 65, to 10, hb 10, be 5, asp 5, sp 5
2304 : poo+do 60, to 5, be 20, hb 5, fm 5, asp 5
2305 : poo+do 70, be 10, hb 10, nm 5, sl 5
2306 : poo+do 60, to 5, be 15, hb 5, nm 5, sl 5, asp 5
2307 : poo+do 65, be 10, hb 10, nm 5, sl 10
2308 : poo+do 65, be 20, hb 5, nm 5, sl 5
2309 : poo+do 60, be 20, hb 10, nm 5, sl 5
2310 : poo+do 75, be 10, hb 5, nm 5, sl 5
2311 : poo+do 65, be 15, hb 5, nm 10, sl 5
2312 : poo+do 60, be 20, nm 10, sl 10
2313 : poo+do 60, eo 15, be 10, nm 5, sl 5, hb 5
2314 : poo+do 55, be 15, sl 10, nm 15, hb 5
2315 : poo+do 55, be 15, nm 15, sl 15
2316 : poo+do 50, be 20, hb 10, nm 10, sl 5, asp 5
2317 : poo+do 60, be 10, hb 15, nm 5, sl 5, asp 5

Querceto-Fagetum
3301 : so 20, be 60, ns 5, sl 5, hb 5, bch 5
3302 : so 20, be 60, ns 5, bch 5, sl 5, hb 5
3303 : so 20, be 60, ns 10, sl 5, ll 5
3304 : so 20, be 65, ns 5, sl 5, ll 5
3305 : so 20, be 65, ns 5, sl 5, ll 5
3306 : so 15, be 70, ns 5, sl 10
3307 : so 15, be 60, ns 10, sl 10, ll 5

3308 : so 10, be 60, ns 10, sl 10, ll 5
3309 : so 20, be 60, ns 15, sl 5

Fagetum pauper inferiora
3311 : so 5, be 85, sl 5, nm 5
3312 : so 5, be 85, nm 5, sl 5
3313 : be 95, nm 5
3314 : be 95, nm 5
3315 : so 5, be 80, sm 5, nm 5, sl 5
3316 : be 85, nm 10, sl 5
3317 : be 90, nm 5, sl 5
3318 : so 5, be 90, nm 5

Fagetum pauper superiora
4301 : be 85, sf 10, nm 5
4302 : be 85, sf 10, nm 5
4303 : be 80, sf 10, nm 5, sl 5
4304 : be 80, sf 10, nm 5, sm 5
4305 : be 70, sf 5, sm 10, nm 10, lpm 5
4306 : be 80, sf 5, nm 10, sl 5
4307 : be 80, sf 10, sm 5, nm 5
4308 : be 80, sf 10, ashsp 5, nm 5
4309 : be 80, so 5, sf 10, nm 5

Fagetum typicum
4311 : be 80, sf 10, ll 5, sm 5
4312 : be 85, sf 10, nm 5
4313 : be 75, sf 5, sm 10, nm 5, ll 5
4314 : be 80, sf 10, sm 10
4315 : be 80, sf 5, sm 15
4316 : be 80, sf 5, sm 5, se 5, ae 5
4317 : be 80, sf 10, sm 5, ll 5
4318 : be 75, sf 15, jsm5, ll 5
4319 : be 80, sf 10, sm 5, ll 5
4320 : be 80, sf 15, sm 5

Abieto-Fagetum inferiora
5301 : be 60, sf 35, sm 5
5302 : be 65, sf 25, sm 10
5303 : be 60, sf 35, sm 5
5304 : be 60, sf 30, sm 5, se 5
5305 : be 60, sf 35, sm 5
5306 : be 60, sf 30, sm 5, se 5
5307 : be 65, sf 35
5308 : be 60, sf 40

Abieto-Fagetum superiora
The tree species distribution to the south of the bioclimatic line and that of the montane areas not included in the spruce altitudinal vegetation zone is given in the brackets.
6301 : be 60, sf 20, ns 15, sm 5 (be 80, sf 20)
6302 : be 60, sf 20, ns 10, sm 5, se 5 (be 70, sf 25, sm 5)
6303 : be 55, sf 20, ns 15, sm 10 (be 60, sf 30, sm 10)
6304 : be 40, sf 20, ns 10, sm 15, se 15 (be 55, sf 25, sm 15, se 5)
6305 : be 65, sf 20, ns 10, sm 5 (be 65, sf 20, sm 15)

Mesotrophic-nitrophilous ecological interseries B/C

Carpineto-Quercetum acerosum
1401 : poo+do 80, to 5, fm 5, nm 5, sl 5
1402 : poo+do 75, to 5, fm 10, nm 5, asp 5
1403 : poo+do 80, to 5, fm 10, nm 5
1404 : poo+do 75, to 5, fm 5, nm 5, sl 5, asp 5

Fageto-Quercetum acerosum
2401 : poo+do 65, tor 5, be 5, nm 15, sl 10
2402 : poo+do 65, be 10, nm 10, sl 10, fe 5
2403 : poo+do 55, be 10, nm 15, sl 10, fe 10

Querceto-Fagetum tiliosum
3401 : be 60, so 20, nm 5, sl 10, fe 5
3402 : be 65, so 15, ll 5, sl 10, nm 5
3403 : be 60, so 15, sl 5, lpv 10, sl 10
3404 : be 60, so 20, ll 10, sl 5, nm 5

Fagetum tiliosum
4401 : be 65, sf 5, sm 10, nm 5, ll 10, se 5
4402 : be 60, sf 5, ll 15, sm 10, nm 5, se 5
4403 : be 55, sf 5, ll 20, sm 10, nm 5, se 5
4404 : be 55, sf 5, ll 20, sm 10, se 10
4405 : be 55, sf 5, ll 20, sm 15, se 5
4406 : be 50, sf 5, ll 20, sm 15, se 5, nm 5

Fageto-Aceretum inferiora
5401 : be 60, sm 20, sf 10, se 5, ae 5
5402 : be 60, sm 20, nm 5, sf 5, se 5, ae 5
5403 : be 60, sm 15, nm 5, sf 5, se 5, ae 10
5404 : be 55, sm 20, ae 10, nm 5, se 10
5405 : be 60, sm 25, ae 10, se 5
5406 : be 60, sm 15, se 15, sf 10
5407 : be 55, sm 20, se 20, sf 5

Fageto-Aceretum superiora
6401 : be 75, sm 10, se 5, sf 5, ae 5
6402 : be 70, sm 15, sf 5, se 5, ae 5
6403 : be 65, sm 15, se 10, sf 5, ae 5

6404 : be 70, sm 20, se 5, ae 5
6405 : be 75, sm 15, se5, sf 5
6406 : be 70, sm 20, se 5, sf 5
6407 : be 65, sm 20, se 10, sf 5
6408 : be 60, sm 20, se 15, sf 5

Fageto-Aceretum humile
6411 : be 80, sm 15, ba 5

Acereto-Piceetum
7401 : ns 80, sm 10, ba 10
7402 : ns 90, sm 5, ba 5
7403 : ns 90, sm 5, ba 5
7404 : ns 80, sm 15, ba 5
7405 : ns 80, sm 15, ba 5, be 5

Ribeto-Mughetum
8401 : mp 80, ns 5, cb 5, ba 5, sr 5

Eutrophic-nitrophilous (maplewood) ecological series C

Carpineto-Aceretum inferiora
1501 : oag 30, to 10, sl 20, fm 20, nm 15, asp 5
1502 : oag 45, to 10, fm 15, nm 15, fe 10, asp 5

Carpineto-Aceretum superiora
2501 : oag 40, to 5, sl 20, ll 10, nm 5, fm 10, fe 5, hb 5, asp +
2502 : oag 40, to 5, sl 15, ll 5, nm 15, fm 10, fe 5, hb 5, asp +
2503 : oag 40, be 5, nm 20, ll 10, sl 10, asp 10, hb 5

Tilieto-Aceretum inferiora
3501 : be 30, sm 15, nm 10, ll 20, sl 10, fe 5, asp 5, ba 5
3502 : be 35, sm 20, nm 20, ll 10, fe 5, se 5, ba 5
3503 : be 45, oag 5, sm 15, ll 20, sl 5, fe 5, se 5
3504 : be 40, sm 20, ll 20, dbagg 5, sl 5, nm 5, asp 5
3505 : be 35, sm 15, jvp 10, lpv 20, sl 10, asp 10,
3506 : be 30, sm 20, ll 20, jvm 10, sl 10, fe 5, se 5
3507 : be 40, sm 20, ll 20, nm 10, se 10

Tilieto-Aceretum superiora
4501 : be 40, sm 20, ll 20, nm 5, se 5, ae 5, ba 5
4502 : be 40, sm 25, ll 20, se 5, ae 5, ba 5
4503 : be 40, sm 20, ll 15, sf 10, ae 5, se 5, sl 5
4504 : be 35, sm 20, ll 20, sf 5, ae 5, sl 5, nm 5, se 5
4505 : be 40, sm 20, ll 15, sf 10, ae 5, se 5, nm 5
4506 : be 40, sm 25, ll 15, sf 5, ae 5, se 10

Fraxineto-Aceretum inferiora
5501 : be 30, sf 20, sm 20, ae 20, se 10
5502 : be 25, sf 15, sm 20, se 20, ae 20
5503 : be 25, sf 20, sm 15, se 25, ae 15

Fraxineto-Aceretum superiora
6501 : be 20, sf 20, ns 20, sm 20, se 10, ae 10
6502 : be 30, sf 15, ns 15, sm 20, se 10, ae 10
6503 : be 20, sf 20, ns 15, sm 20, ae 15, se 10

Eutrophic alkaline-calciphilous (limestone-based) ecological series D

Corneto-Quercetum
1601 : puo 40, to 20, vo 20, cch 10, ashsp 10
1602 : puo 30, oag 20, to 5, cch 15, chsp 10,
ashsp 15, asp 5 1603 : puo 30, oag 15, hb 20, to
5, fm 5, ashsp 10, cch 5, asp 10
1604 : puo 20, oag 30, fm 10, nm 10, sl 10, ashsp 10, asp 5, bch 5
2601 : oag 40, puo 20, to 5, be 5, fm 10, sl 10, hb 10

Fageto-Quercetum dealpinum
2611 : poo 50, puo 15, be 10, fm 5, sl 10, cch 10
2612 : poo 45, be 10, puo 10, nm 5, fm 5, sl 10, cch 10, sp 5

Pinetum dealpinum
2621 : sp 85, oag 5, ashsp 5, asp 5
3621 : sp 80, oag 5, be 5, ashsp 5, asp 5

Corneto-Fagetum
3601 : be 65, oag 15, fm 5, cch 10, ashsp 5

Querceto-Fagetum dealpinum
3611 : be 20, oag 20, puo 15, hb 15, fm 15, cch 15
3612 : be 30, oag 25, puo 5, hb 10, nm 5, fm 10, sl 5, cch 10

Fagetum dealpinum inferiora
4601 : be 60, sf 20, ashsp 10, el 5, sp 5
4602 : be 50, nm 10, ll 10, sf 10, ashsp 10, el 5, sp 5
4603 : be 55, nm 10, el 5, sf 15, ashsp 10, sp 5
4604 : be 60, sf 30, el 5, sp 5
4605 : be 60, sf 20, nm 10, ashsp 10

Fagetum dealpinum superiora
5601 : be 50, sf 10, sp 10, el 10, ashsp 15, yew 5
5602 : be 45, sf 25, el 5, sp 5, ashsp 10, sl 5, yew 5
5603 : be 55, sf 20, sp 5, el 5, ashsp 10, nm 5
5604 : be 40, sf 30, sp 10, el 10, ashsp 5
5605 : be 60, sf 10, sp 10, el 10, sm 5, ashsp 5
5606 : be 50, sf 20, sm 10, se 5, sp 5, el 5, ashsp 5

Fageto-Piceetum inferiora
6601 : be 40, ns 20, sf 10, el 10, sp 5, ba 5, ashsp 10
6602 : be 40, ns 20, sf 10, el 10, ashsp 10, sm 5, ba 5
6603 : be 35, ns 20, sf 20, el 10, sm 5, ashsp 5, ba 5

Fageto-Piceetum superiora
7601 : ns 70, el 10, ashsp 10, ba 10
7602 : ns 70, el 20, ashsp 10
7603 : ns 70, el 10, ashsp 15, ba 5

Pineto-Laricetum inferiora
6611 : el 50, sp 30, ashsp 10, ba 10

Pineto-Laricetum superiora
7611 : el 40, ns 30, ashsp 10, ba 10, sp 10

Mughetum calcicolum
8601 : mp 80, ashsp 5, cb 5, ba 5, sr 5

Oligotrophic (acidic) hydric (waterlogged and wet) order of forest type groups "a"

Betuleto-Quercetum
001 : oag 50, bsp 30, sa 20
002 : oag 25, bsp 30, sa 45
003 : oag 65, bsp 20, sa 15

Betuleto-Alnetum
011 : sa 80, bsp 20
012 : ga 35, sa 15, bsp 25, ns 15, sp 5, wi 5

Abieto-Piceetum
021 : ns 60, sf 35, ba 5
022 : ns 65, sf 30, ba 5
023 : ns 70, sf 10, sp 10, bsp 10

Pinetum ledosum
031 : mp 60, sp 30, bsp 10

Eutrophic nitrophilous hydric (waterlogged and wet) order of forest type groups "c"

Fraxineto-Alnetum
901 : sa 80, eb 5, ae+nla 15

Alnetum incanae
911 : ga 80, ns 10, eb 5, wi 5

Saliceto-Alnetum
921 : sa 40, wpo 10, wi 40, eb 10
922 : wi 40, wpo 20, sa 30, eb 10
923 : wi 40, sa 30, wpo 30
924 : wi 45, sa 35, wpo 20
925 : wi 45, sa 25, wpo 30

Querceto-Fraxinetum
931 : eo 70, nla 20, eb 5, wpo 5
932 : eo 80, nla 20

Ulmeto-Fraxinetum populeum
941 : fe 35, wpo 20, nla 20, eo 20, eb 5
942 : fe 40, wpo 20, nla 20, eo 20
943 : fe 40, wpo 15, nla 25, eo 20

Ulmeto-Fraxinetum carpineum
951 : fe 40, eo 20, nla 20, hb 5, fm 5, eb 5, sl 5
952 : fe 40, eo 20, nla 20, sl 5, hb 10, fm 5
953 : fe 40, eo 20, nla 20, hb 10, fm 10
954 : fe 35, eo 25, nla 15, hb 15, fm 10

Ulmetum
961 : fe 80, fm 10, hb 5, nla 5

Explanation of the abbreviations

sp	Scotch pine	*Pinus sylvestris* L.
sf	silver fir	*Abies alba* Mill
mp	mountain pine	*Pinus mugo* Turra subsp. *pumilio*
cp	cedar pain	*Pinus cembra* L.
ns	Norway (common) spruce	*Picea abies* (L.) Karst.
el	European larch	*Larix decidua* Mill. (Haenke)
yew	yew	*Taxus baccata* L.
be	beech	*Fagus sylvatica* L.
bsp	birch sp.	*Betula* L. sp.
cb	Carpathian birch	*Betula pubescens* ssp. *carpatica* (Kit. ex Willd.) Aschers. et Graebn
asp	ash sp.	*Sorbus torminalis* (L.) Crantz
se	Scotch elm	*Ulmus glabra* Huds., syn. *Ulmus montana* Stock.
fe	field elm	*Ulmus minor* Mill., syn. *Ulmus campestris* L.
to	European Turkey oak	*Quercus cerris* L.
bch	bird cherry-tree	*Cerasus avium* (L.) Moench
eb	European bird cherry	*Padus avium* Mill., syn. *Prunus padus* L.
oag	oaks agg.	*Quercus* agg.
so	durmast oak, sessile oak	*Quercus petraea* (Matt.) Liebl.
eo	English (common) oak	*Quercus robur* L.
puo	pubescent oak	*Quercus pubescens* Willd.
poo	polycarpic oak	*Quercus polycarpa* Schur
do	dalechampic oak	*Quercus dalechampii* Ten
vo	live oak (virgiliana)	*Quercus virgiliana* Ten
cch	dog wood, cornelian cherry	*Cornus mas* L.
hb	hard beam, common hornbeam	*Carpinus betulus* L.
sa	sticky alder	*Alnus glutinosa* (L.) Gaertn.
ga	grey alder	*Alnus incana* (L.) Moench
ba	rowan, bird ash	*Sorbus aucuparia*
ae	European ash	*Fraxinus excelsior* L.
nla	narrow leaved ash	*Fraxinus angustifolia*
sm	sycamore maple	*Acer pseudoplatanus* L.
nm	Norway maple	*Acer platanoides* L.
fm	field maple, hedge	maple *Acer campestre* L.
sl	small leaved lime	*Tilia cordata* Mill.
ll	large leaved lime	*Tilia platyphyllos* Scop.
chsp	cherry sp.	*Cerasus mahaleb* (L.) Mill.
ashsp	ash sp.	*Sorbus aria* (L.) Crantz
ea	European aspen	*Populus tremula* L.
sr	stone ribes	*Ribes petraeum* Wulfen
wsp	willow sp. *Salix*	*caprea* L.
wpo	white poplar	*Populus alba* L.
wi	willows	*Salix* L. sp.
Siw	silesien willow	*Salix silesiaca* Willd.

Discussion

Species composition of the forests in Slovakia

The first concise data set on the species composition of the Slovak forests was obtained from the results of a comprehensive survey of their natural conditions carried out from 1950 to 1955. The general site survey was in 1956 followed by a detailed typological survey. The basic mapping unit used in the typological survey of Slovak forests was forest type – associated with the original geobiocoenosis and all modified geobiocoenoses derived from it, as well as its succession phases (Zlatník, 1975). For all Slovak forest types, apart from their characterization, also the target tree species composition has been proposed (Hančinský, 1972). The target species composition reflects the species composition in the stand model of the concerned management group of mature stand at felling age. As stated by Hančinský (1972), the broad proposal of target species composition is in principle a biological-commercial concept, drafted to satisfy economic requirements of forest management and, consequently, taking into account the biologically determined and commercially preferred tree species. The major drawback of such a design was the fact that it was meant to be applied on the corresponding forest types of all forest categories, irrespective of their specific differences. Peculiar requirements given on the species composition of protection forests category and special purpose forests category (in particular those situated in nature reserves and national parks) were completely ignored.

The main scientific disadvantage of the proposal presented by Hančinský (1972) is that it actually doesn't comply with the definition of a forest type. The target species composition of a managed geobiocoenosis was simply applied to the original geobiocoenosis and also to the other geobiocoenoses at the site derived from the original by human influence as well as to the variety of succession phases of both original and changed geobiocoenoses.

Attempt to remove this shortcoming (at least partially) was made in 1974 by a research team of several scientists (Faith et al., 1974). They proposed the target species composition of production forests for forest type groups in which spruce, fir and beech were meant to be the dominant trees. At the same time, the team emphasised the need to design the target species composition for the typological units of protection forests and special purpose forests.

Nevertheless, in Slovakia the economically oriented approach has in general been maintained up to present in management of forest types and of management groups of forest types. The proposed target composition has a great practical significance in forest management planning (forestation, tending and thinning practical measures, silviculture, forest protection and regeneration).

Species composition has a crucial role in dealing with the issue of ecological stability of forest ecosystems. The highest degree of ecological stability is observed in forest stands dominated by autochthonous tree species with natural density and age structure. Species distribution in the post-glacial period was primarily influenced by local climatic and soil conditions at individual sites, ecological requirements of the species, natural competition and selection, together with the general environmental conditions in living components of forest ecosystems according to the Schmid's vegetation belts (Zlatník, 1978).

At present, is air pollution the most significant external factor affecting the forests. In forest stands dominated by non-autochthonous tree species, attenuated by air pollution (especially in spruce monocultures) the risk of pest attack is increasing; sometimes also promoted by inappropriate forest management (e.g. improper tending practices). Restoration of ecological stability of forest ecosystems has become the major problem in forest science at the end of the 20th century.

Ecological stability of forest ecosystems

Ecological stability (ecological dynamic balance) is defined as the capability of an ecosystem to resist changes affecting its condition through a range of stress factors (this feature is defined as **resistance**) and, after the threat of stressors has been terminated, to restore its original dynamic balance or its course of development by means of its own internal mechanisms (defined as **resilience** or flexibility); (according to Vološčuk and Míchal, 1991; Vološčuk, 2000).

Ecosystem's stability depends on the speed of self-restoration and degree of deviation from its original status. In accord with this definition, the ecological stability is one of the ecosystem's capabilities to comply with agents threatening its original balance. Individual succession phases have varying proportions of resistance and resilience. If we focus on the resistance, we will deal with seeking equilibrium between the functions and structures in the ecosystem, and optimisation of the system by minimizing the risk of their fluctuation.

If we mean the resilience, we will try to find optimisation of several possible conditions in order to make the ecosystem capable to adapt itself to a variety of unpredictable stimuli. In forest ecosystems subjected to human use (especially in the category of production forests) the limits of tolerable environmental load are at present a problem of noticeable scientific and practical significance.

In practical management of human-used forests, the resistance, determined by strict keeping to the structure typical for virgin forests, is not the target objective. On the contrary, more emphasis should be put on the flexible resilience, connected with enhancing the ecosystem's capabilities to develop into desirable and scientifically determined condition (e.g. by means of tending measures). Young forest ecosystems have higher degrees of flexible resilience.

Choice of criteria needed for assessment of ecological stability depends on monitoring of the stressor or the group of stressors. One of the main indicators of a change in the ecological stability is the change in the species composition caused by direct introduction of non-autochthonous alien species, or their spontaneous expansion. Other indicators include reduction of organic biomass and minerals that are vital for the ecosystem, presence of fertilization and pollutants negatively affecting the ecosystem processes (airborne pollutants, soil and water contamination, radiation, excessive noise level, etc.).

From the above-mentioned facts it is evident that the reaching of the target ecological stability in human-used ecosystems (production forests) will depend on input of supplementary energy, necessary to invest by humans into inorganic ecotopes (soil, solar energy and precipitation). There is, on the other hand, no need to provide supplementary energy to natural self-regulated ecosystems with an appropriate feedback, which we actually don't want to change or disrupt. Such ecosystems, however, require protection against anthropic damage ensured by means of adaptability-oriented management.

Ecological stabilization may be sophisticated if we deal with internal relationships between living organisms and their environment and between the organisms themselves in conditions of categories of protection forests and special purpose forests. In these forests, any substantial biomass removal (planned felling) should be avoided and pollution prevented, so the stabilisation is only based on self-directed attributes and capacities of the ecosystem components. In the ecosystems of protective forests and special purpose forests, the process is based on mechanisms of self-regulation.

The original species distribution, resulting from the natural succession in the postglacial period, is the main criteria for assessment of ecological stability of protection and special purpose forests. The major role of these stands is their ecological and environmental influence along with other specific functions assigned for human benefit. The timber production in these forests can only be subsidiary. Natural forest ecosystems have a high degree of ecological stability.

As for the management in protection and special purpose forests in nature reserves and national parks, the production function must not be the priority; on contrary, the ecological and environmental aspect must be given the highest and only preference and, consequently, full respect. Measures of regulation of species composition must be applied in accord with the above mentioned priority functions – in order to restore and conserve the natural (origin) species distribution, along with the multi-layered and uneven age structure.

Ecological stability assessment is in principle associated with assessment of synecological stability determined on the background of natural competitions between the tree species, their health and layer structure, i.e. their exploitation of the available space for energy and substances uptake. At the same time, we have to consider the degree of static stability depending on the crown canopy and stem slenderness ratio in dominant and co-dominant trees – the upper and middle stand layers. Assessment of the ecological stability based on these characteristics can only be applied to certain specifically defined succession stages of natural forests, allowing also their mutual comparison. It is not correct to compare between the calculated degrees of ecological stability belonging to different succession stages.

The practical methodology of calculating the degree of ecological stability for mature (climax) forest ecosystems was elaborated by VOLOŠČUK (2000, 2001).

The calculation is based on similarity between the current and target species composition, the sanitary coefficient, the stand layering coefficient (the degree of divergence between the current and the original layer structure), the slenderness ratio (*h/d* ratio), the canopy coefficient and assessment of natural regeneration potential. One of the crucial variables entering the calculation is the degree of divergence between the current species distribution in the studied stands and the original species distribution in natural forest type geobiocoenoses. The percentage of the existing species composition in the forest types of a particular stand is calculated from the data collected on the surveyed research sites.

Data on nature-oriented composition, corresponding to the original proportion of the species in geobiocoenoses in natural forest types may be used in research works, in establishment of principles for forest management in protected areas and forest management of forests belonging to protection and special purpose categories.

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Zastúpenie drevín v prírodných geobiocenózach lesných typov Slovenska

Súhrn

Autor odvodil zastúpenie drevín pre pôvodné geobiocenózy lesných typov Slovenska na základe vlastných experimentálnych skúseností z typologického prieskumu lesov Slovenska v rokoch 1958–1974 a na základe publikovaných literárnych údajov. Číslovanie lesných typov je uvedené podľa HANČINSKÉHO (1972). Názvy skupín lesných typov sú podľa ZLATNÍKA (1956). Autor v práci využil poznatky z riešenia výskumnej úlohy o chorológii domácej dendroflóry v rokoch 1995–1996 na Ústave ekológie lesa SAV vo Zvolene. Naliehavosť potreby vypracovania návrhu zastúpenia drevín v pôvodných geobiocenózach lesných typov Slovenska vyplynula z riešenia grantovej úlohy VEGA 1/0600/03 na Katedre aplikovanej

ekológie Fakulty ekológie a environmentalistiky TU vo Zvolene, zameranej, okrem iného, na výskum ekologickej stability lesných ekosystémov, osobitne prírodných rezervácií a národných prírodných rezervácií CHKO Štiavnické vrchy. Ekologická stabilita je schopnosť ekosystému odolávať zmene svojho stavu vplyvom stresových faktorov a po ukončení pôsobenia stresových faktorov vrátiť sa pomocou vlastných vnútorných mechanizmov k dynamickej rovnováhe, alebo k svojmu normálnemu vývojovému smeru. Významnou súčasťou metodiky stanovenia ekologickej stability je určenie aproximácie súčasného a pôvodného drevinového zloženia lesného ekosystému, stanovenie sanitárneho koeficienta (zdravotného stavu), koeficienta vrstevnatosti (odchýlenia súčasnej vrstevnatosti od pôvodnej), štíhlostného koeficienta (pomer výšky k hrúbke stromu), koeficienta korunovosti (pomer dĺžky koruny k celkovej výške stromu) a posúdenie schopnosti prirodzenej reprodukcie drevín. Drevinové zloženie má teda kľúčovú úlohu v stanovení synekologickej i statickej stability lesného ekosystému.

Predložený návrh pôvodného zastúpenia drevín v prírodných geobiocenózach lesných typov Slovenska možno využiť pri ekologickom výskume lesných ekosystémov, pri stanovení ich ekologickej stability, pri starostlivosti o ekosystémy chránených území a zariaďovaní ochranných lesov a lesov osobitného určenia.

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Short communication

Threatened tree and shrub species in Hungary

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Abstract

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Red Lists of the Hungarian dendroflora were compiled two: in 1989 and in 2003. They have also been provided with information about the threat levels of the Hungarian dendrotaxa and the endangering factors as well. The threat levels and categories were determined on the background of the recommendations by the IUCN. During the last fifteen years, 50 species of the dendroflora have become endangered; on the contrary, the levels of threat of 5 taxa have increased, and only one species could have been cancelled from the Red List. At present, there are 86 endangered tree and shrub species in Hungary. There are 21 stress factors endangering the Hungarian dendrotaxa, from which the proportion of habitat endangering factors is 76.8% and factors directly endangering the plants make 23.2%. This paper presents the whole list of the currently endangered species with the level of threat and the sources of danger, and a list of species possibly endangered in the near future. These lists provide an opportunity to follow the changing levels of threat in the future.

Keywords

Red List, dendroflora, Hungary, endangering factors, threat category

Introduction

Red Lists and Red Data Books concerning either distribution areas or taxonomic groups have been compiled over the whole Earth since the mid-sixties. The purpose of these documents was to give a survey of the level of threat as well as to draw the attention of conservationists to the endangered species. The Red Book of the Hungarian Flora and Fauna was published in 1989 (RAKONCZAY ed., 1989), and the endangered tree and shrub species (BARTHA, 1991, 1992) were also given account of in a separate book.

The threat categories applied in these books are based on the international recommendations, but also certain national characteristics were considered. In 1994, there was a revision by the World Conservation Union Species Survival Commission (IUCN, 1994) with the aim to standardize the categories. The existing terms these were revised and the criteria were completed with quantitative characteristics. On the basis of the new categories, two global scale lists were assembled: The Red List of Threatened Plants (WALTERS, GILLETT, 1998) and The World List of Threatened Trees (OLDFIELD et al., 1998). The review of the threat categories and the criteria has been completed (IUCN/SCC Criteria Review Working Group, 1999) and the recommendations for their adaptation at regional and national levels have been prepared (GÄRDENFORS et al., 1999) recently. The present paper was drafted with the focus of a new aspect. As the extinction of a species is considered to be a stochastic process, classification into the categories corresponds to estimation of the extinction risk. The threat category corresponds to the probability of the extinction of the species in the given area.

Material and methods

The applied threat categories (IUCN, 1994 modified by IUCN/SCC Criteria Review Working Group, 1999) are:

Extinct (EX): A taxon is extinct if there is no reasonable doubt about whether the last individual has already died.

Regionally extinct (RE): A taxon is regionally extinct if there is no reasonable doubt about whether the last individual potentially capable of reproduction has died or disappeared from the region.

Extinct in the wild (EW): A taxon is extinct in the wild if it is only confirmed to survive in cultivation, in captivity or as a naturalised population (or populations) outside its original distribution range. A taxon is supposed to be extinct in the wild if exhaustive, appropriately timed (diurnal, seasonal, annual) surveys carried out in formerly confirmed or expected habitats within its historic range have failed to record even one individual. The timing of such surveys should correspond to the taxon's life cycle and life form.

Critically endangered (CR): A taxon is critically endangered if it is facing an extremely high risk of extinction in the wild in the immediate future.

Endangered (EN): A taxon is endangered if it is not critically endangered but is facing a very high risk of extinction in the wild in the near future.

Vulnerable (VU): A taxon is vulnerable if it is not critically endangered or endangered but is facing a high risk of extinction in the wild in the medium-term future.

Lower risk (LR): A taxon has lower risk status if – according to the evaluation it does not satisfy the criteria for any of the categories critically endangered, endangered or vulnerable. Taxa included in the lower risk category can be specified into three subcategories:

- **Conservation dependent** (CD): A taxon focused by a continual taxon-specific or habitat-specific conservation programme. To stop the care would result in the taxon belonging to one of the above described threatened categories within five years.
- **Near threatened** (NT): A taxon not qualified as conservation dependent, but close to being qualified as vulnerable.
- **Least concern** (LC): A taxon which is not qualified as conservation dependent or near threatened.

Data deficient (DD): A taxon for which there is lacking appropriate information for a direct or indirect assessment of its extinction risk based on its distribution and/or population status. A taxon in this category may be well studied, and its biology well known, but appropriate information on abundance and/or distribution is lacking.

Not evaluated (NE): A taxon is not evaluated when it has not yet been assessed against the criteria.

The recommendation of the IUCN/SCC Criteria Review Working Group (1999) suggests to cancel the category 'Conservation dependent'. At the same time, GÄRDENFORS et al. (1999), suggested to append the category 'Regionally extinct'.

The classification of a species into the threatened categories (CD, EN, VU) is carried out using quantifying criteria (ranging from A to E). Each taxon must be tested with all the criteria, but it's enough to satisfy a single criterion to be assigned to the appropriate category. The list of the testing criteria is the following (IUCN, 1994):

A. Population reduction in forms 1. or 2.:
   1. An observed, estimated, deduced or suspected reduction by at least 80% (CR), 50% (EN), 20% (VU) within the last 10 years or three generations. The specifying characteristics are the following (it is sufficient to comply with one of them):
      (a) Direct observation
      (b) An index of abundance of the taxon
      (c) A decline in area of occupancy, extent of occurrence and/or quality of habitat

    (d) Actual or potential levels of exploitation
    (e) The effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites.
  2. A reduction by at least 80% (CR), 50% (EN), 20% (VU) expected or estimated to be met within the next ten years or three generations, based on (and specifying) any of (b), (c), (d) or (e) above.

B. Extent of occurrence area estimated to be less than 100 km^2 (CR), 5,000 km^2 (EN), 20,000 km^2 (VU) or area of occupancy estimated to be less than 10 km^2 (CR), 500 km^2 (EN), 2,000 km^2 (VU) and meeting (estimated) at least two of the following criteria:
  1. Severely fragmented or known to exist at only a single location
  2. Proceeding decline – observed, deduced or supposed, according to any of the following items:
    (a) Extent of occurrence
    (b) Area of occupancy
    (c) Area, extent and/or quality of habitat
    (d) Number of locations or subpopulations
    (e) Number of mature individuals.
  3. Extreme fluctuations concerning any of the following criteria:
    (a) Extent of occurrence
    (b) Area of occupancy
    (c) Number of locations or subpopulations
    (d) Number of mature individuals.

C. Population number estimated to be less than 250 (CR), 2,500 (EN), 10,000 (VU) mature individuals and moreover compliance with 1. or 2.:
  1. A proceeding continual decline estimated to be at least of 25% (CR), 20% (EN), 10% (VU) within 3 years or one generation, whichever is longer or
  2. A continual decline, observed, suspected, or deduced, in numbers of mature individuals and population structure in the form of:
    (a) Severely fragmented (i.e. no subpopulation estimated to contain more than 50 (CR), 250 (EN), 1,000 (VU) mature individuals)
    (b) All individuals are in a single subpopulation.

D. Population number estimated to be less than 50 (CR), 250 (EN), 1,000 (VU) mature individuals.

E. Quantitative analysis showing the probability of extinction in the wild resulted at least at 50% within 10 years or 3 generations (CR), 20% within 20 years or 5 generations (EN), 10% within 100 years (VU).

Regional and national Red Lists must contain the proportion of the regional (national) population, which means the percentage of the individuals of the taxon living in a given place – in this case in Hungary, from the global population – the total number of individuals of the taxon living in the wild worldwide. After the recommendations by Gärdenfors et al. (1999) there are five categories based on the ratio of the regional (national) population to the global:

I. < 2.5%
II. 2.6–10.0%
III. 10.1–25.0%
IV. 25.1–50.1%
V. > 50.1%

In the Red List of the Hungarian tree and shrub species are specified the following features (See Appendix):

- The threatened categories applied at national level – Hungary (**HU 2003**),
- Current ratio of the national (regional) to the global population (**nP/gP**),
- The threatened categories of the former Red Data Book (Rakonczay ed., 1989) (**HU 1988**),
- Sources of danger, endangering factors.

Sources of danger, endangering factors

A. Factors endangering the habitats
I. Changes in the cultivation methods
  1. Mining, raw material exploitation
  2. Grassland ploughing
  3. Orchard, vineyard planting
  4. Afforestation
  5. Land fragmentation, road construction.
II. Changes in the habitat conditions
  6. Drainage, turf-cutting
  7. Clear cutting, rough forest management methods

8. Intensive grassland management, over sewing
9. Karstwater, groundwater lifting
10. Spontaneous forestation, over scrubbing
11. Forestation with alien species
12. Invasion of alien weeds
13. Overpopulated game-stock.

III. Mechanical damage to the habitat and vegetation
14. Intensive tourism
15. Military activity
16. Trampling caused by motocross, hang-glider or mountain bike.

B. Factors endangering the plants directly
17. Flower picking, plant collecting, trade
18. Introgressive hybridization, gene pool erosion
19. Reproduction, regeneration problems
20. Burning, fire
21. Shrub clearing.

Results

Comparison between the Red Lists of the Hungarian dendroflora assembled in 1988 and in 2003 enables us to obtain an overview of the changes, which have happened in the last fifteen years (Table 1).

In Table 1 we can see that in 1988 belonged 32 of the Hungarian tree and shrub species in the category 'Not evaluated', 45 species in 'Vulnerable', 8 in 'Endangered' and 4 in 'Critically endangered', 4 species were 'Regionally extinct'. On the other hand, in 2003 only 7 species were classified in the category 'Data deficient', but 45 species were 'Vulnerable', 25 'Endangered', 11 'Critically endangered', and 5 species 'Regionally extinct'. We can also evaluate the changes and trends within the individual categories over the last fifteen years. Table 2 shows the distribution of 21 endangering factors. In Table 3 are listed the species, which at

Table 1. Changes in the threat levels of the Hungarian dendroflora between 1988 and 2003

		2003					Total in 1988
		DD	VU	EN	CR	RE	
1988	NE	1	22	4	5	–	32
	VU	6	21	13	3	2	45
	EN	–	2	5	1	–	8
	CR	–	–	2	2	–	4
	RE	–	–	1	–	3	4
Total in 2003		7	45	25	11	5	

Table 2. Distributions of the factors endangering the Hungarian dendroflora

Sources of danger, endangering factors	Percentage
A. Factors endangering the habitats	76.8%
I. Changes in the cultivation methods	13.3%
II. Changes in the circumstances of forest sites	59.4%
III. Mechanical damage to the habitat and vegetation	4.1%
B. Factors endangering the plants directly	23.2%

Table 3. Pink List: Tree and shrub taxa in Hungary having high probability to be endangered in near future

Alnus incana (L.) Mönch	NT	*Rosa agrestis* Savi	NT
Calluna vulgaris (L.) Hull.	LC	*Rosa caesia* Sm. in Sow.	NT
Castanea sativa Mill.	NT	*Sambucus racemosa* L.	NT
Cerasus fruticosa Pall.	LC	*Ulmus glabra* Huds.	NT
Cerasus mahaleb (L.) Mill.	LC	*Ulmus minor* Mill.	NT
Colutea arborescens L.	LC	*Ulmus procera* Salisb.	LC
Lonicera xylosteum L.	LC	*Vaccinium myrtillus* L.	LC
Padus avium (L.) Miller	LC	*Viscum album* L.	
		subsp. *abietis* Abrom.	NT
Ribes uva-crispa L.	LC	subsp. *austriacum* Vollm.	LC

present are not endangered, but will probably endangered in near future.

Discussion

Comparing between the data from the years 2003 and 1988 (Rakonczay ed. 1989, Bartha 1991), we can identify changes in the threat levels to the Hungarian tree and shrub species (dendroflora). At present *Andromeda polifolia*, *Ostrya carpinifolia*, *Ribes petraeum*, *Rosa stylosa*, *Spiraea crenata* can be considered extinct from the Hungarian flora and other 11 species are in the category Critically Endangered. 25 taxa are endangered, further 45 taxa are considered vulnerable. There are 7 species whose level of threat is unknown. Compared to 86 in the year 2003, in 1988 were only 61 taxa of the 188 Hungarian tree and shrub species endangered, which means a 40% growth over the last fifteen years. Some of the 32 taxa added to the Red List in 2003 might already have been endangered in 1988, but our knowledge about them was not sufficient. Only the floristic surveys in the last years have revealed the existing threat level to these species. *Quercus frainetto* is the only species that could have been removed from the list, as its stands have increased and become more stable. Analyzing Tables 1, 4 we can see that 32 species (on the diagonal) had the same status 1988 and in 2003, that means that their level of threat has not been changed. In the case of 50 species (over the diagonal), of which 2 species (*Ribes petraeum* and *Rosa stylosa)* have been extinct from Hungary, the levels of threat have increased. On the contrary, the threat levels of only five species have been decreased. *Salix nigricans* was considered extinct at the end of the eighteenth century, but in the recent years, a new locality was found. Four other species – *Clematis alpina*, *Spiraea salicifolia*, *Ribes nigrum, Vaccinium oxycoccos* show an improved status – not due to the active management but to the finding of new localities. In Table 4 we can see that there are 21 factors endangering the tree and shrub species. Factors endangering the habitats are three times more frequent than the factors endangering the plants directly (Table 2). Factors causing changes to the cultivation methods have the strongest impact; their percentage is 13.3%. The proportion of factors causing changes in the habitat conditions is the highest, nearly 60%. On the basis of these figures and the new research results in botany, a prediction for near future can be submitted. There are 18 taxa currently not endangered but having a high probability to become endangered soon (Table 3). Eight of them perhaps immediately, other 10 somewhat later.

Conclusion

Analyzing the results it can be stated, that in the last one and a half decades the number of endangered tree and shrub species has increased by 40% in Hungary. While in 1988, 61 taxa were classed into any of the categories, in the year 2003, 86. The level of threat has increased in case of the greater part of the endangered species (approximately 50 species). Appraising the endangering factors it was found, that factors being connected with changes in the circumstances of forest sites had the largest effects in these processes.

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Appendix

Table 4. Threatened tree and shrub species in Hungary, and their endangering factors

Taxa	HU 2003	nP/ gP	HU 1988	Endangering factors
GYMNOSPERMAE				
Ephedra distachya L.	EN	I	VU	1–4, 8, 10, 12, 15, 17, 19, 20
Taxus baccata L.	EN	II	VU	11, 13, 17, 19
ANGIOSPERMAE				
Acer acuminatilobum J. Papp	CR	V	NE	19
Alnus viridis (Chaix in Vill.) Dc.	VU	I	VU	1, 7, 10, 15, 21
Amelanchier ovalis Medik.	VU	I	VU	1, 10, 11, 13, 15, 20
Amygdalus nana L.	EN	I	VU	1, 10, 11, 13, 15, 17, 20, 21
Andromeda polifolia L.	RE		RE	(6)
Betula pubescens Ehrh.	EN	I	NE	4, 6, 7, 9, 10, 18
Carpinus orientalis Mill.	EN	I	VU	13, 19
Clematis alpina (L.) Mill.	VU	II	EN	7, 11, 17, 21
Cornus sanguinea L. subsp. *hungarica* (Kárp.) Soó	DD	?	VU	?
Coronilla emerus L.	VU	I	VU	1, 7, 13, 21
Cotoneaster integerrimus Medik.	VU	I	VU	7, 11, 13
Cotoneaster niger (WAHLBG.) Fries	VU	I	NE	7, 11, 13
Cotoneaster tomentosus (AIT.) Lindley	VU	II	NE	7, 11, 13
Crataegus monogyna Jacq. subsp. *curvisepala* (Lindm.) Soó	DD	?	VU	?
Crataegus nigra W. et K.	EN	II	EN	7, 11, 13, 18, 21
Daphne cneorum L.				
subsp. *cneorum*	VU	II	VU	7, 10, 11, 12, 13, 14, 16, 17, 20
subsp. *arbusculoides* (Tuzson) Soó	VU	V		
Daphne laureola L.	VU	I	VU	1, 7, 11, 13

Continued Table 4

Taxa	HU 2003	nP/ gP	HU 1988	Endangering factors
Daphne mezereum L.	VU	I	NE	7, 11, 17
Hippophaë rhamnoides L.	CR	I	CR	1, 6, 10, 11, 15
Lonicera caprifolium L.	VU	I	NE	7, 11, 14, 17, 21
Lonicera nigra L.	CR	I	VU	1, 7, 13
Malus dasyphylla Borkh.	VU	?	NE	7, 11, 18
Myricaria germanica (L.) Desv.	CR	I	VU	1, 6, 10
Ostrya carpinifolia Scop.	RE		RE	(3, 5, 7) ?
Populus nigra L.	EN	I	NE	6, 7, 11, 18
Pyrus magyarica Terpó	CR	V	CR	5, 18, 19
Pyrus nivalis Jacq.	EN	I	EN	3, 5, 18, 19, 20
Pyrus austriaca Kern.	EN	V?	VU	3, 5, 19
Rhamnus saxatilis Jacq.	EN	I	VU	4, 7, 10, 11, 18, 21
Ribes alpinum L.	EN	I	EN	1, 7, 13
Ribes nigrum L.	EN	I	CR	6, 11
Ribes petraeum Wulf. in Jacq.	RE		VU	(7)
Ribes rubrum L. agg.	VU	I	VU	7, 11, 12
Rosa arvensis Huds.	VU	I	NE	4, 11, 12, 21
Rosa gizellae Borb.	VU	I	NE	21
Rosa glauca Pourret	DD	I	NE	21
Rosa hungarica (Borb.) Degen	VU	II	NE	2, 7, 11, 21
Rosa inodora Fr. em. Klást.	VU	I	NE	7, 11, 21
Rosa kmetiana Borb.	CR	I	NE	21
Rosa livescens Bess.	VU	I	NE	2, 3, 4, 5, 10, 16, 21
Rosa pendulina L.	VU	I	VU	7, 11, 21
Rosa polyacantha (Borb.) Degen	VU	I	NE	2, 7, 11, 21
Rosa scabriuscula Sm. em. H. Br.	CR	I	NE	7, 21
Rosa sherardi Davies	CR	I	NE	7, 11, 21
Rosa stylosa Desv.	RE?	I	VU	
Rosa szaboi (Borb.) Facsar	EN	I	NE	7, 21
Rosa tomentosa Sm.	VU	I	NE	7, 11, 21
Rubus senticosus Koehler ex W. et Gr.	DD	?	VU	?
Ruscus aculeatus L.	VU	I	NE	7, 11, 17
Ruscus hypoglossum L.	VU	I	VU	7, 11, 13, 17
Salix aurita L.	VU	I	VU	6, 7, 9, 18, 21
Salix elaeagnos Scop.	EN	I	NE	1, 6, 21
Salix nigricans Sm.	EN	I	RE	5, 6, 10
Salix pentandra L.	EN	I	EN	6, 9, 11, 21
Sorbus aria (L.) Cr.	VU	I	NE	1, 7, 11, 18

Continued Table 4

Taxa	HU 2003	nP/ gP	HU 1988	Endangering factors
Sorbus domestica L.	VU	II	NE	3, 5, 7, 11
Sorbus graeca (Spach) Lodd.	VU	II	NE	1, 7, 11, 18
Sorbus hazslinszkyana (Soó) Májovský	CR	I	EN	7, 18, 19
Transition between sections *Aria*				
Sorbus buekkensis Soó em. Kárp.	VU	V	NE	7, 11, 18
Sorbus danubialis (Jáv.) Kárp.	VU	V	NE	7, 11, 18
Sorbus javorkae (Soó) Kárp.	VU	V	NE	7, 11, 18
Sorbus pannonica Kárp.	VU	V	NE	7, 11, 18
Sorbus sooi (Máthé) Kárp.	VU	V	NE	7, 11, 18
Sorbus aria section x *S. torminalis* microspecies				
Sorbus adami Kárp.	EN	V	VU	7, 11
Sorbus andreanszkyana Kárp.	DD	V	VU	7, 11
Sorbus bakonyensis Jáv. em. Kárp.	EN	V	VU	7, 11
Sorbus balatonica Kárp.	VU	V	VU	7, 11
Sorbus barthae Kárp.	EN	V	VU	7, 11
Sorbus borosiana Kárp.	CR	V	VU	7, 11, 13, 19
Sorbus decipientiformis Kárp.	DD	V	VU	7, 11
Sorbus degenii Jáv.	VU	V	VU	7, 11
Sorbus eugenii-kelleri Kárp.	VU	V	VU	7, 11
Sorbus gáyeriana Kárp.	DD	V	VU	7, 11
Sorbus gerecseensis Boros et Kárp.	EN	V	VU	7, 11
Sorbus karpatii Boros	VU	V	VU	7, 11
Sorbus latissima Kárp.	EN	V	VU	7, 11
Sorbus pseudobakonyensis Kárp.	VU	V	VU	7, 11
Sorbus pseudolatifolia Boros	VU	V	VU	7, 11
Sorbus pseudosemiincisa Boros	EN	V	VU	7, 11
Sorbus pseudovertesensis Boros	VU	V	VU	7, 11
Sorbus redliana Kárp.	EN	V	VU	7, 11
Sorbus semiincisa Borb.	VU	V	VU	7, 11
Sorbus simonkaiana Kárp.	VU	V	VU	7, 11
Sorbus vertesensis Boros	VU	V	VU	7, 11
Sorbus x *rotundifolia* (Bechst.) Hedl.	CR	I	NE	7, 11
Spiraea crenata L.	RE		RE	(3, 4, 5, 11, 21)
Spiraea media Fr. Schm.	VU	I	NE	10, 11, 14, 13, 17, 21
Spiraea salicifolia L.	VU	I	EN	6, 7, 13, 21
Vaccinium oxycoccos L.	EN	I	CR	6
Vaccinium vitis-idaea L.	VU	I	VU	1, 7, 14
Vitis sylvestris C. C. Gmel.	EN	I	EN	6, 7, 11, 19, 21

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Ohrozené druhy stromov a krov Maďarska

Súhrn

V rokoch 1989 až 2003 sa pripravil červený zoznam maďarskej dendroflóry. Tento zoznam obsahuje ohrozené taxóny spolu so zdrojmi ohrozenia. Posudzovanie miery ohrozenia a následné zaradenie taxónov do ohrozovaných skupín sa vykonalo v súlade s návrhmi IUCN. Za posledných 15 rokov pribudlo 50 nových ohrozených druhov, u 5 druhov sa miera ohrozenia znížila, na druhej strane, len v prípade jedného taxónu sa zrušil zápis v červenom zozname. V súčasnosti je v Maďarsku medzi ohrozenými taxónmi vedených 86 druhov stromov a krov. Z 21 činiteľov ohrozujúcich dreviny v Maďarsku 76,8 % priamo zasahuje ich biotopy. Podiel činiteľov priamo ohrozujúcich rastlinstvo je 23,2 %. V článku sa uvádza zoznam aj tých taxónov, ktoré sa v blízkej budúcnosti stanú ohrozenými, ďalej úplný zoznam doteraz ohrozených druhov i s mierou ohrozenia spolu so zdrojmi ohrozenia. Tieto zoznamy umožnia v budúcnosti sledovať zmeny miery ohrozenia.

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Personalia

The eighties birthday of Assoc. Professor Jan Patočka

On September 25, 2005, Assoc. Prof. Jan Patočka, DrSc. will celebrate his important anniversary – 80 years of age.

Assoc. Prof. Jan Patočka was born in South Bohemia, in the town of České Budějovice in a family of an opera singer. He attended Jirsik Gymnazium in České Budějovice, and then he studied at the Faculty of Natural Sciences of the Charles University in Prague. In 1948 he completed his doctorate (RNDr.) and in 1957 he received his Ph.D. In 1962 he accomplished his habilitation thesis in forest zoology and entomology at the Faculty of Forestry of the University of Forestry and Wood Sciences in Zvolen. In 1970 he successfully defended his scientific dissertation at the Faculty of Natural Sciences of the Comenius University in Bratislava.

After his studies, he began to work at the Research Institute of Forest Management in Banská Štiavnica (Central Slovakia). Later, the Institute has been removed to Zvolen. Since 1989, Assoc. Prof. Jan Patočka has been working at the Institute of Forest Ecology of the Slovak Academy of Sciences in Zvolen.

Beginning with 1970, Assoc. Prof. Patočka was discriminated and oppressed – due to the politic background of that time. He was immediately drawn off his post of Head of the Department. All the research projects in ecology of forest insects running under his guidance had been stopped. He was forbidden to contact foreign research institutions, he could not submit his papers for publication, and he could not teach at the university. In spite of the successful defending his dissertation, he could not be awarded with the DrSc. title, which he obtained no sooner than in 1990. Nevertheless, this long-term politic persecution did not stop him pursuing his intensive research work in the privacy.

Assoc. Prof. Patočka is the author of a great number of original scientific papers, especially on taxonomy, morphology and ecology of Lepidoptera. The author's bibliography has been published in other articles (KULFAN 1997, KULFAN et al., 2000; KULFAN, in print). Important are monographs on Lepidoptera associated with poplars (*Populus* spp.), oaks (*Quercus* spp.) and firs (*Abies alba*). In these works presents the author a comprehensive pattern of bionomy, ecology, distribution and importance of moths and their larvae. He was the first who elaborated the identification keys for Lepidoptera larvae feeding on these woody plants. He also published pioneer works on influence of food, biotope and climate on population dynamics of forest Lepidoptera. His research resulted also in practical outcomes for pest control in forest management. Naturally, his results have been applied with profit in both theoretic and applied forest research and management in several countries in Europe. This research was crucially important for progress in both general ecology (SCHWERDTFEGER, 1963, 1968, 1975) and forest protection (SCHWENKE, 1978). Assoc. Prof. Patočka has published a number of valuable data about the Lepidoptera species distribution. As the first, he recorded hundreds species in Slovakia or Central Europe. He is a co-author of description of three new species of Lepidoptera (*Scythris bengtssoni*, *Epinotia slovacica* and *Argyresthia tatrica*) and two other species were named after him (*Athrips patockai*, *Bryotropha patockai*). Assoc. Prof. Patočka is a world-wide recognised specialist in taxonomy of Lepidoptera larvae and pupae. He has published a lot of identification keys for pupae. The book in two volumes summarising the knowledge on the pupae of Central European Lepidoptera is appearing in this year (PATOČKA, TURČÁNI 2005a, 2005b).

On the occasion of his 80th birthday, we wish to Assoc. Prof. Patočka strong health and much success in his personal and private life.

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Book rewiew

Ogródy botaniczne w Polsce [Botanical gardens in Poland] by Alexander Łukasiewicz, Jerzy Puchalsky. Warszawa: ARW Arkadius Grzegorczyk i Fundacja “Homo et Planta“, 2002. 362 p.

The authors present an engaging survey aboutbotanical gardens, arboretums, dendrological gardens, gardens with medical plants and palm houses in Poland. The book is storiated with apposite full-coloured photographs. It is printed on glazed paper, with a stylish hard cover.

The Introduction, except of preliminary information about the work, provides a general map of accommodation of the individual subjects in concern. There are listed the following Botanical Gardens: Ogród Botaniczny Uniwersytetu Jagiellońskiego w Krakowie (Bogdan Zemanek); Ogród Botaniczny Uniwersytetu Wroclawskiego (Magdalena Mularczyk); Ogród Botaniczny Uniwersytetu Warszawskiego (Teresa Bielska); Ogród Botaniczny Uniwersytetu im. Adama Mickiewicza w Poznaniu (Alexander Łukasiewicz); Ogród Botaniczny Uni-wersytetu im. Marii Curie-Sklodowskiej w Lublinie (Kinga Misztal, Maciej Kwiatkowski); Ogród Botaniczny – Centrum Zachowania Różnorodności Biologicznej Polskiej Akademii Nauk w Warszawie (Jerzy Puchalsky, Wiesław Gawryś); Ogród Botaniczny w Łodzi (Janina Krzemińska-Freda); Ogród Botaniczny Leśnego Parku Kultury i Wypoczynku w Bydgoszczy (Karol Dąbrowski); Ogród Botaniczny Instytutu Hodowli i Aklimatyzacji Roślin w Bydgoszczy (Gabriela Majtkowska, Włodzimierz Majtkowski, Jan Schmidt, Grzegorz Żurek); Górski Ogród Botaniczny im. Mariana Raciborskiego w Zakopanem(Halina Piękoś-Mirkowa); Gołubieński Ogród Botaniczny (Zbigniew Butowski).

The list of the Arboretums, Specialized Gardens and Dendrological Parks: Arboretum Kórnickie (Władislaw Bugała); Arboretum SGGW w Rogowie (Jerzy Tumiłowicz); Arboretum w Wojslawicach. Filia Ogrodu Botanicznego Uniwersytetu Wrocławskiego (Hanna Greszczak-Nowak); Arboretum w Przelewicach (Łucja Swiłło); Arboretum i Zakład Fizjografii w Bolestraszycach (Jerzy Piórecki); Arboretum v Gołuchowie (Barbara Olejnik); Arboretum w Wirtach (Urszula Nawrocka-Grześkowiak); Ogród Dendrologczny Akademii Rolniczej im. Augusta Cieszkowskiego w Poznaniu (Władysław Danielowicz, Jacek Zatorsky); Arboretum Leśne w Zielonce (Marian Grodski); Arboretum w Glinnej (Jerzy Tumiłowicz); Arboretum Leśne im. Prof. Stefana Białoboka w Sycowie (Jarosław Sęktas); Leśne Arboretum Warmii i Mazur w Kudypach k. Olsztyna (Jerzy Tumiłowicz, Czesław Hołdyński, Witold Szumarski); Arboretum w Kopnej Górze (Krzysztof Łaziuk); Arboretum Bramy Morawskiej w Raciborzu (Jan Duda, Paweł Kojs, Aleksandra Rusin, Tomasz Rusin, Waldemar Szendera, Wiesław Włoch).

Gardens with medical plants: Ogród Roślin Leczniczych Instytutu Roślin i Przetworów Zielarskich w Plewiskach (Jan Kozłowski); Ogród Roślin Leczniczych Akademii Medycznej we Wrocławiu (Eugeniusz Kuźniewski, Anna Jezierska-Domaradzka); Ogród Roślin Leczniczych Katedry i Zakładu Farmakognozji Akademii Medycznej w Gdańsku (Wojciech Cisowski, Maria Zielińska-Stasiek, Jolanta Zarembska, Stefan Wilk).

Palm Houses: Palmiarnia Poznańska (Michal Śmiłowski, Zbigniew Wargowski), Palmiarnia Miejska w Gliwicach (MZUK Gliwice).

Each treated subject is provided with the following data: official name, address, year of the establishment, geographic coordinates, altitude, territorial district classification, area, estimated number of taxons, visiting hours, name of the Director, short historical review, ecological characteristics, description of plant collections and their allocation, information about public-profit and scientific outcome driven and further possible use of the subject.

The book provides an excellent survey about the above listed subjects through the whole territory of Poland. It is suitable for a wide spectre of readers, both in Poland and in abroad, equally laics and experts. It is incentive for establishing contacts for co-operation in the area as well as for commercial use. Well-arranged and comprehensive survey can also be very useful for the tourists – at choice and identification of their subjects of interest.

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Book

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Dissertation

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

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