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FOREST MANAGEMENT SYSTEMS AND REGENERATION OF FLOODPLAIN FOREST SITES

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Content

Conference objectives

Floodplain forests are ones of seriously endangered forest ecosystems. Coming to existence as an anthropogenic ecosystem they cannot survive in their present form without human intervention but may be on the other hand adversely affected by human activities.

The objective of the conference is to assess and analyze different management methods used in floodplain forests with respect to the fulfilment of certain functions in the Czech Republic and abroad, and to learn more about the most problematic stage in the creation of these forests – their regeneration.

I. BLOCK: FOREST MANAGEMENT SYSTEMS

FOREST MANAGEMENT SYSTEMS OF FLOODPLAIN FORESTS IN THE FOREST ENTERPRISE ŽIDLOCHOVICE (LZ LČR ŽIDLOCHOVICE)

Tomáš Blaha

Abstract
The paper deals with management in the floodplain forests on the Židlochovice Forest enterprise territory. The author gives a brief overview of the history of floodplain forests origin and silviculture, basic ecological and management conditions and the specificities of alluvial forests in the region. Artificial regeneration of pedunculate oak (*Quercus robur* L.) by sowing and planting, protection of artificial crops from game damage, fungal diseases and forest weeds are also described. The author characterizes tending (thinning, cleaning) in pedunculate oak stands as well.

Key words
pedunculate oak (*Quercus robur* L.), floodplain forest, silviculture, forest protection, forest tending

INTRODUCTION

Floodplain forests in southern Moravia belong to the most valuable ecosystems in central Europe. They are situated on the lower reaches of the Morava, Dyje, Svratka and Jihlava rivers and cover the total surface area of 9.5 thousand hectares, which represents one third of all alluvial forests in the Czech Republic. The singularity of the complex is amplified by the interconnection between the ecosystems of the alluvial forests, floodplain meadows and wetlands.

The Židlochovice Forest Enterprise (hereinafter "LZ") is located on a territory characterized by a very low forest coverage of 15 %; more than 80 % of the landscape is intensively used for agricultural purposes. It is also important to be aware of the fact that all forests in the concerned territory represent an artificial ecosystem which is a result of silvicultural management by man – forester.

LOCALIZATION OF THE TERRITORY, SITE CONDITIONS

Židlochovice LZ is one of enterprises directly operated by Lesy České republiky, s.p. (LČR - Forests of the Czech Republic). The present forest management plan is valid from 2000 to 2009. The Forest Enterprise extends on a cadastral surface area of 173,000 ha in two Natural Forest Regions: NFR 35 – Jihomoravské úvaly (South-Moravian Grabens), and NFR 33 – Předhoří Českomoravské vysočiny (Foothills of the Bohemian-Moravian Upland). In total, the Židlochovice LZ operates 22,500 ha in two forest management units (hereinafter "FMU"): Židlochovice FMU and Moravský Krumlov FMU.

When divided into categories, there are 39 % of commercial forests, 1 % of protection forests and 60 % of special purpose forests in the Židlochovice LZ.

The tree species composition in the Židlochovice LZ is characterized by prevalence of broadleaved species (90 %). Conifer trees form 10 % of the tree species. Oak 45 %, ash 16 %, robinia 6 % and poplar 6 % dominate among the broadleaved species and pine 8.6 % and spruce 1 % among the conifer tree species.

Pedunculate oak in the Židlochovice FMU takes up the surface area of 4,300 ha in the current species composition, i.e. 25 % of the timber land area which is 17,057 ha. This surface area should be increased to 7,110 ha, i.e. the target tree species representation increase to 42 %.

The current oak stands are predominantly mixed. Primary tree species are pedunculate oak and narrow-leaved ash mixed with hornbeam, linden and elm. Aggressively regenerating field maple grows in numerous locations.

Floodplain forests are located in the Natural Forest Region of South-Moravian Grabens, namely in the Dolnomoravský úval Graben in the lower reaches of Morava and Dyje rivers and in the Dyjsko-svratecký úval Graben in the lower reaches of Svratka and Jihlava rivers and at their confluence with the Dyje R. The territory is characterized by depressions with a flat relief on Late Tertiary (Neogene) and Quaternary rocks. The wide alluvial plain of the Morava and Dyje rivers above the surface of which rise small islands of low terraces takes up the lowest part. The youngest surficial deposits are Holocene alluvia which are sandy, loamy and clayey. Primary soil types are loamy–brown and sandy-loam – orthic alluvial greyzems, loamy-clay semigleys and gleys. Predominant Forest Altitudinal Vegetation Zone is Oak and prevalent forest types are 1L, 2L, 1U and 3U.

Average annual temperature in the forest enterprise territory is 9 ºC. The annual precipitation amount is roughly 550 mm and the range of altitudes of the alluvial area falls in the interval of 150 – 200 m a.s.l.

Intensive game management (world-famous pheasantry and game preserves with red, mouflon and fallow deer and wild boar) is a significant feature of the forest enterprise.

DEVELOPMENT OF THE FLOODPLAIN FOREST

Floodplain forests were exploited already in the earliest times; evidence of human settlement dates back to the palaeolithic times (mammoth hunters). The forests were of great importance also for the Slavic Great Moravian Empire. Starting from the 13th century, alluvial forests in the Břeclav Region gradually came to be incorporated into the property of the Princely House of Lichtenstein which was exploiting them until 1945. High level of Lichtenstein management can be documented on the working plans and other forest management records. The oldest plans go back to 1764. Since the beginning of the 19th century when the development of intensive forest management commenced, rotation period came to be extended in the tree species of significance up to 100 years, and low productivity meadows were afforested. Great care was paid to reforestation of oak, chiefly by means of large-scale sowing of acorns. Gradual and intentional transformation of a considerable area of grazing forests into a traditional closed high forest thus occurred. Commonly represented tree species used to be smooth-leaved elm and European white elm. The management took on the form of a clear-felling system on large areas at the utilization of alternate forest and farm crops. Stumps used to be extracted because this type of fuel was highly desirable.

Clear-felling system with stumping and later with the milling of stumps and with the whole-area soil preparation prior to reforestation by oak seedlings or by seeding acorns is used until today.

After 1945, the water regime in floodplain forests was particularly affected due to inconsiderate regulation of the watercourses. Water was drained into the territory of southern Moravia where it flowed into the floodplain forest. Problems with flood damages to agricultural and forest soils became more severe and overpopulating mosquitoes started to be a serious problem. The construction of the Nové Mlýny hydroengineering structure and the regulation of channels of the Dyje, Morava, Svratka and Jihlava lower reaches did not cure the situation. On the contrary, the groundwater table decreased and by rendering spring floods impossible the forest stands sustained great damage chiefly due to drought. During the floods, however, when the water is let into the floodplain forests, damages worth several million crowns are incurred on forest stands, forest roads, game-proof fences, agricultural production, fixed assets and wildlife.

FLOODPLAIN FOREST MANAGEMENT IN THE ŽIDLOCHOVICE FOREST ENTERPRISE

Forest regeneration

At present, the main system used to regenerate oak is whole-area regeneration by compartments either by sowing or planting. Planting is made after whole-area site preparation by means of furrow planting reforesting machines. Roughly 9 to 10 thousand pieces of transplants are planted per 1 ha. Sowing is carried out on plots after whole-area soil preparation. The amount of 250-300 kg of acorns is sown in a mechanized manner or manually under hoe. Spacing is chosen in such a manner to allow for subsequent mechanized treatment of the young plantation. Framework forest management regulations for oak stipulate management groups of stands 185, 187 and 195. Rotation period is determined from 110 to 140 years and the regeneration period from 20 to 30 years. Maximum size of the clear-felled area pursuant to Act No. 289/1995 Coll. on forests is 1 ha. An exception of 2 ha is permitted for the management groups of stands on alluvial sites. Maximum width of a clearcut is not limited and establishment of young plantations is 7 years. Pursuant to the Decree the minimum share of soil-improving and reinforcing tree species is 15 %.

Ash regeneration is executed primarily by natural regeneration and by the release of young plantations with stumps of the original stand being retained. Regeneration of other woody species is usually performed without whole-area site preparation.

Natural regeneration of pedunculate oak is not performed. Main reasons for failure of pedunculate oak natural regeneration are as follows:

- lack of acorns, low occurrence of seed years
- occurrence of forest weed – free growing open stands
- problematic weed control
- seedlings are very attractive for the game

Basic method is artificial regeneration of oak stands on a site subjected to whole-area soil preparation. At present, the following technologies of soil preparation by chipper rotary cultivators are employed:

- whole-area to a minimum depth of 5 cm, slash was removed from the stand
- whole-area to a minimum depth of 5 cm, slash was not removed from the stand
- whole-area to a minimum depth of 20 cm, slash was removed from the stand
- whole-area to a minimum depth of 20 cm, slash was not removed from the stand
- whole-area to a minimum depth of 5 cm, stumps milled off to a minimum depth of 20 cm, slash cleared from the stand

– whole-area to a minimum depth of 5 cm, stumps milled off to a minimum depth of 20 cm, slash was not cleared from the stand

The cost of site preparation ranges from 28 to 55 thousand CZK.ha^{-1} in dependence on the used technology.

Protection from game damages

Regenerated areas of young plantations must be protected from game damage. Fully-functional fence is the best protection in the forest enterprise. Coating the transplants with repellents is used to a smaller degree. Traditional garden wire mesh with the size of the square mesh 5 by 5 cm and height of 160 cm or 200 cm is used for the fence (Fig. 1). Higher fence is used in open red deer hunting districts. In forest districts with game management in the preserves special "game preserve mesh" is used with the mesh size of 10 cm by 10 cm and the height of 200 cm or 220 cm, depending on the species of the kept game. The forest district weaves the mesh itself. Although the utilization of forest knot mesh was tried in the district, it did not however prove effective neither in the game preserves, nor in the hunting districts with red deer and hares.

Fig. 1: Fenced plantation of pedunculate oak

The following coating repellents are used to protect the transplants. The well-proven Morsuvin and also Aversol and Repentol are used in the winter period and Aversol and Stop Z against browsing in the summer.

Protection against fungal diseases

In the first two or three years after planting, it is appropriate to treat the transplants against oak mildew. It is recommended to perform the measure preventively. We use a specially adapted sprayer carried on a tractor. The applied formulations are Kumulus and Sulikol K. In the course of the year, the spraying is done twice according to the weather.

Weed control

Conditions for rapid growth of herbaceous and woody weeds are ideal in the floodplain forests. Frequently, these weeds are strongly aggressive, quickly dominating and suppressing the planted nursery stock. They reach up to several meters of height in untreated sites. One of the very important conditions for the ensurance of the sound emergence of tree species transplants is their protection against forest weeds until the young plantation becomes established.

Protection of oak seedings

In the period of acorn germination, clearcuts regenerated by seeding must be controlled. Undesirable, largely herbaceous weeds emerge earlier than the acorns and take hold of the reforested areas. If the clearcut areas are overgrown, a whole-area spraying by Roundup agent is done shortly before the oak seedlings start to push against the soil surface. The device used for the treatment is sprayer carried on a general-purpose wheeled tractor. After the performed operation the weed dies and rows of oak seedlings start to show. The subsequent operation is then carried out in a manner similar to reforestation by planting.

Protection of young oak plantations after planting

Reforestation is usually performed on whole-area prepared sites free of forest weeds. If the forest weed starts to appear in the first year following the forestation, it is recommended to hoe the transplants in the row once or twice. Mechanized treatment is performed between the rows by means of a small tractor. We can decide for one of the following operations depending on the species, size and weed density:

- soil loosening – rotary cultivation
- mowing – mulching
- chemical treatment by cased sprayer (Roundup)

The protective measure is carried out 2 to 3 times a year according to the weather and weed size. It is expedient to combine mechanical and chemical treatments.

If a further protection of transplants in the row is necessary, it is possible to use mowing by sickle or by a short scythe and/or to apply chemical treatment by using cased sprayer. This protection is also practised on sites without whole-area soil preparation and at places inaccessible to mechanization – water-logged and small sites.

In young plantations a proper protection is to be ensured chiefly in the first years after reforestation and subsequently until they become established.

If undesirable fast-growing tree species appear in the rows between the oak transplants (white poplar, white willow, field maple, etc.) or if they dominate or threaten the oak transplants development in their earliest stage, they can represent a deadly danger to their existence by taking control of the main level. These tree species therefore need to be cut out; ideally in the autumn months (September). Also, the small stumps have to be coated with herbicide (Roundup) which will prevent their further reproduction.

In the first years after reforestation, the oak grows slowly – it "sits." While a stand is being established, it is necessary to assure a sufficient number of individuals equally distributed over the area, i.e. 8,000 pieces. Oak is a literally light-loving tree species and does not tolerate shading of a more permanent nature. But at first, it is necessary to keep it in a dense canopy.

Silviculturalists and economists have arrived at a conclusion that cultivation of oak is economically advantageous and profitable only when it is focused on the production of valuable assortments.

Cleanings

Prior to approaching juvenile thinnings, it is necessary to make the site accessible by dividing the stand into individual workspaces roughly 20 m wide. Extraction tracks are 3 m wide.

The first cleaning treatment is performed when the stand height reaches 4 - 5 m, i.e. between the 10^{th} and 12^{th} year of age. The stems are already cleaned to the height of a person and the interior of a stand is sufficiently accessible and transparent. Stand density does not usually get modified during the first treatment and reduction in the number of trees is not performed. Self-thinning is taken into account, stand density will become reduced naturally. The treatment is therefore to be localized particularly in the dominant and main levels in which poor quality and economically undesirable branchy overtopping and wolf trees are felled.

The second juvenile thinning follows after approximately 5 years depending on the young growth density and is focused on the modification of density in the young growth of 6–8 m in height. The cleaning is therefore relatively heavy with the resulting stand density being reduced by it to roughly 6,000 trees per hectare with the spacing of approximately 1.2 m at maintaining fully enclosed canopy. Good horizontal canopy is a means to encourage height increment and stem cleaning. Also during the second cleaning treatment, the negative selection is carried out only in the main level with the sub-level being neglected. The selection serves to adjust the situation in favour of higher quality individuals which are given conditions to produce regular crowns.

The third juvenile thinning treatment at the age of 20 - 25 years, when the stand has already reached the height of 10 - 12 m, is usually the last one. This improvement measure already involves a positive selection in the main level. This operation involves the release of qualitative individuals in the crown space of the dominant level. Treatment of the lower height classes of the suppressed level becomes intensified and accompanied by the reduction in the number of individuals on the plot in order to boost diameter increment and increase the stand stability. Spacing between the trees becomes adjusted to 1.5 m after the cleaning with their number amounting to 4 thousand $pcs.ha^{-1}$.

Thinnings

The most suitable tending method is crown thinning. In stands up to 50 years of age the crown thinning is a thinning for quality the aim of which is finding of approximately 400 promising trees located roughly 5 m from each other.

Older large-diameter stands are subjected also to increment thinnings to produce maximum diameter increment with the growing of 200 target trees at a spacing of about 7 m.

The sub-level plays an important part in the oak stands. Oak, as a distinctly light-loving tree species, cannot create it by itself. The tending and later soil-protection and shading functions preventing the weed infestation and the occurrence of epicormic stem shoots are assumed by naturally regenerated shade-bearing species such as ash, linden, hornbeam, elm, field maple and various shrubs.

An ideal older oak stand should be 2-storied with a maximum amount of high quality oaks in the main level, which can grow together with ash and a well-kept lower storey of shade-bearing broadleaved species.

FOREST FUNCTIONS AND METHODS OF THEIR ENSURANCE

Economic objectives of the Židlochovice Forest Enterprise are based on the "Basic principles of forest policy" and they are fully consistent with the Act on forests No. 289/95 Coll. and elaborated documents of the forest policy of LČR which determine the main objectives and economic strategy for forest administration in the ownership of the state.

Economic strategy of LČR – LZ Židlochovice draws on the LČR mission and the condition of the forest which it was entrusted with for management. Basic concept is sustainable management.

The forest functions are expressed by their division into categories. Principal categories in the Židlochovice Forest Enterprise are commercial forests and special purpose forests focused on game management.

The role of the commercial forests is a well-balanced fulfilment of all forest functions. Non-wood producing functions in the production forests are mostly ensured spontaneously by exercising differentiated management according to the natural conditions.

The management of special purpose forests must be executed in such a manner to achieve or preserve the purpose for which the forests were designed.

The category of production forests was allocated 11 management groups of stands (MGS) (7,177 ha of timber land).

The category of protection forests was allocated 1 MGS (196 ha) and 26 MGS were allocated to the category of special purpose forests (9,683 ha).

On the basis of their function, the special purpose forests are further divided as follows:

- Forests in the first zones of Protected Landscape Areas (PLA), Nature Reserves (NR), Nature Monuments (NM) and National Nature Reserves (NNR)
- Forests with increased soil-protection, water-protection, climatic and landscaping functions
- Forests for the conservation of biological diversity
- Forests in acknowledged game preserves and self-sustained pheasantries
- Forests in which public interest requires different management methods (MUNA)

In many a case the above functions overlap.

The basic principles of state forest policy specify that the precondition for ensuring public interests in forests is the preservation of the existence of the forest itself as a source of the functions in question. By safeguarding the stability of forests and by affecting the transformations of their tree species composition, the forests will be capable of fulfilling their function also in the future. To assure the actual existence of the forest and improvement of its condition, LČR – LZ Židlochovice uses the principles of sustainable management adopted in the document Programme of Sustainable Forest Management – Forest Tending and

Regeneration. It concerns particularly the increase in the share of noble hardwoods during forest regeneration (mainly oaks), assurance of the prescribed percentage of soil-improving and reinforcing woody species, enhancement of the proportion of natural forest regeneration and decrease in the share of incidental fellings.

ECONOMICS OF FOREST MANAGEMENT IN THE FLOODPLAIN FOREST

Cultivation of broadleaved species with respect to the economical perspective can be profitable only if it is oriented to the production of high-quality large-diameter assortments, i.e. veneer logs and special industrial logs. Growing weak, curved and knotty mass is economically unprofitable.

The high proportion of large-diameter quality assortments can be achieved in stands only by consistent and continuous silvicultural selection for the entire period of tending with the objective of enhancing the share of good quality individuals. Professional cleaning until the age of 25 years is decisive for the quality of the final yield production. Early thinnings must support prime quality and promising trees (at least 400 $pcs.ha^{-1}$) from which the target trees will be finally chosen (around 200 $pcs.ha^{-1}$). Thinnings in the oak stands are fundamentally performed in the main level. Until the middle of the rotation period, crown thinning for quality is to be carried out – in which a maximum possible share of quality individuals in the stand is formed – which is then followed by increment thinning focused on the production of diameter increment.

In the course of all tending operations, cleaning treatments and thinning measures, the stand must remain sufficiently stocked and with closed canopy in the main level in order to encourage the height growth and elongation of smooth stems. Very important for the quality of oak stands is the admixture of shade-bearing broadleaved species (linden, hornbeam), which constitutes a shade-bearing sub-level with the covering, tending and soil-improving functions.

METHODS AND EFFICIENCY OF COOPERATION WITH STATE ADMINISTRATION AUTHORITIES, NATURE CONSERVATION BODIES AND NON-SPECIALIST ORGANIZATIONS

Cooperation with the state administration is mainly satisfactory because the employees in the relevant offices have experience with forest management and are interested in the preservation of forests in the landscape.

As far as the cooperation with nature conservation bodies is concerned, negotiations are not easy. An advisory board was established for issues concerning the Pálava Protected Landscape Area. As far as the non-professional organizations are concerned, we are mostly in good terms with them, unless they are not directly biased by naturalists.

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SYSTEMS OF FLOODPLAIN FOREST MANAGEMENT IN THE PROTECTED LANDSCAPE AREA OF THE LITOVELSKÉ POMORAVÍ GIVING THE STATE-OWNED FOREST AS AN EXAMPLE

Jiří Eichler

Abstract

The present study describes the system of forest management and forest regeneration in floodplain forests of the Protected Landscape Area Litovelské Pomoraví giving the management of the Forests of the Czech Republic (LČR) as an example. The forests are focused on production of high-quality wood and nature conservation. The species composition is very varied; dominant is European ash and pedunculate oak. Management is distinctly differentiated according to the management group of stands of different functions, e.g. production, nature conservation, preservation of the gene pool. Species, which are geographically allochthonous and unsuitable for the forest site, are eliminated; natural regeneration is supported on regeneration plots of preferably not more than 0.60 ha. All this includes data of felling, forest regeneration and economy of management of this forest region.

Key words

Litovelské Pomoraví, floodplain forest, Forests of the Czech Republic, forest function

INTRODUCTION

The Protected Landscape Area Litovelské Pomoraví (hereafter only PLA) occupies a narrow strip of forests along the river Morava between the towns Olomouc and Mohelnice. The territory is usually divided into "Doubrava" (Oakwood), which is not directly affected by the Morava River and whose forests lie mainly in Forest Altitudinal Vegetation Zones 2 and 3 (hereinafter FAVZ) and "floodplain", which lies inside and along the inland delta of the Morava River and is immediately affected by the river and whose forests lie mainly in FAVZ 1. The total area of the forests in the PLA is 5,403 ha (Management Plan for the PLA Litovelské Pomoraví 1997), of which the largest parts are state-owned and communal forests.

The present study deals with the problem of forest management in floodplain localities of the above area; as an example the Forests of the Czech Republic Management, Forest District Šternberk, are given. The selected stands stand for the majority of problems in this complicated region.

LOCALISATION OF THE AREA, SITE CONDITIONS

The area of the studied floodplain forest is ca 1,124 ha and is localised by compartments 767 to 799 according to the Forest Management Plan of the Morava River Valley for the period from 1 January 2000 to 31 December 2009 (hereinafter only FMP) and by groups of forest types (hereafter only GFT) 1L-elm floodplain, 1U-poplar floodplain and 1G-willow-alder wood; it lies in the Střeň forest district and is formed by two more or less continuous blocks of forest along and inside the branches of the Morava River. With a few exceptions they are all floodplain forests in the Střeň forest district. The whole area lies in the Natural Forest Region No. 34 - Hornomoravský úval Graben; in terms of geology and pedology it is formed by Neogene and Quaternary sediments, in terms of the climate the territory comes under the warm region with average annual temperature of 8 °C, average annual sum of precipitation 600-700 mm, in recent years only 450-500 mm (FMP Pomoraví 2000). In terms of typology the area is formed by elm floodplains (GFT 1L) on 1,038 ha, poplar floodplains (GFT 1U) on 66 ha and willow-alder grove (GFT 1G) on 20 ha. A great part of the stands is regularly flooded; during the 1997 floods most of the territory was flooded.

DEVELOPMENT OF THE FLOODPLAIN FOREST, SPECIES COMPOSITION

Systematic forest management in the floodplain forests of the PLA dates back roughly to the mid-18th century. Up to that time the forests were exploited by so-called selective cutting (creaming) or as an important source of acorns for feeding farm animals. In the late 18th century the area from Skrbeň and Hynkov was described as a nice oak forest (coppice of a 25-year rotation period and ca. 30 % proportion of reserves). From written documents of those times we can see that there were virtually no clearings in the forest and almost the entire forest was regularly inundated. Already at that time is was difficult to regenerate oak as it had been recommended to plant strong saplings. In 1833, the working plan based on the area control method was a serious intervention into the forest. Forests were to be geared up for the production of a coppice; the predominating species was oak in the upper storey of 300 - 400 years of age, to a lesser extent younger elm and ash. Ash, alder, aspen, linden and willow made up the lower storey. In some parts of the present-day forests there were extensive meadows and pastures with sporadic over-mature reserved trees. Basically we can say that before 1950 the predominating acreage of floodplain forests was managed as an environmentally-friendly coppice-with-standards forest and ca. 35-year rotation of the coppice. After that due to economic reasons the forest was converted to large-diameter forest; evidence of this intervention are extensive areas of stands of younger age categories. In spite of a number of problems in the past, thanks to wise forest managers the condition of the forests of the present PLA have been preserved at a very decent standard compared to other areas (rich species composition, extensive area of storeyed stands in character close to natural etc.) (Management Plan for the PLA 1997).

Tab. 1 shows the present species composition of the monitored area of the floodplain forest; the species composition is very varied, predominant is ash and oak. Unfortunately the forest management plan does not differentiate sessile oak and pedunculate oak, nonetheless it is apparent that in this locality pedunculate oak is more widely spread. Poplars are mostly various clones of improved poplars; a negligible part is European aspen. Apart from Scotch pine there is also eastern white pine and European black pine. The other undifferentiated species include for instance horse chestnut, ash-leaved maple and shrubs, primarily bird cherry. The 27 % proportion of storeyed stands gives a true picture of the spatial differentiation of the stands.

MAIN FOREST FUNCTIONS AND METHODS OF THEIR ASSURANCE

The entire system of management in the floodplain forest administered by the Forests of the Czech Republic, Forest District Šternberk arises from the basic strategic and long-term economic objectives of the Forests of the Czech Republic.

Basic strategic targets:

- regeneration and preservation of stable forest ecosystems

- applying the principle of sustainable management, exploitation of forests in such a manner and extent to ensure their stability, biodiversity, production capacity, regeneration capacity, vitality and ability to fulfil the beneficial function of the forest on a permanent basis
- preserving the forest as a sustainable natural resource for the benefit of the generations to come

Table 1: Selected parameters of the territory according to woody species (FMP Pomoraví and forest management records of the LČR, s.p.)

Woody species	**Area** (ha)	**Composition** (%)	**Volume felled in 2002-2006** (m^3)	**Artificial regeneration in 2002-2006** (ha)	**Natural regeneration in 2002-2006** (ha)
Spruce	15.43	1.37	1,845	0	0.25
Pine	19.87	1.77	507	0	0
Larch	5.23	0.47	730	0.10	0
Oak	311.09	27.67	6,187	14.52	0
Slavon oak	3.87	0.34	0	0	0
Red oak	7.04	0.63	373	0	0
Hornbeam	27.88	2.48	1,176	0	0.48
Norway maple	2.05	0.18	0	0	0
Sycamore maple	36.72	3.27	597	2.62	0.70
Field maple	2.30	0.20	6	0	0
Ash	389.70	34.66	11,001	11.03	2.88
Elm	2.67	0.24	114	2.44	0
Robinia	0.70	0.06	2	0	0
Birch	8.99	0.80	271	0	0.28
Black walnut	3.86	0.34	30	0	0
Cherry	0.60	0.05	9	0	0
Linden	137.13	12.20	3,055	6.47	0.10
Alder	96.80	8.61	2,965	22.56	0.66
Poplars	45.53	4.05	7,024	0	0
Willow	5.70	0.51	41	0.87	0
Other	1.03	0.09	83	0	0
Total	1,124.19	100.00	36,016	60.61	5.35

Some long-term economic objectives:

- creating an optimal relation between the fulfilment of all functions of the forests managed by LČR and a market economic environment. At the same time to ensure permanent production of high-quality wood substance respecting and developing the environmental function of the forest
- consistent differentiation of management linking up with differentiation of site conditions and current stand conditions

- long-term conceptual preparation of stands convenient for natural regeneration in terms of the site, species, age and genetics

Multi-functional management of the floodplain forest in the Středň Forest District is based on these principles.

Definition of the main forest functions

The function of the forest in an allotted space is based on the zone in which the forests are placed within the PLA and the connecting management groups of stands in which the functional objective is further specified. Forests of the 1st zone of the PLA Litovelské Pomoraví are formed by small-scale forests of particularly protected areas (hereinafter MZCHÚ) and the gene pools. In the FMP they are earmarked as special-purpose forests. Forests of the 2nd zone are commercial forests. Tables 2, 3 and 4 give a survey of the most important management groups of stands and the basic parameters of framework economic directives. The tables do not provide data on soil-improving and reinforcing species. Under the conducted method of regeneration and existing woody species composition these data are of no significant importance.

General functional focus of the forest with regard to the existence of the PLA and demarcation of the Litovelské Pomoraví Bird Region

General directives for the management of the management groups of stands indeed contain the basic limits for management; nevertheless, during the effectiveness of the present FMP two important events took place, which shifted the economic activities in the forests to a completely different and more concrete level.

In 2004 the Management of the PLA Litovelské Pomoraví and the LČR, Forest District Šternberk made an agreement on setting-up the rules for conducting some forest activities.

Table 2: Selected management groups of stands in the region of interest – special-purpose forests (according to the FMP Pomoraví)

Management group of stands	3185	4185	8185
Area (ha)	80	117	128
Target management	19 - management of floodplain sites – National Nature Reserve Vrapač	19 - management of floodplain sites – other areas of particular protection	19 - management of floodplain sites, gene base Oak
Stand type	Oak, ash, other	Oak, ash, other	Oak of good quality
Function	Nature conservation	Nature conservation	Gene pool preservation
Rotation period	200	200	140
Regeneration period	p*	p*	30

*p – physical age of the stand

Table 3: Selected management groups of stands in the region of interest – commercial forests (FMP Pomoraví)

Management group of stands	195	197	198	297
Area (ha)	260	446	38	27
Target management	19- management of floodplain sites	19- management of floodplain sites	19- management of floodplain sites	29- management of alder sites on waterlogged soil
Stand type	Oak of good quality	Broadleaves mixed (ash)	Poplar	Alder
Function	Production	Production	Production	Production
Rotation period	140	100	40	60
Regeneration period	30	30	20	20

Table 4: Target species composition of selected management groups of stands (FMP Pomoraví)

Management group of stands	Target species composition
195	Oak 7, ash 2, linden (alder, maple) 1, elm, poplar, willow, hornbeam, cherry
197	Oak 4, ash 4, maple 1, linden 1, elm, alder, willow, hornbeam, cherry, poplar
198	Oak 6, ash 2, maple 1, linden 1, elm, hornbeam, poplar
297	Alder 5, ash 3, maple 2, birch, aspen, poplar, oak
3185	According to Management Plan
4185	According to Management Plan
8185	Oak 7, ash 2, linden (alder, maple)1, elm, poplar, willow, hornbeam, cherry

In this relatively complicated document the limits for management were distinctly and in terms of operation clearly concretised for management, particularly in commercial forests. They are for instance the following principles:

- to introduce procedures of shelterwood management systems
- to reduce the maximal area of regulated regeneration elements in stands with a majority of autochthonous woody species in terms of geography and forest site to 0.60 ha and in stands with a majority of allochthonous woody species in terms of geography and forest site to 1.00 ha
- to specify the number of uncleared woody species left in the course of regulated regeneration differentiated according to the size of the regeneration unit
- to specify the principles for conducting tending felling, in the first place not reducing the composition of admixed and interspersed autochthonous species in terms of geography and site
- to specify the number of woody species in the first forestation based on the size of the regeneration unit: up to 0.30 ha one species; up to 0.60 ha two species, up to 1.00 ha three species

- agreement not to conduct main intentional cutting and skidding between 1 April and 31 August of the current calendar year if not agreed otherwise
- agreement on the regime and marking and determining felling in the MZCHÚ
- agreement on the regime of discussing and mutually approving projects of silvicultural and felling activities in commercial forests
- agreement on the execution and marking of trees left to spontaneous decomposition and leaving the den trees (Agreement based on provision § 68, art. 2 of Act No. 114/1992 Coll., 2004)

The other event was the delimitation of the Bird Area of the Litovelské Pomoraví according to the Governmental Decree of 15 December 2004. Pursuant to this Decree are further restrictions, namely according to § 3, 1b): "In bird areas, with the exception of built-up and to be built-up community areas, only after previous consent of the respective body for nature conservation no main or intermediate planned cutting shall be carried out in forest stands with 50 % or more beech or oak older than 80 years, in forest stands with 50 % or more ash older than 60 years, in forest stands with 50 % and more maple, hornbeam, alder and linden older than 50 years, in forest stands with 50 % or more willow and poplar older than 30 years, in the period from 16 April to 31 July." Taking into account the species composition in the locality according to Tab. 1 it is evident that the overwhelming majority of forest stands comes under this decree and in combination with the limitations of the above Agreement in actual fact only tending felling up to 40 years and some selected tending felling of more than 40 years may be carried out in the period from 16 April and 31 July in the locality. Nonetheless I would like to add that within such a vast property as the Forests of the Czech Republic dispose of in the region, such limitations cause only small operational difficulties; in this period the production capacities can be moved to the not too distant regions outside of the PLA. Otherwise such limitations would naturally affect the owner as these limitations would have an impact on all his property.

Management in special-purpose forests

Management in special-purpose forests focused on nature conservation is represented by two management groups of stands (hereinafter only MG). Both concern forest management in the small-scale particularly protected areas (MZCHÚ). The long-term objective of development control on the greater part of the area is to regulate the development of the present, mostly near-natural stands of a commercial forest character towards more mature forms of stands more like a natural forest (Management Plan of the PLA 1997). It includes MG 3185 and MG 4185 – management of floodplain sites in the National Nature Reserve Vrapač, of other nature reserves (e.g. Hejtmanka, Litovelské luhy) and nature monuments. These management groups of stands partly overlap with MG 8185 – gene reserve of oak. Management measures in this unique locality are based on the approved management plan and are limited to special-purpose selection felling to allow natural regeneration, reduction of geographically allochthonous woody plants or species unsuitable for the locality (particularly spruce, robinia, red oak, boxelder, improved poplar) (Forest Management Plan Pomoraví 2004). In the seed years shelterwood group felling of the target group of woody species is carried out to ensure natural regeneration. In localities overlapping with the gene reserve of oak, increment thinning of selected trees was performed to open the crowns and to improve fertility. Incidental felling is rare and only after agreement with the PLA Management, primarily to prevent the distribution of pests (tracheomycosis, some insect pests), or to ensure passability of river channels (extreme amount of incidental felling in the Morava River channel after the tornado in 2004). For demonstration purposes: in 2002 to 2006 felling was executed in MG 3185 (NNR Vrapač) of 293 m^3, of which 169 m^3 was red oak and 104 m^3 improved poplars. The amount of incidental felling was 43 m^3.

Forests intended for preservation of the gene pool, in this case MG 8185 – gene reserve No. 167a for DB, JL and JS – "Vrapač", partly overlap with other management groups of stands as mentioned above. Therefore the methods of management do not greatly differ from the above principles. Unfortunately only ash and elm satisfy one of the basic conditions of functional gene reserve, i.e. natural regeneration of the woody species for which the gene reserve had been declared. In general, the natural regeneration of pedunculate oak is still at the stage of experiments. The basic problem is a poor to zero harvest in the present decade. That is also the reason why no oak seed was obtained from the gene reserve. The situation of the other two species is much better, especially that of ash.

Problems of the commercial forest

Tab. 3 gives the basic management groups of stands where the production function is predominating and Tab. 4 gives the target species composition.

The most important is MG 197, management of floodplain sites in mixed stands with ash as the dominant species. The stands are regenerated and tended relatively intensively, as can be seen in Tab. 1 on felling. In the past period, ash was the most frequently felled species. Especially the regeneration is relatively rapid, for two principal reasons. It was deemed necessary to create a sufficient number of starting points for natural regeneration in order to regenerate overmature ash stands as quickly as possible. Right now it is necessary to sustain the rate of regeneration felling in order to fell the ash in time, at least in a rotation period of 100 years and regeneration period of 30 years according to the present framework directives for management, if need be to reduce the rotation period to 90 years, particularly to prevent devaluation of the wood, i.e. colouring of the heartwood and butt rot. The proportion of natural regeneration of ash in the total natural regeneration is the highest of all woody species and at present there is no reason to slow down further development. It is only necessary to ensure a sufficient admixture of ameliorating species to prevent the growth of extensive stands of pure ash.

Another important group is represented by stands with dominant pedunculate oak in MG 195. In the past period regeneration of these stands was not given preference; Tab. 1 shows that total felling of oak is well below the size of its area. Here again there is a number of reasons. In the first place a stronger seed year was expected and is still hoped for, in order to be able to continue in experiments with natural regeneration and ensure sufficient amount of seeds from local sources. Secondly it is because felling of these stands from the commercial point of view is much less acute than felling and developing the neglected regeneration of ash and poplar stands and stands with alder. Unfortunately we have not seen a seed year in this decade; on top of that, due to the drop of groundwater table and spells of drought, incidental felling of dead standing oak trees has recently increased and approaches thousand cubic meters a year. It is premature to draw conclusions; in floodplain forest there has been a number of different periods of the dieback of certain species (e.g. massive dieback of linden in the past two decades, which virtually does not continue any more); nevertheless it is necessary to monitor this phenomenon. In any case felling in this management group of stands will increase in the following years. Rules similar to those concerning the preceding management group of stands apply to regeneration of oak stands with admixtures of species where natural regeneration is easier (ash, maple). Natural regeneration is also preferable in these stands, even at the cost of not keeping the required proportion of oak in the target species composition.

Another important and interesting management group of stands is MG 198, poplar management. Stands of improved poplars should be regenerated in a 40 year rotation and regeneration period of 20 years. Tab. 3 might indicate that the area of this management group of stands is not very important but it is not so. In the past 5 years the volume of poplar clones felled was more than 7,000 m^3 (Tab. 1), and that is more than of penduncculate oak. It was because all poplar stands reached the age when their regeneration should be completed. However this is not always successful and these stands will be going through intensive regeneration for the entire following decade. It is a great commercial loss because the quality of butt wood is constantly deteriorating also because in the 1950's the stem bases were very large and for many customers they are useless, even though they are healthy. Poplar stands usually grow in localities where the groundwater level is high; regeneration must proceed sensitively to avoid the occurrence of bigger clear areas, which it would difficult to regenerate. In part of the stands poplar forms the upper storey and ash with alder the lower storey. If the process was correct, in many cases the poplars of the upper storey were successfully felled, after which zero or only minimal forestation followed. Subsequent artificial regeneration of these stands took place with other woody species than poplar because improved poplar as geographically allochthonous cannot be grown in the PLA. Sufficient amounts of indigenous black poplar are not yet available and for the time being black poplar is used for the forestation of sediment loads on the embankments of the Morava River; it is managed and carried out at the general expenses of the PLA Administration.

The last management group of stands is MG 297, management of alder sites on waterlogged sites. The parameter of regeneration is a 60-year rotation and a regeneration period 20 years. If alder is to be a commercial woody species in a floodplain forest on these sites, it must be regenerated in time. Logging alder at the age of 80 or 90 years on these waterlogged localities is an economic disaster.

Summary of the forest management in floodplain forests of the Střeň Forest District

As we can see in Tab. 1 the average annual volume felled per 1 ha in the region in question is 6.40 $m^3.ha^{-1}$. This is more than the average for the entire FMP Pomoraví, particularly because of the higher growing stock in floodplain forests. Due to the demands of the stands the felling intensity will probably increase in the future, especially if we manage to markedly develop and take advantage of natural regeneration. Considering that there are enough mature stands and that all available forms of regeneration are applied the so far observed limits for the size of regeneration elements by regulated areas should not endanger the necessary increase in regeneration felling. At the present time the average area of the regeneration unit is ca 0.42 ha (qualified operational estimate) but even if regeneration of the oak stands is more intensive this figure is not expected to increase dramatically. The standard of forest tending is very high and is done on the basis of accepted rules giving preference to the removal of geographically allochthonous and site unsuitable species. The absolute majority of artificial regeneration is done by slit planting and bare-rooted planting. Brushwood is cleaned manually or with a slash rake; crushing the brushwood with a rotary cultivator is not efficient economically or ecologically. Moreover, a large proportion of the broadleaved smallwood is the object of self-production and is used as cheap ecological fuel by the local population. Conventional technology is used for logging operations; forwarders are used for skidding pulp wood and small-diameter round timber. Since the small forwarders are environment-friendly they are used, as demanded by the PLA Administration, preferentially in most logging operations carried out in the small-scale particularly protected areas.

In terms of forest protection the floodplain forest is endangered only a little. Out of the abiotic factors insignificantly detrimental is only the wind (with the exception of the tornado in 2004, which caused a relatively heavy damage, including clearings). Out of the biotic factors in certain periods it is the oak leaf roller moth damaging oak stands, and other pests of oak. The beaver is spread over the entire area of the floodplain forest damaging all woody species. For the time being the damage is not very severe, but due to the number of the animals it can be expected that over time the damages will increase considerably.

Game management in the forest is always a very topical and controversial issue. Fallow and roe deer have an immediate effect on the results of forest plans in the floodplain forests. The owner of the forest regulates their numbers using legal options. Discussions on whether these legal options are sufficient with respect to the importance of the forest, or if they have always been applied, is not the objective of the present paper.

OTHER FUNCTIONS OF THE FOREST AND THEIR PROVISION

In the area of interest the forest fulfils all the other functions, which arise from its location and specificities. The most important is the flood control function of the forest. During high discharges in the Morava River the floodplain forests in the Litovelské Pomoraví are always inundated. In general, forest management can influence this function by proper management and, to be concrete, assuming the responsibility for a sound approach to how much wood should be left in the immediate vicinity of the water courses. Floating wood may worsen the flow capacity of the riverbeds and endanger people’s settlements. Another important function of the forests is recreational because of the proximity of large agglomerations. The Forests of the Czech Republic support this function as they do in other forests.

ECONOMICS OF FOREST MANAGEMENT

To give an idea about the economic results of the floodplain forest in question the basic data are given in Tab. 5. Since it is difficult to break some economic data down to a concrete stand and because the Forests of the Czech Republic have a very variable method of timber sales (stumpage sale, roadside sale etc.) and because accurate conversion to the given locality is very difficult, the presented data should be considered to be a qualified estimate.

Table 5: Selected economic parameters of the floodplain forest in the Střeň Forest District

Year	Total volume felled (m^3)	Sales of wood converted to the locality - "stumpage sale" (thous. CZK without VAT)	Average conversion of wood - "stumpage sale" (CZK/m^3)	Total costs for silvicultural operations (thous.CZK without VAT)	Result (thous.CZK without VAT)	Result per 1 m^3 of felling (CZK/m^3)
2002	7,452	1,480	199	1,652	-172	-23
2003	8,061	1,420	176	2,124	-704	-87
2004	6,600	1,230	186	1,930	-700	-106
2005	6,602	1,450	234	1,425	25	4
2006	7,701	2,150	279	1,719	431	56

It is very difficult to comment table 5. Several factors affected the economics of management: development on the broadleaved wood market, structure of felling, structure of silvicultural activities, method of sales of the state-owned enterprise and also the limiting requirements arising from the obligation to fulfil other than economic functions of the forest. It is not the task of the present paper to evaluate the contribution of these factors on the total economic results of management. In this locality by his own authority the forest manager can influence the following processes and in doing so improving the economics of management:

- optimal balance of felling both in overmature and economically less attractive stands, and in economically attractive stands taking into account the current demand on the broadleaved wood market (varied species composition outright calls for felling to order)
- maximal use of natural regeneration and with it reduction of costs for silvicultural activities
- due to the ongoing boom in broad-leaved fuel and assumption that it will last, to consider the possibility of management in a medium-sized forest on a definite area
- from a long-term prospective there is a possible option between growing species with a shorter rotation period and worse quality of wood and species with a long rotation period but higher quality of wood; above all it is an option between the variant of ash and maple on the one hand and oak on the other)

At the present moment most of the circumstances affecting management in the floodplain forest of the Střeň Forest District are favourable and in the next years the results of management should improve.

METHODS AND EFFICIENCY OF THE COOPERATION WITH STATE ADMINISTRATION AND BODIES OF NATURE CONSERVATION

As mentioned above the floodplain forest in the area in question is subject to a considerably higher number of directives, regulations, rules and laws than forests in other areas. In order to be able to carry out proper management in these stands under these circumstances, contact among all said institutions must be correct and relatively frequent, and in everyday practice it is. The forest manager must consult virtually all management measures with the PLA Administration on a regular basis. All disputes must be settled in time and continuously. A large amount of stands in this area is regenerated at an age earlier than given by law. This requires a relatively frequent contact with the authorities of state administration and frequent discussions to make exceptions for felling in stands younger than 80 years. Dissolution of district offices and transferring their competency to communities with wider competency has complicated these discussions because the number of officials with whom it is necessary to deal has increased. Unambiguously it must be said that all discussions with state administration, the Administration of the PLA Litovelské Pomoraví and with local government authorities are traditionally very correct and efficient.

CONCLUSION

The extraordinary character of the floodplain forest in Litovelské Pomoraví is the object of interest both of experts and of non-professional public. The Czech Forestry Association organises scientific seminars there, universities carry out research activities, excursions of students and foresters from other parts of the Czech Republic and also from abroad come here.

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FOREST MANAGEMENT SYSTEMS IN LOWLAND FORESTS OF CROATIA

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Abstract
The lowland forests of Croatia are immense biological, ecological and general economic assets that have been managed by forestry profession for more than two centuries. The management of lowland forests in Croatia is generally based on the natural regeneration and natural forest dynamics. All silvicultural treatments are carried out with the aim of achieving the optimal stand structure throughout the stand's life cycle and preparing the site and stand for natural regeneration. In cases when the young natural generation is less dense, a combination of natural and artificial regeneration methods is used. The paper analyzes some basic features of lowland forests of willows and poplars, black alder, narrow-leaved ash and pedunculate oak.

Kew words
lowland forests, *Salix* spp., *Populus* spp., *Alnus glutinosa* Gaertn., *Fraxinus angustifolia* Vahl, *Quercus robur* L.

INTRODUCTION

The lowland forests of Croatia occur in the area north of Karlovac, mainly between the rivers Drava, Sava and Dunav. They extend at altitudes between 80 and 150 meters.

This area covers 353,487 ha in all, or 15 % of the total forested area in Croatia. Of this, 215,479 ha refer to the forests of Slavonian pedunculate oak (*Quercus robur* L.), 38,678 ha to narrow-leaved ash (*Fraxinus angustifolia* Vahl), 25,355 ha to black alder (*Alnus glutinosa* Gaertn.), 15,212 ha to autochthonous willows, primarily white willow (*Salix alba* L.), 3,754 ha to domestic poplars (*Populus alba* L. and *Populus nigra* L.), 16,290 ha to the cultures and plantations of poplars and willows, and 38,719 other hardwood. The total growing stock is 103,814,000 m^3, and the annual increment is 3,038,174 m^3 (GFMP RH 2006 – 2015).

These forest stands are found in sites that are regularly flooded, periodically flooded with high groundwater levels, and not flooded at all with a lower groundwater level (Vukelić, Rauš 2001). The characteristics of micro-relief and soil change in dependence on the duration, intensity and frequency of floods, the kind and quantity of alluvial deposits, and the fluctuations of groundwater. This directly determines the manner and type of forest management system, especially the regeneration of forest stands.

The most common types of soils are alluvial soils, gley soils, and lowland pseudo-gleys on elevations. The macroclimate of the region is continental, with mean annual temperature of 10.3 – 11.2 °C and precipitation of 800 – 900 mm in the west, and 600 – 700 mm in the east of the area (Seletković, Tikvić 2005).

The management of lowland forests in Croatia is generally based on the natural regeneration and natural forest dynamics. All silvicultural treatments are carried out with the aim of achieving the optimal stand structure throughout the stand's life cycle and preparing the site and stand for natural regeneration. In cases when the young natural generation is less dense, a combination of regeneration methods is used (natural + artificial by sowing seeds or planting seedlings).

The shelterwood system is the most widespread. The clearcutting system has never been an important method of forest management in Croatia. In fact, it is banned by the Forest Law. The exception relates to the regeneration of forest cultures and plantations and to pioneer stands (willows, poplars and black alder).

SILVICULTURE OF SOFTWOOD BROADLEAVES

Forests of willows and poplars (*Salix* spp. and *Populus* spp.)

Floodplain forests of willows and poplars are characterized by constant water and soil dynamics, which gives rise to incessant changes in site conditions. These forests are a mosaic of willow and poplar stands where stages of initial origin and optimal development alternate. The nature of willow and poplar forest dynamics ends with the terminal stage usually represented by a stand mixed with some of the hard broadleaved tree species (ash, oak).

Phytocoenological research identifies and describes the following principal natural forest communities in Croatia:

a) thicket of purple osier (*Salicetum purpureae* Wend.- Zel. 1952)
b) forest of almond willow (*Salicetum triandrae* Malc. 1929)
c) forest of white willow with bedstraw (*Galio-Salicetum albae* Rauš 1973)
d) forest of white willow and black poplar with dewberry (*Salici-Populetum nigrae rubetosum caessi* Rauš 1976)
e) forest of black and white poplar (*Populetum nigro-albae* Slav. 1952)
f) forest of spreading elm and narrow-leaved ash with pedunculate oak (*Fraxino-ulmetum laevis* Slav. 1952).

The order of these communities reveals their dynamics: from wetter towards drier communities, from more intensively flooded to those which are flooded regularly but for shorter periods, from initial towards terminal communities, from pioneer towards the final form of riparian forests (Anić et al. 2005).

The term thicket of purple osier is used to describe the morphology of these stands because of the distinct density and the rod-like appearance of the purple osier. The dense thickets enhance the accumulation of sediments and other materials and are responsible for the gradual "rising" of the terrain. These fragmentarily distributed stands have no commercial significance.

Stands of almond willow are pioneer stands inhabiting the shoals and islands in the Danube and Drava (Rauš 1992; Rauš, Matić 1990), as well as the depressions from which water retreats the latest (Pernar et al. 2004). They take up the lowest hydrographic positions of recent alluviums at the lowest boundary of forest vegetation. They are short-lived (about ten years), they occur rapidly and decline just as rapidly. As almond willow declines in one locality, its carr regenerates and develops on new sediments. Similarly to the stand type described above, dense carrs of almond willow also play an important role in sediment accumulations and in the creation of conditions for the occurrence of white willow.

The distribution of white willow stands includes riparian micro-depressions, bogs and river islands, the edges of swampy habitats. These stands continue on the previously described carrs and thickets or directly on swampy habitats. The most areas under this phytocoenosis have been ameliorated using various technical treatments, as well as hybrid poplars. Since white willow is a typical pioneer tree species, its stands undergo natural generative regeneration in bare clearcut regeneration areas (Rauš, Matić 1987).

Stands of white willow and black poplar occupy medium terrain positions above willow forests but below poplar forests. In these stands, black poplar is on the lowest boundary of its occurrence. According to Rauš (1992, 1976), this stand type forms an optimal stage in the silvidynamic development of riparian forests in Croatia.

Stands of black and white poplar inhabit the best quality sites in high positions of alluvial terraces and islands in riparian areas. For this reason, this stand type has great silvicultural importance. The composition mix may be in the form of single trees or group of trees. This stand type clearly reveals an interaction between the ecological site conditions and the biological properties of the trees. Natural regeneration is enhanced by the light and mobile seed, the annual seed crop, the sprouting vigor from the stump and roots, and water as the main ecological factor (Rauš, Matić 1990).

Stands of white willow, white willow with black poplar and stands of black and white poplar, as pioneer stands, can be regenerated with clearcutting. Strip cutting (strip width equals 2 to 3 stand heights) is recommended.

In sites in which advanced pedogenetic processes have established the conditions for the growth of pedunculate oak and narrow-leaved ash, poplar stands should be regenerated simultaneously with a change in the tree species (conversion). From the standpoint of natural forest dynamics, this involves the replacement of a pioneer or transitional forest with a terminal forest. The procedure includes natural and artificial regeneration (sowing seeds or planting seedlings) of pedunculate oak, narrow-leaved ash and other tree species that occur in the terminal community of riparian forests. Regeneration is carried out under the shelter and shelterwood cuts are applied. After opening the canopy of the old poplar stand with a seed cut, the previously prepared site should be regenerated. Site preparation involves removing weeds and shrubs that might impede regeneration, breaking up the surface soil layer and fencing off the stand. Crowns of poplar trees left for the final cut should be used to regulate the amount of light needed by oak seedlings and young growth, as well as to prevent weed growth (Anić et al. 2005a).

Stands of spreading elm and narrow-leaved ash with pedunculate oak inhabit the highest positions of riparian areas. The stands occur fragmentarily and have almost no commercial importance. The stands thrive on older and better developed alluvial soils with distinct pedogenetic processes. They represent a terminal stage in the silvidynamic development of riparian forests. Stands in the terminal developmental stage in the riparian area, with regard to silvicultural properties of the constituting tree species (pedunculate oak, narrow-leaved ash, spreading elm), are regenerated under the crown shelter of old trees. The shelterwood method in a shortened regeneration period is recommended (seed and final cut). In the event of insufficient seeding, regeneration may be combined (natural and artificial).

The area of riparian forests entails not only natural forest communities but also artificial forest stands (forest cultures and plantations) of willows and poplars. The tradition of nursery production of poplars and willows and the establishment of their cultures and plantations in Croatia goes back over 120 years (Matić et al. 2005).

Poplar cultures have a character of pioneer stands. After several decades of pioneer stand growth, the soil becomes unsuitable for poplar growth, particularly for the ecologically vulnerable clones of Euro-American and American black poplars. For these reason they should be converted and hardwood broadleaves tree species should be introduced that build up terminal natural forest communities of a floodplain area. In the lowland floodplain region of Croatia it is the pedunculate oak with its accompaniments – ash, elm, maples, hornbeam, and others. The process of establishing new poplar and willow cultures in suitable sites is simultaneously continued.

Forests of black alder (*Alnus glutinosa* Gaertn.)

Phytocoenological and synecological research has revealed a mosaic-like distribution of natural stands of black alder in the entire range of floodplain forests in Croatia (Rauš 1996, 1993, 1975, 1975a). More spacious forest complexes of black alder are found in the upper course of the river Drava, while in other regions it inhabits smaller areas in the form of small and medium-sized stands or groups and clumps of trees within the complex of pedunculate oak forests.

From the aspect of natural forest dynamics, the stands of black alder have been described in their initial, optimal and terminal stages. The stages differ with regard to the moisture degree and floral composition (Rauš, Vukelić 1998; Rauš 1975, 1971), as well as the stand morphology and structure (Anić et al. 2005). Stands in the initial and optimal stages are usually pure or may contain some willows and narrow-leaved ashes, as well as spreading elms in the optimal stage. The stands in the terminal stage are mixed. The gradually retreating black alder is accompanied by pedunculate oak, narrow-leaved ash, common hornbeam, field maple and spreading elm. In other stands of the lowland forests, black alder has the role of a secondary tree species. In pedunculate oak stands, especially the floodplain ones, it often fills the gaps in the oak tree overstorey left over from oak and elm dieback.

Black alder stands are usually regenerated in bare regeneration areas in the form of strips. Seedlings (3,000 – 5,000 pieces.ha^{-1}) are planted simultaneously. Cutting is preceded by site preparation involving the removal of ground vegetation and shrubs.

If the properties of the site inhabited by black alder stands have changed (transitional or terminal stage of natural forest dynamics) and no longer suit black alder but favor other tree species, the mixture of species should be changed. In accordance with the silvidynamic development, a transitional stand of black alder in the terminal developmental stage is replaced by a stand of pedunculate oak. This stand has the character of the final forest (climax-forest) in the lowland and floodplain regions of Croatia. The procedure is similar to that applied to poplar stands. It is accomplished under the crowns of old trees with the shelterwood method in two cuts on average (seed and final cut). Regeneration is artificial because after the seed cut the regeneration area is planted (400 – 600 kg.ha^{-1}) or sown (700 – 1,000 kg.ha^{-1}) with acorns or planted with seedlings of pedunculate oak (10,000 – 15,000 kg.ha^{-1}). Two to three years later, depending on the condition of the young growth, the parent trees of black alder are finally felled.

SILVICULTURE OF HARDWOOD BROADLEAVES

Forests of narrow-leaved ash (*Fraxinus angustifolia* Vahl)

These forests cover an area of almost 39,000 ha, of which 80 % occur in the forest complexes of the upper course of the river Sava in Croatia. They grow on distinctly clayey gleyic soils. They are regularly flooded in spring and autumn. In the complexes at Jasenovac they are exposed to the natural water regime.

Narrow-leaved ash thrives in a variety of sites ranging from wet bottomlands, where it forms a wet forest boundary towards a swamp, to fresh, humid micro-elevations. Differences in the morphology and structure of ash stands depend first of all on the frequency, duration and height of floods, the freezing of floodwater, and the water regime in the soil. From these aspects, the stands of narrow-leaved ash have been described in their initial, optimal and terminal stages (Anić 2001).

In the initial stage, the majority of the trees are deformed. The base stems are asymmetrically thickened and the stems are deformed. The trees are often forky. The level reached by flood and frozen flood water is clearly visible. In the optimal stage of development, a stand of narrow-leaved ash is in full growth. It is the most clearly delineated from other communities and has the best ecology. The optimal stage represents a typical ash forest, phytocoenologically defined by the name *Leucoio-Fraxinetum angustifoliae* (Glavač 1959). These stands are mainly pure. Deformations are still visible (centric or eccentric thickenings) at the stem base and in the lower part of the stem. Other forms of deformations (sable-like growth, twisted growth, bendiness) are less frequent. In the last, final, fresh, or terminal stage, the stand of narrow-leaved ash reaches its terminal boundary and begins to change. It assumes a transitional character. All the deformations of the trees disappear in the terminal stage of ash development. The trees have regularly developed stem bases, straight stems and high crowns.

Stands in the initial developmental stage should be allowed to develop naturally towards the optimal stage. In these stands, the seedlings of narrow-leaved ash occur but rarely reach the stage of young growth due to excessive moisture. The gradual opening of the canopy in small areas provides better conditions in the regeneration area for seedling survival and hampers weeding and waterlogging. A seeding cut should increase light intensity by a maximum of 15 %. To achieve completely successful regeneration, the regeneration area should be restocked with seedlings of narrow-leaved ash.

Stands in the optimal stage are regenerated with the shelterwood method with strip felling in two cuts (seed and final cut). In sites threatened by a false indigo invasion and in sites at risk from floods and ice, the regeneration period is prolonged with the application of a subsequent cut (Matić 1971; Dekanić 1970). In this case, trees left for the final cut should be retained in the regeneration area as long as possible. Regeneration should begin in the year of full crop or in the year following the full crop year. Depending on the stand structure, the intensity of the seed cut should be such that the level of light in the regeneration area is increased by approximately 15 %. If artificial regeneration is needed, it is recommended to plant seedlings (5,000 – 7,000 pcs.ha^{-1}).

Stands of narrow-leaved ash in the terminal stage are regenerated under the canopy of old trees with the shelterwood method in two cuts (seed and final cut). A preparatory cut will be applied depending on the closure and shape of the tree crowns in the parent stand, the composition of the lower storey, and the condition of the regeneration area. This means that regeneration will be accomplished with a combination of natural and artificial regeneration, and all tree species in the regeneration area will be used. Artificial regeneration involves the introduction of acorns or seedlings of pedunculate oak (after the seed cut) with the goal of increasing its share in the composition mix to the level reached by pedunculate oak in a floodplain forest (60 – 70 %). The rest relates to the young natural growth of narrow-leaved ash and other tree species. Reconstruction is performed in small areas, because the diversity of the micro-relief is responsible for the occurrence of young growth of narrow-leaved ash in more humid parts of the regeneration area and of pedunculate oak in drier parts of the regeneration area. Other tree species will inhabit the regeneration area in accordance with their ecological constitution.

Forests of narrow-leaved ash are among the most important floodplain forest ecosystems in Croatia. Apart from being a pioneering tree species, narrow-leaved ash also thrives in unfavorable, mostly swampy conditions where other species cannot survive. Furthermore, it is the most important tree species in the restoration of degraded pedunculate oak stands.

Forests of pedunculate oak (*Quercus robur* L.)

Pedunculate oak, which accounts for one tenth of all the forests, is the most precious tree species inhabiting lowland and floodplain regions in Slavonian part of Croatia (Slavonian oak).

Pedunculate oak in Slavonia forms two main forest associations: with *Genista elata* (*Genisto elatae-Quercetum roboris* (Ht. 1938) and with common hornbeam (*Carpino betuli-Quercetum roboris* /Anić 1959, Rauš 1969/). The first association belongs to the group of floodplain forests, while the second belongs to the group of lowland forests outside the reach of flood waters.

In Croatia, this tree species forms large coherent complexes, such as Spačva (40,000 ha), Lonjsko polje (30,000 ha), Pokuplje (10,000 ha), Repaš (5,000 ha), as well as forests in the area of Česma, Donji Miholjac, Našice, Slatina, and others (Klepac 2000).

Today, the total forest area dominated by pedunculate oak is 215,479 ha. Of this amount, 210,259 ha are under forest management. Commercial oak forests are of the first, second and third generation, starting from the first cuttings in virgin forests of Slavonian pedunculate oak. Past stands were formed with regeneration under the crown of old trees according to different variants of the shelterwood system (Matić et al. 2003, 1999; Dekanić 1974).

Pedunculate oak forests that are excluded from forest management cover 10,468 ha (Klepac, Fabijanić 1996). The aims of protecting pedunculate oak forests are manifold (Vukelić, Rauš 2001) and include the conservation of natural properties, above-average age, dimensions and high timber volume, highlighting excellent management practices in stands containing high-quality trees, stressing geographical and synecological particularities of their distribution, and others.

Management of pedunculate oak forests in Croatia has a tradition of over 200 years. Management practices are characterized by long rotation (120 – 140 years and more), intensive tending from the earliest developmental stages, early thinning and natural regeneration with the shelterwood system.

Until the 18th century, forests of pedunculate oak in Croatia were of a virgin structure and were almost untouched by any organized impact (Matić 1996). The management and use of pedunculate oak did not occur much before the 18th century. Cutting down of trees began at the end of the 18th century and culminated during the 19th century. According to the data by Šafar (1966), 98,000 ha of old forests of Slavonian pedunculate oak were cut down in the period 1860 to 1920.

Natural regeneration took place under the crowns of old trees. Different cutting methods were employed. The oldest regeneration method (Kozarac 1887) had a regeneration period lasting for 5 years. Five years prior to cutting, cattle grazing was banned in stands to be cut down. When young oak growth was dense enough, the old trees were cut down. Trees were often cut down even when there were not enough young oaks in the soil, the result being the occurrence of hornbeam or ash stands. Consequently, a cutting method with a regeneration period of 10 – 15 years was soon implemented. During this period, old oaks would seed the area and only trees of other species were cut down in order to ensure enough light for young oaks. When the young generation did not need the shelter of old oak trees any more, they were cut down. Regeneration with shelterwood cutting in two cuts, and later in three cuts, was thus introduced.

Today, commercial stands of pedunculate oak are regenerated under the crowns of old trees using the shelterwood method in two or three cuts. The regeneration period lasts for 5 – 8 years, depending on the growth of the young generation and the competition of other species. Usually, two cuts and a shorter regeneration period are applied to so-called floodplain forests of pedunculate oak (ass. *Genisto elatae-Quercetum roboris)*. Three cuts with a longer regeneration period are applied to forests of pedunculate oak with common hornbeam.

Stands are regenerated naturally or artificially. Artificial regeneration is executed according to the principles of natural regeneration. This means that after the preparatory or seeding cut, acorn is sown or planted, or two-year-old oak seedlings are planted under the crowns of old trees (Matić et al. 1999).

According to Matić (2000), successful management with forests of pedunculate oak requires that fundamental principles of management be adhered to. These are:

- Regeneration of pedunculate oak forests should be done naturally or artificially under the canopy of crowns with shelterwood felling.
- Forests of pedunculate oak can be self-regenerated on the soils possessing the properties of forest soils. Regeneration on non-forest soils (agricultural, degraded, etc.) does not ensure quality, stability and productivity of the future stand.
- To regenerate pedunculate oak naturally or artificially, 700 to 1,000 kg of acorns per hectare is needed, while artificial regeneration with a hoe requires 400 – 600 $kg.ha^{-1}$. For regeneration with seedlings, 10,000 – 15,000 $plants.ha^{-1}$ are required.
- In case of dieback or degradation of pedunculate oak stands, regeneration should be aimed at re-establishing the pedunculate oak directly if the soil has not degraded, or indirectly by planting pioneering tree species, most commonly black alder and narrow-leaved ash.

SUMMARY

The lowland forests in Croatia are immense biological, ecological and general economic assets, which have been managed by forestry profession for more than two centuries, and are among the best preserved and the most important in Europe.

They are structurally diverse ecosystems. Their morphology and structure change in dependence on the water regime, geomorphology, alluvial properties and anthropogenic impacts. A natural floodplain forest is a mosaic of regularly flooded stands, periodically flooded stands with high groundwater and unflooded stands with lower groundwater levels. In terms of origin, development, texture, structure and silvicultural treatments, there are softwood floodplain stands (with the predominance of willow, poplar, and alder) and hardwood floodplain stands (with the predominance of oak, ash, elm, hornbeam, etc.).

The lowland forests in Croatia are dynamic ecosystems. The characteristics of micro-relief and soil change in dependence on the duration, intensity and frequency of floods, regime of underground water, and the kind and quantity of alluvial deposits. Changes in the forest soil affect spatial and temporal dynamics of forest stands from wetter towards drier types. The more stable the hydro-pedological and climatic conditions are the slower and harder to notice are the changes in the dynamics of stands. When hydrological conditions change abruptly,

primarily as a consequence of hydro-technical operations in the surroundings of floodplain forests, alterations in the dynamics and structure of stands become noticeable in as short a period as several years.

Floodplain forest ecosystems are highly sensitive to anthropogenic impacts, of which a changed water regime is particularly conspicuous. As a rule, hydro-technical operations lead to changes in the sites of aquatic and terrestrial members, and particularly in the forest sites along riverbanks, causing degradation and disappearance of many members of these ecosystems. This is reflected in a decreased increment, weakened vitality, the onset of tree dieback, changes in the tree species composition and the floral structure of shrubs and ground vegetation.

The management of lowland forests in Croatia is generally based on the natural regeneration and natural forest dynamics. The shelterwood system and regeneration under the shelter are the most widespread. The clearcutting system is banned by the Forest Law. The exceptions relate to the regeneration of forest cultures and plantations, as well as to pioneer stands of willows, poplars and black alder.

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THE MANAGEMENT OF FLOODPLAIN FORESTS IN AUSTRIA

Herbert Hager, Helmut Schume, Herbert Tiefenbacher, Ernst Buchleitner

Abstract
Distribution, ecological as well as site conditions and dynamics of Austrian floodplain forests are discussed shortly. The zonation of the forest sites, occurrence of certain tree species and also site productivity has a strong dependence upon site hydrology. Human influence on these riverine ecosystems is not only limited to the modification of river systems through dams dikes and regulation measure, but forestry and also the occurrence of exotic neophytes and especially invasive species have impacted the floodplain forest and are an important factor. Two case studies of management of floodplain forests are given which stand for two quite contrasting management goals. Case study one is from a commercial forest, the Grafenegg forestry domain, where the optimized production of quality timber in the different sites is a main objective, but where also other aspects like recreational and beneficial function of these forests as well as preserving biodiversity are considered and have their value in forest management. Case study two is from the Ramsar Area of the March-Thaya-floodplain forests, where a quite different state of the forest is observed and where a multitude of large and small forest owners should contribute to the goals of nature and wetland conservation and to keep up an old cultural landscape. Threats and problems for the floodplain forests are pointed out.

Key words
floodplain forests, sites, ecology, dynamics, Austria, Danube, March-Thaya rivers, anthropogenic change

INTRODUCTION AND CHARACTERISTICS OF AUSTRIAN FLOODPLAIN FORESTS

Riverine and floodplain forest could be found in Austria at all elevation zones from high montane regions down to the lowlands. They are characterized by steady change of their morphology and sites through riverine processes like flooding, sedimentation and erosion (Seibert 1958; Hohensinner et al. 2005). Usually these processes are more decisive for the occurrence and growth of woody plant species than the zonal climatic and soil conditions. Changing ground water tables and very often ample nutrient supply as well as a strong differentiation in the particle sizes during sedimentation contribute to the great heterogeneity in site, productivity and general ecological conditions (Ellenberg 1982). Despite of the fact that riverine forests may be found along a wide altitudinal gradient and along almost all river systems the most expansive floodplains and floodplain forests could be found in the Tertiary and Quarternary basins and lowlands as well as in the U-shaped valleys of the Inner Alps of Austria.

Due to the diversity of sites and on site hydrological properties there is a very distinct and strong zonation of forest vegetation types and productivity of these types (Hager et al. 1999).

An example of such a zoning of lowland floodplain forest sites is given in Fig. 1 (Margl 1971).

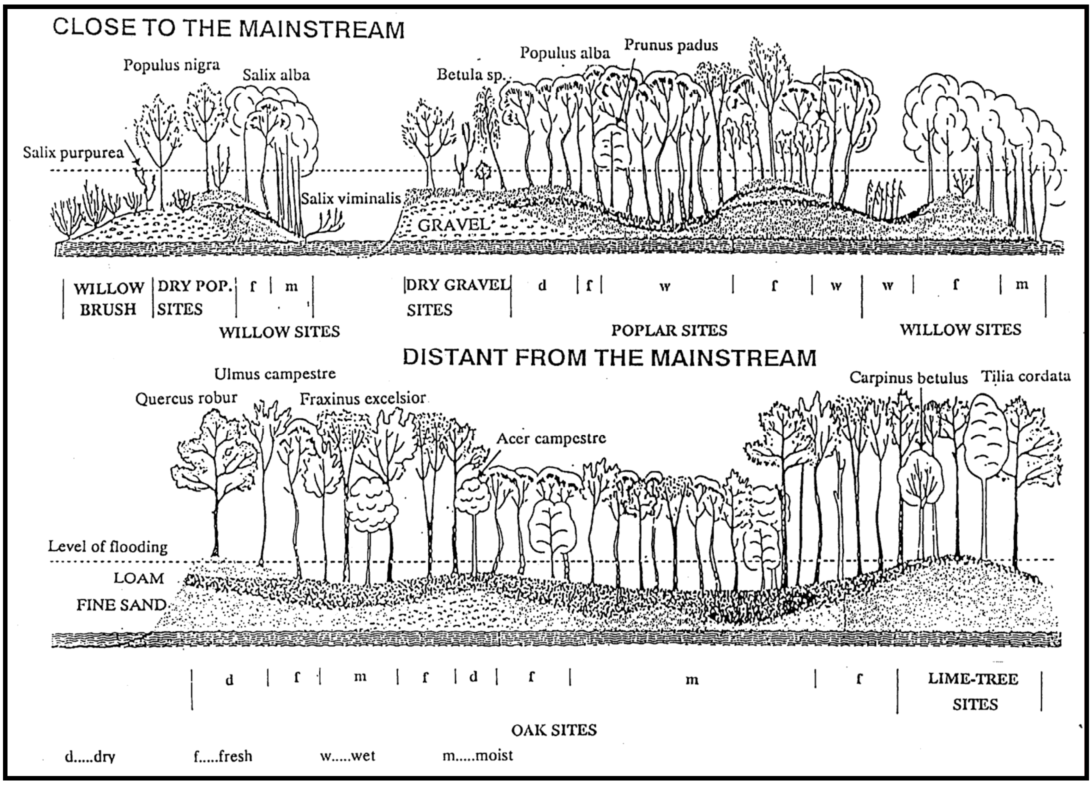

Fig. 1: Schematic zonation of floodplain forest along the Danube in Austria (modified after Margl 1971)

As can be seen from the Fig. 1, site type and site class in the floodplain forests are determined by the relative elevation as compared to the level of flooding and by the duration of flooding. Other important factors are also the texture and depth of the fine sediments above the underlying coarse gravel deposits. Usually the forest sites which are flooded for longer duration and with an annual periodicity are dominated by tree willows or poplars and are classified according to their soil water holding capacities and duration of flooding and/or duration of connection with the groundwater into wet, moist, fresh or dry site types. These site factors are also of importance for on site Leaf Area Index (LAI) and productivity e.g. yield class of the respective forest stands. An investigation in poplar sites along the Austrian Danube showed, that groundwater contact during more than 50 % of the year meant an average annual increment of 29 m^3/a while only occasional groundwater contact (less than 2 % of the year) yielded only less than 17 m^3/a (Haslinger 1998; Hager et al. 1999). The decisive site factors, like for example depth of fine sediment layers, which are so important for site class and forest productivity show considerable small and large scale variability. An investigation by Schume and Hager (2000) revealed for example that even within site units, the depth of the fine sediment layer may be vary considerably, for example from 1.3 m to 3.7 m within a horizontal distance of 30 to 50 m (Fig 2.).

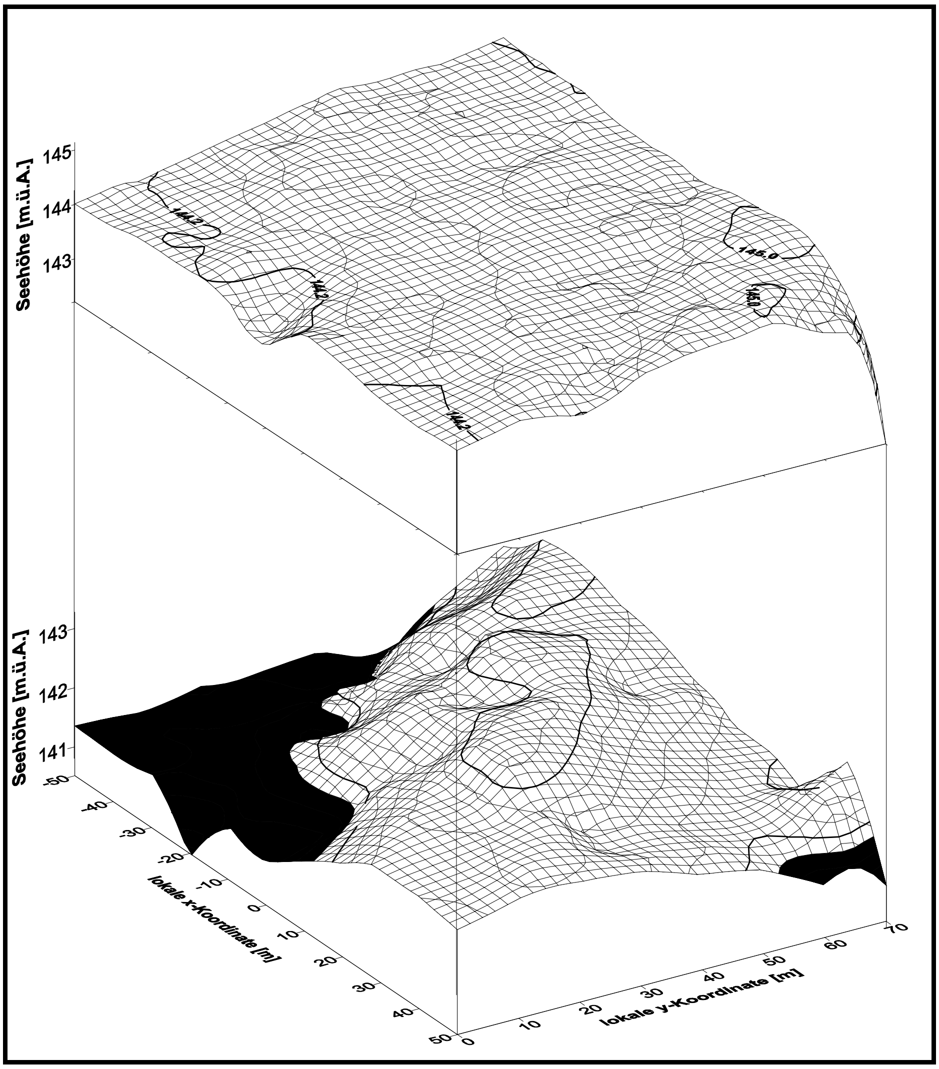

Fig. 2: 3-D Plot of soil surface vs. surface of the gravel layer. The difference in elevation between these two surfaces is equivalent to the depth of fine sediment (Schume, Hager 2000)

The variability of site factors and in consequence of site quality and productivity already indicates that it might be quite complex to manage floodplain forests in an optimal way. In addition management of floodplain forests has to take also into consideration that anthropogenic changes have impacted the ecosystems through the centuries.

ANTHROPOGENIC CHANGES IN THE RIVER FLOODPLAINS

Such changes have been described and investigated for Austrian floodplain forests in more detail by Wildmann (1926), Mader (1987) and also Hager (2000) and Hager, Schume (2002).

The most apparent among these changes are:

- river regulation and flood protection,
- dredging for shipping channels,
- construction of hydroelectric dams.

Further on forestry and also the introduction of invasive exotic plant species have altered the species composition of floodplain forest, which may also result in several management problems especially when nature conservation becomes a dominant goal in management of floodplain forests.

River regulation and flood protection measures have resulted in altered flooding and sedimentation and in grave hydrological changes of forest sites. Eisenmenger (1894) has already described the effects of the great Danube regulation of the 19^{th} century upon the floodplain forests in Austria. He cites that certain sites become drier others become more stagnant and that water circulation as well as sedimentation is severely changed and site class and productivity is generally decreasing. These observations are also repeated by Wildmann (1926), but the author is also citing older sources like a forest inventory from the domain of Hollenburg in Lower Austria, which proves that the forested area has increased after the Danube regulation due to the protection of forest land from erosion by flood water, so called “water break down” of forest stands. He found in the domain records that in 1815 (before the Danube regulation) 59 % of the land area in the floodplain was forested and 41 % fresh gravel and sand deposits or early succession stages of young brush willows. These areas have gradually vanished after the regulation.

It seems to be clear that channel dredging to improve shipping conditions is altering the cross section of the river channel and consequently stage levels of the river for runoff events are altered and thus also the hydrological conditions for the floodplain forests.

Construction of hydroelectric dams, which was rapidly progressing along the Danube after World War II, had further impact on the water cycle in the floodplain forests. Since dam construction means also lateral dike construction along the hydro reservoir, the floodplain forests become hydrologically isolated from the river, and groundwater stage levels are dampened. Only environmental remediation and restoration measures may bring a certain compensation, which may be achieved to a certain degree by dike gates and irrigation channels (“Giessgang”).

Despite of such hydrological restoration methods some sites of the floodplain forests may fall dry and others may be affected by stagnant water (Haslinger 1998; Schume 1998).

Forestry as well as invasive plant species have also had there impact on the floristic composition of floodplain forests and also the management practices. Fig. 3 shows that forestry has introduced newly bred superior hybrid species (e.g. genetic constructions which don’t occur naturally), which account for nearly one quarter of the tree species in the floodplain forests East of Vienna.

In addition so called exotic tree species make up another 7 % of the forest area. The majority of these species are invasive introduced species like *Acer negundo* L. and *Ailanthus altissima* (Mill.) Swingle or *Robinia pseudoacacia* L. These species together with invasive herbaceous plants, for example from the genera *Solidago* or *Impatiens,* can generate quite a number of problems in forest regeneration and also conflict with the goals of nature conservation in the floodplains.

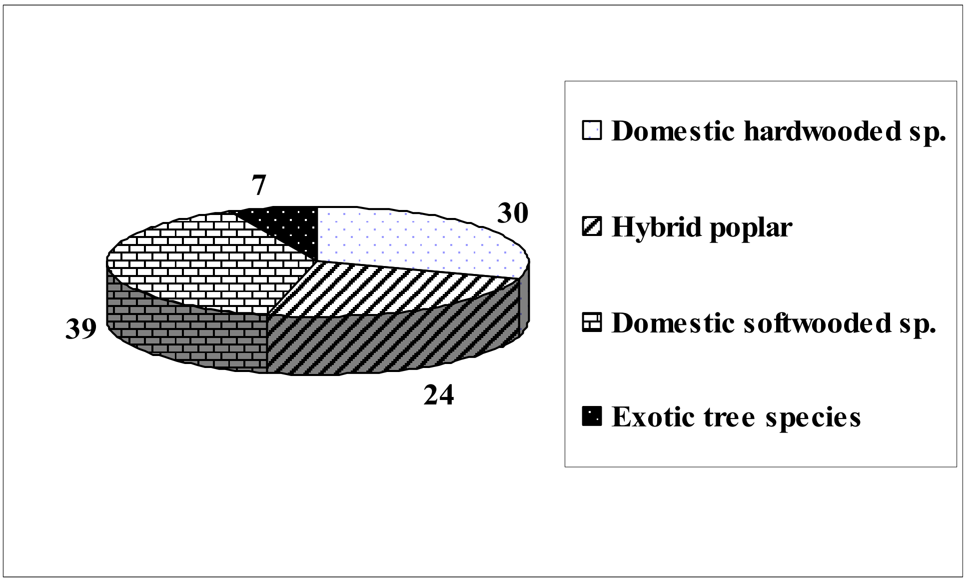

Fig. 3: Distribution of tree species in the floodplain forests along the Danube east of Vienna (Hager, Schume 2002)

CASE STUDY 1: FLOODPLAIN FOREST MANAGEMENT IN THE GRAFENEGG FOREST DOMAIN

Locality and site conditions

The floodplain forests of this forest enterprise are located along the Danube in the Tulln alluvial basin and extend from approximately 30 to 70 km west of Vienna. The Tulln basin is characterised as climatically warm and dry, with little precipitation in winter and frequent dry spells especially during spring. Long-term average annual precipitations are around 600 mm and mean annual temperature is 9.5 °C. Through the last decades a marked decrease in annual precipitation could be observed.

For the total area of the floodplains forests a detailed site classification is available (Jelem 1974). The percentage area of different site types is given in Table1.

But these site classifications were done before the construction of two hydroelectric dams (Altenwörth 1975; Greifenstein 1984). The following hydrological isolation of the floodplain forests due to lateral dikes and dams has altered the sites considerably. The frequency of smaller flooding has decreased and the amplitude of annual groundwater oscillations was dampened. The change of the average level of the groundwater table was not uniform in dependence upon the distance from the hydroelectric dam. Especially the dampened oscillation of the ground water stages has led to a deterioration of growth conditions for most of the autochthonous tree species.

Table 1: Area of different site types Grafenegg Domain Administration after Jelem (1974).

Site type	Area in %	Tree species important for forestry
Moist and wet willow sites	3	willows
Fresh willow sites	2	hybrid poplars
Moist silver poplar sites	5	
Fresh ash - poplar sites	13	
Black poplar sites	5	
Total of all softwooded floodplain sites	**28**	
Moist elm - ash sites	6	ash, black walnut
Fresh elm - ash sites	37	
Dry oak - elm sites	8	
Fresh ash- sycamore maple - elm sites	1	sycamore maple, maple
Moderately fresh oak - ash-linden sites	17	black walnut, oak
Dry oak-linden sites	3	oak
Total of all hardwooded floodplain sites	**72**	

Area, structure of woody species and development of the floodplain forests

The present day mixture of stocking species results from long-term anthropogenic influence. All forested areas were managed during the first half of the 20th century has hunting enclosures for deer and elk species, which had dramatic consequences on the tree species composition. The selective browsing led towards a loss of tree species and resulted in large areas of grey alder coppice forests. After a war caused interruption of regular management the floodplain forests were returned to an orderly practice in 1956. The hunting enclosure was taken down and through considerable silvicultral effort the composition of stocking tree species was changed towards more valuable species. The percentage cover of different forest management units could be changed by these means (Fig.4).

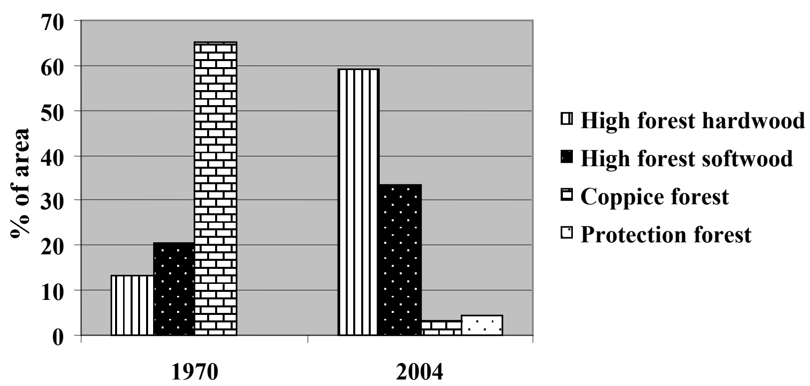

Fig. 4: Change in forest management units for the Grafenegg floodplain forests

Until 1990 fast growing hybrid poplars (controlled cross breeds between the clones of *Aigeiros* and *Tacamahaca*) were planted on vast areas of the forest land to achieve a rapid production of valuable tree species. This led to the fact that less suitable sites were also planted with these hybrids. In consequence planting of hybrids was lately reduced in favour of hardwooded broadleafs. Hybrids are now only planted on floodplain sites (approx. 30 % of the area) and also in parts of the moist to fresh sites of the hardwooded floodplain forests.

This transition from a dominant hunting domain to the production of valuable timber has changed the tree species composition considerably (Fig.5)

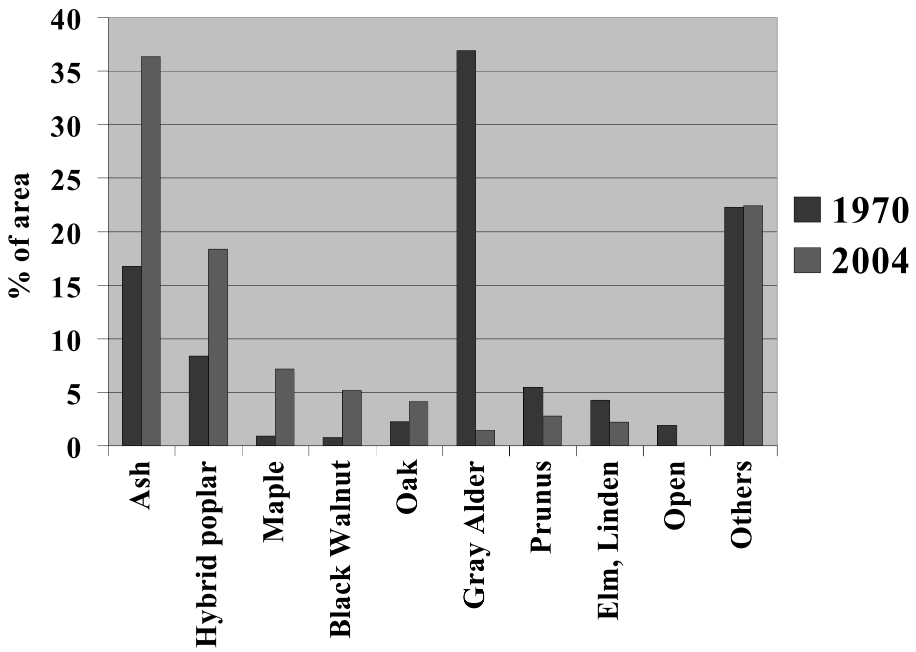

Fig. 5: Tree species composition in the Grafenegg domain in 1970 and 2004.

The priority functions of the Grafenegg floodplain forests and their realization

The priority functions of the floodplain forests in this area are very dependent upon the viewpoint of differing interest groups. From the ownership and its economic viewpoint the production function has first priority and second are recreation and (contracted) nature conservation, while from a national and regional economic as well environmental viewpoint the most important are the beneficial functions upon climate and water balance and also nature conservation. The whole floodplain forest has been declared a Natura 2000 area.

Managment of hybrid poplars

From 1940 onwards afforestation with poplar hybrids took place in special highly productive sites and also along moister ditches, the clones which were used are not documented. Between 1956 and 1959 the enterprise experienced a first wave of intensive hybrid poplar cultivation. Hybrid poplars were afforested at 3x3 m spacing, these afforestations were done nearly in a horticultural manner and were very costly. The area was fertilized the planting stock was secured with stakes and the soil around the plant was loosened by hand. Pesticides were applied as it was necessary. The clones which were used are mostly documented.

After 1960 planting and tending in hybrid poplar cultivation became highly mechanized. The spacing was altered gradually to wider spacing, from formerly 3x3 m to nowadays 8x4 m. From this time on approximately 80 different poplar clones were cultivated. Each afforestation after 1965 has a clear plan of the planted clones or species. A steady improvement of poplar clones and also a frequent change of clones have high priority. Important selection criteria for the planting stock are secure establishment of saplings, resistance against pest and disease and against damage by game animals as well as superior growth performance. To limit the risk of new stands there is no monoclonal afforestation, in each area the planting of at least 3 clones is obligatory. Presently 8 clones are used and the saplings are produced form the enterprises own plant material. The rotation period in the domain could be reduced in the last 4 decades from originally 35 to 40 years to now 26 to 27 years due to the progress in poplar breeding.

Afforestation and tending of stands are now predominantly standardized. The 8x4 m spacing means that only parts of the afforestation area are planted. Sites are prepared for planting by mulching strips of 8 m distance, the remaining area is coppiced with the goal to keep up the biological diversity onsite. Planting is done by means of a planting plough or soil corer. Usually 2 year old rooted cuttings of to 2.5 to 3 m height are planted. In red deer (elk) habitat protective fences are used, otherwise single sapling protection is sufficient.

Tending in the sapling stage means cutting severely competing vegetation and climbers and crown pruning during the first 2 years after planting. Branch pruning with extensible saws is performed afterwards at 3 different stages and reaches up to 7 m height. At the age of 7 to 10 years follows a schematic thinning, where every second poplar is removed.

Management of the hardwooded broadleaf species

In these areas young stands are either created by natural regeneration or partial area planting. But natural regeneration is limited because of the scarcity of old growth. Site preparation and planting is done similar to the hybrid poplar plantations, but with 12x1 m spacing and the tending period for the sapling stage is double length as compared to poplar. Protective fences are obligatory. In these stand selective thinning is performed in a way, so that individual crowns are without competition from the time on, when a desired clear bole length is reached. After 2/3 of the rotation period the number of dominant valuable trees should be at maximum 100 per 1 hectare.

Seeds of sycamore maple, oak, ash and linden for regeneration of the stands are predominantly coming from the forestry domains own certified source stands. All black walnut originates from Grafenegg. Most of the species are either planted or regenerated to form mixed species stands, only oaks are an exemption. Under the aspect of enhanced diversity, the planting of new species is tried regularly.

Economics of forest management

The productive area of floodplain forests in the Grafenegg forestry domain is approximately 2,500 ha and the average annual increment is between 7 and 8 $m^3.ha^{-1}.year^{-1}$. Hardwood timber under standard stand management shows the following division into quality classes: 5 % is veneer and class A, 40 % is class B and 55 % is class C saw timber. The percentage of veneer quality is very much dependent upon the market situation. With a current price bracket for ash of approx. 300 $€.m^{-3}$ for class A timber and 60 $€.m^{-3}$ for class C, a good chance can be identified for enhanced quality and revenues through more intensive stand tending.

The management goal with all species is to achieve a straight lower bole clear of all branches for at least 25 - 30 % of the total final height. The final DBH in poplars should be between 50 - 60 cm and in hardwood timber 60 - 70 cm. All important tree species, except oak, tend at a higher age towards wood discoloration and rot, which starts frequently from dead branches. This is one of the reasons to keep the rotation period as short as possible, other reasons may be also the necessity to delimit stand risk (from floods, wind storms….) and the return period for the tied up capital investment. Within the depicted management concept hybrid poplars reach harvest maturity at 25 - 30 years and hardwood timber at 60 - 70 years age (an exemption is birch). Height and diameter increment of oak is in the juvenile stages lower than in other hardwooded broadleaf species, but in later age oaks are catching up.

Grafenegg forestry domain estimates, that there is only a limited possibility to reduce costs by outsourcing services, due to the fact that there is only limited know-how concerning practical management of broadleaf forest stands within possible service providers. That's why the enterprise has to rely on its own innovation potential to optimize tending and treatment of stands. This means also that there is a higher risk for management errors which may show up later on.

Regeneration methods

One of the prerequisites for natural regeneration is superior or at least good genetic quality of the stand, which should be rejuvenated, but frequently it is missing. Naturally regenerated stands have in the Grafenegg forestry domain slower growth in the youth stages which prolongs the production period by 10 - 15 years. In naturally regenerated stands under traditional management, lasting canopy closure and steady dieback of branches leads towards discoloration of heartwood, this is especially and frequently the case with ash. It is not known a release thinning at a later stage, with a resulting enhanced diameter increment, may also decrease the risk of heartwood discoloration. Finally natural regeneration means for the Grafenegg enterprise savings in planting and site preparation costs, but these are counterbalanced by higher tending costs.

The management of planted stands can be more easily standardized and also mechanized. But one of the prerequisites, that artificial regeneration makes sense and leads towards economic success, is the availability and selection of genetically superior planting stock.

CASE STUDY 2: FLOODPLAIN FORESTS OF THE LOWER MARCH-THAYA REGION, RAMSAR AREA

The wetlands of the March and Thaya rivers in the tristate region of Austria, Czech and Slovak republic were declared a wetland-area according to the Ramsar-Convention. Therefore the main objective of this case study is to document current floodplain forest status, the management practices, threats and possible remediations in the face of an old cultural landscape and a valuable wetland area.

In the year 1991 the area was visited by an expert commission which was monitoring the observance of the Ramsar convention. In its final resume the commission documented the importance of this wetland area, but it had also to note that despite of the dedication of this area to the Ramsar convention principles, the area is experiencing considerable decline in its functionality. The monitoring commission therefore recommended that a so called "concept for sustainable and wise use of the wetlands" should be worked out. Project leadership for this effort was given by federal and provincial government authorities to the Austrian

"Distelverein". Information on the March-Thaya floodplain forests within this essay is partly drawn from the final report of the project working group on forests and forestry in the concerned area.

Area and land use

The concerned area, which was investigated for a wise land use concept of the Ramsar-Area March-Thaya floodplain forests, encompasses approximately an area of 123 km^2. It is in general terms a more or less wide strip along both rivers which extends for something like 65 km in north-south direction. Of this area there are approximately 39 % arable lands, 31 % forests 11 % built over areas (like settlements, dams or channels), 6 % open water courses and 5 % meadows, which are cut on a regular basis (Gamper et al. 1992). The forested area is close to 3,860 ha and is mainly composed of azonal floodplain forest associations within the zonal northern Subpannonian mixed oak forests. The forest area follows as an interrupted more or less wide band the course of the rivers Thaya and March between the village of Bernhardsthal and the mouth of the March river with the Danube. The largest continuous floodplain forest complexes are found between Hohenau and Drösing and respectively between Zwerndorf and Marchegg, each of them is close to 1,000 ha in area (Fig.6).

Climate of the area

The concerned area is situated within the Subpannonian climatic region of eastern Austria, which is characterized by low annual precipitation around 600 mm. Summers have a moderate precipitation maximum, where frequent droughty conditions and high temperatures can be encountered. Average temperatures for July are around 20 °C, while the annual average temperature is around 9 °C. Average monthly precipitation in the area shows two minima, one in spring and another in late summer / early fall. Winter temperatures are cold, with average temperatures of January around -2 °C. The snow cover during winters is rather sparse and not very long lasting.

During the last decades a general decrease of 10 % of annual precipitation against the long-term averages could be observed.

Geology and soils

The concerned area of the lower March-Thaya region consists mainly of terraces of pliocene age which are partly covered by a loess mantle. The lowest and youngest terrace is the present floodplain of the rivers and is composed of alluvial material, which was transported by both rivers. The alluvial material is dominantly siliceous and only traces of calcareous material are contained.

The alluvial soils along the March river are different from alluvial soils along the Danube, which may be attributed to the character of the river and also to differing geological and morphological features of the watershed area.

Alluvial soils of the area feature fine sediment content (diameter < 2mm) of nearly 100 %. Especially the average silt and clay content of 50 %, is highly responsible for the availability of soil water stores and for soil aeration. This may contribute to the fact that soils along the two rivers are heavily gleyic, and are more in character of gleysols then of alluvial soils.

Soils are also high in humus substance content and are of dark colouring down to a depth of 1 m, which points also towards poorer aeration and protection of humid substances against microbial breakdown.

Besides the above described alluvial soils (fluvisols), some forests and floodplain forests are also found on remnants of old Quarternary gravel terraces (in German so called: "Parzen"), stocking upon chernozem soils. Upon sunken terraces in lower elevations histosols may be found, many of them with disturbed water regimes and dried up.

Hydrology

River channel morphology in the lower regions of the March and Thaya rivers is of the meander type. Average annual discharge amounts to 111 $m^3.sec^{-1}$ with an average flow velocity of 0.6 $m.sec^{-1}$ in the lower reaches of the river. The area of the watershed is close to 26,000 km^2 and it spreads predominately through the lowland and lower montane elevational zones, therefore the rivers are characterized by a spring flooding regime. Average monthly discharge shows a pronounced maximum for the month March and April.

Because of the very low river bed slope, sediment transport is mostly limited to the very small grain fractions i.e. sand, silt and clays, which constitute the main bed load. Due to regulation of the stream course, bed slope of the March river was increased from 0.015 % to 0.018 %, while the slope of the Thaya river increased from 0.031 % to 0.037 %, which altered the discharge characteristics of both rivers. The construction of dams and storage basins in southern Moravia along the Thaya river altered also the discharge characteristics. March and Thaya rivers are on the Austrian side also flanked by 67 km of flood protection dams. In addition in many instances the area is cut up by a large number of drainage ditches, which are drying out some of the fields, meadows and also forests.

Forest sites and natural forest associations in the March-Thaya floodplain

The above given soil characteristics combined with a more extreme subcontinental climate leads towards the very unique composition of floodplain forest associations. The characteristic and unique tree species of these forests is *Fraxinus angustifolia* Vahl which becomes also the dominant tree species of the forests and replaces the common ash (*Fraxinus excelsior* L.).

In contrast to the floodplain forests of the Danube region, where *Alnus incana* (L.) Moench is found, in some site classes in the floodplains along the Thaya and March river, *Alnus glutinosa* (L.) Gaertn. is found, and even neophytic plant species are different between the two systems. For example *Aster parviflorus* Nees is replacing in clear-cuts along the March and Thaya river the dominating *Solidago virgaurea* L. species, which is omnipresent in such locations along the Danube floodplains. Or the frequent understorey tree species *Prunus padus* L., which is often found in the Danube forests, is completely missing in the March floodplains.

The main natural forest associations are different types of floodplain forest associations, while small fractions of the forested areas outside of the floodplains are covered with zonal oak-hornbeam forests. On special sites, like sanddunes and histosols, other special azonal forest associations are found.

For the concerned forest area (as it is displayed in Fig. 7), there is only for the Liechtenstein forestry enterprise and for the forests which are owned by the WWF a forest site mapping available. Where the site map of the Liechtenstein ownership is approximately 40 years old and is due to severe changes in the hydrology of the March and Thaya river more or less out dated. A more recent forest site map is available for the lower March floodplain forests of approximately 1,000 ha.

This site map, which was worked out and published by the Austrian Forestry Research Station (Jelem 1975), shows the site type and also the natural forest association for each site type. The pertaining site types and forest associations are given in Table 2.

Table 2: Site type and natural forest association

	1.+ 2.	Non woody associations
Soft wood	3.	Salix triandra site
	4.	Salix alba site on clay soils
	5.	Salix alba site on sandy soils
	6.	Populus nigra site
	7.	Populus alba site
Hard wood	8.	Ulmus effusa - Fraxinus angustifolia site on heavily gleyic soils
	9.	Fraxinus angustifolia - Ulmus campestre - Quercus robur site on medium gleyic soils
	10.	Fraxinus angustifolia - Quercus robur - Acer campestre - Carpinus betulus site on light gleyic soils
	11.	Fraxinus angustifolia - Tilia site on sandy soils (higher bank sediments)
	12.	Fraxinus angustifolia - Quercus robur - Tilia - Acer campestre site on tschernosem soils (Tilia sites)

Drescher (1986) mapped for 130 ha of former March river oxbows the actual and also the possible potential vegetation types and drafted some recommendations for a nature reserve oriented management of these forest areas.

Lazowski (1986) described for the concerned area the following natural forest types:

For the softwood floodplain forest: *Salicetum-triandro-viminalis*

Salicetum albae-rubentis

For the hardwood floodplain forest: *Leucojo-Fraxinetum angustifoliae*

Querco-Ulmetum

Querco-Ulmetum minoris Subass.v. Carpinus betulus

Actual forest types and tree species distribution

Through the implication of forest management practices are natural vegetation associations transformed into forest associations, which are more or less close to natural conditions. This extends in the floodplains of the March and Thaya river from pure willow or poplar coppice stands in the softwood sites, through coppice with standards of oak and ash with mixed hard- and softwoods in the understorey, towards even-aged pure ash stands with high forest management.

For approximately 50 % of the forests there are management plans, based on repeated forest inventories, available. From these forest inventory data the following tree species distribution on an area basis could be deducted:

Willows	5 % of the area	Ash	39 %
Poplars	17 %	Oak	12 %
Alder	2 %	Black Locust	3 %
Hybrid Poplar	19 %	Other species	13 %

The fraction of exotic (i.e. non autochthonous or neophytic) tree species is, with a total of approximately 10 %, comparatively low. While the floodplain forests along the Danube east of Vienna, which are in conversion towards a national park, have 33 % of exotic tree species.

When tree species proportions are compared between the northern region of Drösing - Hohenau, the southern region of Zwerndorf - Marchegg and the Danube region between Vienna and Wolfsthal, a pronounced north to south gradient, with a flowing transition between floodplain forests of the "March-river-type" and the "Danube-river-type" can be observed (Fig. 6).

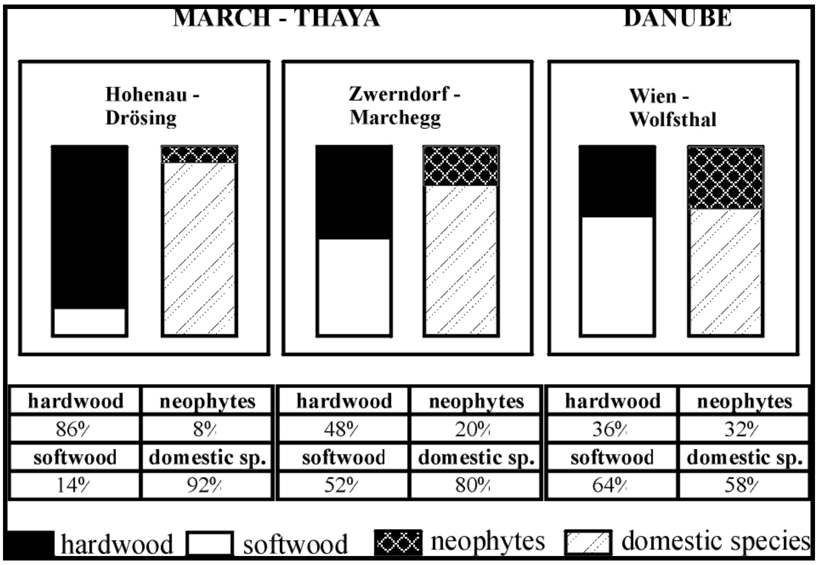

Fig. 6: Comparison of tree species composition between March-Thaya and the Danube floodplain forests

For old growth stands of the whole area Hackl, Lebenits, Lux (1993) give the following tree species composition:

Willows and Poplars	39 %	Pine	5 %
Ash	31 %	Hybrid Poplar	4 %
Oak	13 %	Other Species	8 %

Growth and age classes for the area show an exceedingly higher proportion of old growth. From the total forest area the following areas are stocked with:

Old growth	1,243 ha	Sapling stage	162 ha
Tree stage	1,120 ha	Young growth	101 ha
Pole stage	338 ha	Non stocked	262 ha

Ownership and forest users

For the development of a wise-use-concept for the Ramsar-area of the March - Thaya floodplain wetlands all forest landownerships of more than 50 ha size were investigated. More then two thirds of the total forest area is under such a landownership which exceeds 50 ha. The following "larger" forest owners could be identified:

Forest management, Nature reserve March floodplain (WWF)		814 ha	
Foundation Fürst Liechtenstein, Forest Managment Unit Hohenau		590 ha	
Agricultural communities	Drösing		
	Jedenspeigen		
	Markthof		
	Ringelsdorf		
	Stillfried		
	Zistersdorf	total	680 ha
Community Forest	Drösing		
	Weiden	total	275 ha
Sum of all large forest holdings on the March Thaya floodplain		2,360 ha	

The rest of the floodplain forest area is predominantly under ownership by individual farmers with forest lot size smaller than 50 ha. For the whole area, when agricultural community holdings are included, a total of 50 % ownership by farmers or smaller agricultural enterprises can be estimated.

Present day forest management practices

In the concerned floodplain area all three classical forest managment practices (coppice, coppice with standards and high or yield forest) are currently applied. In addition typical (plantation) treefarm management practices are found where hybrid poplars are cultivated.

Main tree species in the high forest is ash (*Fraxinus angustifolia* L.), which is predominatly grown in pure stands by the larger forestry enterprises. Besides ash another species of major importance is Oak (*Quercus robur* L.). High forest management practices are usually only implied in the sites of the hardwood floodplain forest.

From the species composition and from inventory data it can be concluded that approximately 30 % March-Thaya forest are high forests.

Coppicing with standards, also in its degraded form of coppice with only few standard trees, is practiced mainly in the agricultural community forests. It covers approximately 40 % of the forest area, mainly on intermediate sites which are neither extremly wet or dry.

In the wet sites of the softwood floodplain forests the management practice of coppicing in willow and poplar is wide spread with the smaller farmforest landholdings. Pollarding in willow is also found as a relic and dying out management practice, which is usually found along meadows or water ways. Approximately 20 to 25 % of the forest area is used for coppicing, while 5 to 10 % is used for hybrid poplar plantation forestry.

In the most xeric sites, the gravel terrace relics, coppicing is done in hornbeam forests which have very often an admixture of black locust.

An overview of forest management practices and their characteristics are given in the Table 3.

Table 3: Forest management practices in the March-Thaya floodplain forests

Management practices			
Characteristics	high forest	coppice with standards	coppice
Main tree species	ash, oak	upp.storey: ash, oak und.storey: oak,ash. poplar,elm	willow, poplar
Rotation period	80-120yr.	upp.storey: 3to5x30yr. und.storey: 30yr.	25-30yr
Regeneration practice	seeds artificial regenaration	sprouts and seeds natural regeneration	sprouts natural regeneration
Forest products	50 % saw logs 50 % fire or pulp wood	20 % saw logs 80 % fire or pulp wood	100 % fire or pulp wood
Value generated	high	medium	low
Ownership	forest enterprises	forest enterprises agricultural communities	agricult. communities farmers farmers
Ecological features	+ long rotation - mono species - one storied - artificial regneration	+ multistoried + multi species + natural regeneration	+ natural regeneration - short rotation - ptly. one storied

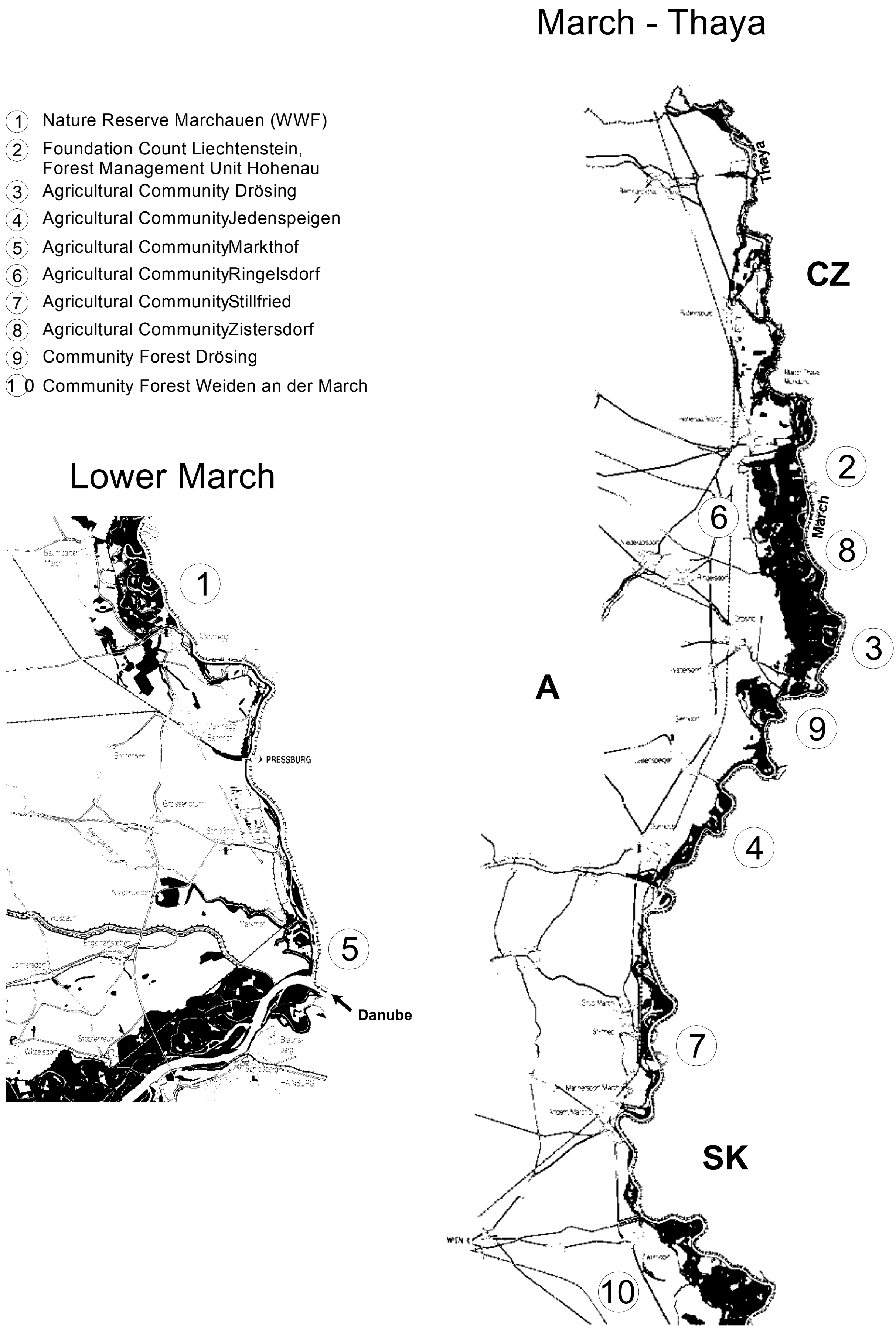

Fig. 7: Forests in the project area and forest ownership for forest land larger than 50 ha

Average wood increment in standing stock for the whole floodplain forest is estimated as between 6 and 7 $m^3 \cdot ha^{-1}.year^{-1}$, which is due to a higher proportion of hardwood tree species a little bit lower than the average increment for the Danube floodplain forests.

Threats and disturbances on the floodplain forests and possible remediation

The sustainability of the floodplain forest ecosystems is besides of minor influences hampered or endangered by seven major impacts upon the ecosystems. These are:

* Deterioration of the water relations of the sites
* Imission of atmospheric pollutants
* Introduction of exotic and not site adapted tree species
* Oak decline and oak dieback
* Oak mistletoe
* Game browsing
* Disturbances from hunting, fishing and recreational use of the forests

As cited above, floodplain forests face the most important threat from hydrologic disturbances which stem from regulation of the stream course and from hydroengineering structures. But stream water quality is also rather poor and should be ameliorated by implication of latest technology in waste water treatment. Remedies may come from opening of old branches and oxbows and routing of flows through these waterways and from extensive sewage treatment.

Forest sites are not only impacted by such classical pollutants as for instance SO_2 but also by deposition of lead and other heavy metals, as is proved by the Austrian bioindicator monitoring system. Progressing environmental standards and pollution reduction measures on both sides of the border are progressing and should bring alleviation.

Oak decline and dieback effects especially the floodplain forest oaks (*Quercus robur* L.) which are already prestressed by the disturbances and deterioration of the hydrologic regime of the March and Thaya rivers (Schume 1992; Huber 1993). Mistletoe seems to be also more successful in destabilizing of oaks, when their water relations are under disturbance. Oak decline as multiple stress phenomenon will react positive, when some stressors e.g. pollution and hydrological change are reduced or mitigated.

The endangering effect of game browsing is on the one hand related to the number of ungulates in the forest area and on the other to the disturbance of the game populations from human activities. The game management group of the Ramsar wise use study group should bring forth game management concepts which match game population size and forest regeneration needs.

The introduction of not site adapted tree species is mainly related to forest management practices. These have brought forth exotic tree species as well as introduced *Fraxinus excelsior* L. instead of *F. angustifolia* L. in the floodplain forests. Replacing the introduced species and also *F. excelsior* L. by *F. angustifolia* L. was up to recent times quite problematic because of the lack or scarcity of certified planting material for *F. angustifolia* L.

Existing nature reserves and protection areas

The floodplain forests as shown in Fig. 7 are currently falling into the following nature reserves or formal or voluntary protection zones:

Name and status	Forest area concerned
a) Ramsar area	3,860 ha
b) Nature protection zone	
Angern March oxbow	27 ha
Lower March Floodplain	814 ha
Kleiner Breitensee	x ha
c) Voluntary nature reserve (out of utilisation)	
(Austrian Water Ways Authority)	
March cutoff No. IV	16 ha
March cutoff No. VI	20 ha
March cutoff No. XV	45 ha
d) Voluntary nature reserve (use restrictions)	
(Austrian Water Ways Authority)	
March cutoff No. XIV	12 ha
March cutoff No. XVIa	18 ha

Resume

The floodplain forests of the lower March and Thaya river are despite of the quoted impacts and dangers for their existence a set of unique forest ecosystems in Central Europe. Forest management and the utilization of the forests as a resource by the local farming population have changed the primary floodplain forest into a unique cultural landscape. These impacts have also transformed some of the forest ecosystems in regard to their overall appearance, but they have left tree species composition and the stocking of forest sites fairly close to natural climax conditions. These floodplain forests, which straddle an international border with the Czech and the Slovak republics, could be judged as being meso- to oligo-hemerobic. Some threats for these floodplain forest ecosystems and their sustainability and functionality exist. Since these threats and anthropogenic impacts upon the forests exist on both sides of the border it should be a trilateral effort to either ameliorate or abolish these threats for the preservation of these treasured wetlands in the heart of Europe.

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FORESTRY MANAGEMENT SYSTEMS APPLIED TO LEIPZIG'S FLOODPLAIN FOREST

Andreas Sickert

Abstract

Leipzig's Floodplain Forest has been developed -influenced by men- to an ecosystem with a huge biodiversity, a high economical potential and a great value for recreation. The objective of its management is a maximal benefit using all important functions (ecology, economy, recreation). The City Forest Department has named exact aims for the tree species composition to strive for. The forest management is realized by a kind of high forest system with small clear cuts especially by Common Oak.

Key words

Leipzig's Floodplain Forest, maximal benefit (ecology, economy, recreation), forest management, aims for the tree species composition, sustainable use

INTRODUCTION

The landscape conservation area "Leipzig's Floodplain Forest" is located in the south-east part of Germany in the Federal State of Saxony. It includes an area of about 5,900 hectares. The total amount of woodland on the territory of the landscape conservation area is about 1,700 hectares. The City of Leipzig is the owner of about 1,200 hectares, the Federal State of Saxony of about 450 hectares and 50 hectares are private property. Parts of the landscape conservation area are more restricted as nature protection areas. The forest stretches out from the south adjoining large lignite mining sites to the Northwest along the rivers Elster, Luppe and Pleiße. A special feature of Leipzig's floodplain forest is that a large part of it is found right between built-up areas. A large portion of the forest runs right through the city from the south to the northwest and divides the urban region, whereas in other cities the forests are literally in its vicinity.

The floodplain is part of a meandering system, which is influenced by men since settlement and intensive land use began. Main features are its fertility caused by a huge loam layer accumulated as a result of wood clearings and regularly flooding in the springtime. During the last centuries this landscape has suffered dramatic changes by development and river control. Wide areas in the southern part are actually devastated. Finally the change from the coppice with standard-system to the high seedling forest system and the absence of annual flooding led to visible changes of the species diversity.

Leipzig's Floodplain Forest and its adjoining pastures and meadows have a significant importance for climate, biodiversity and recreation within the city.

CLIMATE

Leipzig's Floodplain Forest is found in an area of transition from maritime (in the centre and southern area) into a strong continental influenced climate in the western zone. Due to the different effects of the "Rain shadow" arising from the Harz Mountains on the forest area, relatively strong differences in the rainfall quantity exist.

The measured average annual sum of precipitation in the years between 1901 and 1950 at the Meteorological Station Schkeuditz was 516 mm, whereas the measurements at the Leipzig and Leipzig south stations were showing 545 mm and 621 mm respectively (data from the GDR meteorological and hydrological service).

The area right westerly of the city border was thereby allocated to the forest climate standard UTT (lower mountain positions and hilly landscape with a very dry climate). The floodplain forest located in the city region is graded in the forest climate standard UT (lower mountain positions and hilly landscape with a dry climate).

The measured mean annual temperature is about 9.0 °C.

The average length of frost period before the main vegetative season lasts 79.3 days. The main wind direction is west (46 %) (data from the GDR meteorological and hydrological service).

GEOLOGY AND SOILS

The large part of Leipzig's Floodplain Forest soil is covered with an alluvial loam layer.

The highest point in the region of Leipzig's floodplain forest is found at the "Gautzscher Spitze" (the southern floodplain forest) with a height of 111.5 m above the sea level whereas the lowest point with 95.9 metres is found in a former loam pit near the junction Hinterforstweg-Hainischer Weg.

The important and widely spread soil type in Leipzig's Floodplain Forest is the floodplain Holocene alluvial loamy soil of the Vega type. This soil type is partly gleyed and consists mainly of Bitterfeld`s alluvial loamy-semi gley.

Diluvial and alluvial gravel and sand are mainly found under the alluvial loam layer. The formation of the alluvial loam layer was the most important prerequisite for the development of the hardwood floodplain forest in the area of the present landscape protection area. The surface level was thereby increased and this led to fewer and shorter floods. Furthermore, the deposited alluvial loam has an increased nutrient value (class Rich) and a high pH –value (6-7). These processes are closely related with human settlement. Cuttings in the catchments areas of the river "Weiße Elster" and the "Pleisse" favour the erosion of uncovered soil through precipitation. The eroded material was deposited in the area of Leipzig's floodplains. Consequently the valuable hardwood floodplain forest owes its existence to a great deal to the human beings activities.

The formation of humus layer and an Ah-horizon was not able take place due to the periodic accumulation of the alluvial loam. The thickness of the alluvial loam layer and water supply are decisive for the present site conditions. The water supply was immense influenced by human activities. There was a drop in the periodical floods because of the river regulation measures and also an intense decline of the ground water table. Through this, a development in the course of some semi-terrestrial site conditions was initiated.

FORESTRY SITE CONDITIONS

There is a predominant appearance of the nutrient value standard "Rich" in the landscape protection area. Most of the sites in the floodplains are hydromorphic influenced and possess the humid standard "fresh floodplain" (Ü2) and "humid floodplain" (Ü1).

GROWTH AREAS, GROWTH DISTRICTS

Leipzig's Floodplain Forest is found in the forestry growth area 24–Leipzig's sand loess basin. The area within the margins of the floodplain (in the landscape protection area of Leipzig's floodplain forest) was identified as the growth district 2401 "Leipziger Elster Aue".

TREE SPECIES COMPOSITION

Table 1: Tree species composition (according to the actual Forest management, effective day: 1. 1. 2003)

Tree species	Proportion (%)
Ash (*Fraxinus excelsior*)	39
Common Oak (*Quercus robur*)	20
Sycamore (*Acer pseudoplatanus*) and Norway Maple (*Acer platanoides*)	20
Poplar (*Populus spec*.) and other softwood trees	5
Small-leaved Lime (*Tilia cordata*)	4
Hornbeam (*Carpinus betulus)*	3
Elms (*Ulmus* spec.)	1
Others (Common Beech (*Fagus sylvatica*), Red Oak *(Quercus rubra)*, Coniferous trees etc.)	8

DISTRIBUTION OF THE AGE GROUPS OF THE MOST IMPORTANT TREE SPECIES

In Leipzig's Floodplain Forest dominates an unbalanced age structure as the following numbers of the city forest demonstrate.

It is remarkable that Sycamore dominates in the age group II to IV that means in the age of 21 to 80 years, whereas Ash dominates in the age groups VI and VII that means in the age of 101 to 140 years. Common Oak dominates the age groups VI to VIII that means in the age of 101 to 160 years. Beside this it is remarkable that Common Oak is also found in higher age groups up to group XII that means up to 240 years.

Table 2: Distribution of the age groups of the most important tree species in the area "Burgaue"

Age Group	**Tree Species (ha)**						
	BAH	**FAH**	**FUL**	**GES**	**HBU**	**PAP**	**SEI**
1		0.1		3.3		0.2	**2.4**
2	6.0		1.0	8.9		7.7	1.2
3	**24.8**		0.4	14.4	1.0	2.1	1.6
4	**11.4**			8.5	1.6	0.8	1.5
5	9.0			14.9	1.1		4.2
6	4.5			27.0	1.1		5.0
7	2.1			**39.4**			17.1
8				2.1			1.5
9							0.2
10							0.3
12							1.8
			0.1				
Grand Total	57.8	0.1	1.5	118.5	4.8	10.8	36.8

BAH = *Acer pseudoplatanus,* FAH = *Acer campestre*
FUL = *Ulmus spec.,* GES = *Fraxinus excelsior,*
HBU = *Carpinus betulus,* PAP = *Populus spec.,*
SEI = *Quercus robur*

Table 3: Distribution of the age groups of the most important tree species in the area "Connewitzer Holz":

Age Group	**Tree Species (ha)**						
	BAH	**FAH**	**FUL**	**GES**	**HBU**	**PAP**	**SEI**
1		0.2	0.2	4.0		0.4	**5.7**
2	**21.2**	0.8	0.7	26.7	0.3	5.6	2.1
3	**42.5**			22.4	6.2	7.4	5.8
4	13.1			11.4	0.6	0.5	10.5
5	7.1			19.7	2.1		7.4
6	0.6			**58.3**			24.9
7				**36.3**	0.8		19.3
8				0.8			18.9
9							3.7
10							1.6
12							0.9
Grand Total	84.5	1.0	0.9	179.6	9.6	13.9	100.8

BAH = *Acer pseudoplatanus,* FAH = *Acer campestre*
FUL = *Ulmus spec.,* GES = *Fraxinus excelsior*
HBU = *Carpinus betulus,* PAP = *Populus spec.*
SEI = *Quercus robur*

HISTORY OF DEVELOPMENT

The intermittent depositing of alluvial sediments began about 7,300 years ago (in the middle of the atlanticum). The cause for this alluvial loam accumulation is still under discussion. Woodland clearance activities and the natural erosion process are seen as the main reasons for the sedimentation.

Site conditions were to a large extent changed due to the alluvial loam formation. The substance that formed the alluvial loam and later as sediment deposited was rich in nutrients. The nutrient rich loess eroded in the catchments area of Leipzig's rivers was the principal reason for this nutrient richness. There was and still presently a high pH-value (6-7) in the alluvial loam layer due to the relatively high calcium concentration. A humus layer and the so-called Ah-Horizon (mixture of humus and mineral soil) could not develop because of the constant sedimentation. A levelling of Leipzig's floodplain and a consequential raising of the surface level took place as a result of the alluvial loam's deposition.

The alluvial loam layers in the region of Leipzig have presently a thickness of 0.5 m (e.g. "Gautzscher Spitze") up to 4 m (e.g. in the northern area of the "Connewitzer Holz"); the average alluvial loam layer has a thickness of about 2 m. The rivers flow intensively deep in the alluvial loam's incised beds.

The rivers were still meandering but were strongly "tamed" by the alluvial loam and flow relatively less (mainly only during the floods in spring) over the shore.

The present forest sites (alluvial type of sites) were slowly built and they also created the basis for the development of the floodplain's hard wood. This meant that in connection with the increase of the alluvial loam's layer thickness and the elevation of the nutrient's supply as well as the increased water management that were beside the periodical floods relatively dry, living conditions were created whereby an increased number of the hard wood species could immigrate into this region.

A transitional forest community was at first on a large scale created. This portrayed the transition from the floodplain's soft wood to the hard wood type according to the micro sites intensity tends to one or the other forest ecosystem. This consisted mainly of highly floodwater resistant tree species of both forest communities (Common Oak, willow, poplar, alder, and elm).

The utilisation of the forest also increased because of the enlarged settlement. Large-scale wood clearing was as well carried out in the marginal areas of the floodplains. The forests outside the margins of the flood areas were to a large part cleared. The site factors were partially by means of river regulation and hydraulic engineering measures influenced. The forest utilisation was intensified, but remained mostly "sustainable". The management in the so-called coppice with standards system was predominantly created in order to meet the demand of the different wood assortment.

This meant that a few, widely spread large tree stand were left (mainly oak). The lower storey consisting mainly of coppice and root shoots developed under these trees. This underwood was after every 15-20 years cut down to gain firewood. The large trees were used to gain timber and oak must. Thereby the strong oak developed into the main stand.

The coppice with standards system in Leipzig's floodplains was maintained up to the middle of the 19^{th} century and came to an end in 1870 by means of the first forest management planning implementations.

Table 4: Tree composition around 1870 in the city forest districts of "Connewitz and "Burgaue" (around 1870)

Tree species	Connewitz Species proportion (%)	Burgaue Species proportion (%)
Common Oak *(Quercus robur)*	60	67
Elm *(Ulmus spec.)*	20	12
Hornbeam *(Carpinus betulus)*	13	7.3
Aspen *(Populus tremula)*	5	0.3
Alder *(Alnus spec.)*	0.7	2.5
Lime *(Tilia spec.)*	0.6	7.3
Maple *(Acer spec.)*	0.4	2.7
Ash *(Fraxinus excelsior)*	0.3	0.9

The figures above apparently show a less maple and ash quantity. The maple species can only withstand periodically short enduring floods and therefore they are unable to survive the regular floods taking place. The reasons for the less ash proportion is up to date not completely explained. The deliberate inequity by the forest management and the less flood tolerance (compared to the oak species) is also supposed to play a role. According to Dister (1983), the oak's flood tolerance lasts to many months, the Elm's tolerance lasts at least 100 days, the ash's tolerance goes on for a maximum of 35 to 40 days and the tolerance of Sycamore (*Acer pseudoplatanus*) amounts to 8 days.

Forest management planning implementation measures were carried out in the middle of the 19th century in the forests of the different owners. These measures brought the coppice with standards system to an end. This occurred in 1870 in Leipzig's city forest. The high forest system was later adopted and it is presently widely spread and dominant in the whole of the centre of Europe. It was besides planned to use Leipzig's city forest through the means of a clear cutting system. The tree species composition and the forest structure changed considerably after a long time due to the new silvicultural system and also to the fact that the forest was left partly to develop on its own.

The tree species that were deliberately driven back and also through this type of management underprivileged, especially the Ash *(Fraxinus excelsior)* and the Sycamore *(Acer pseudoplatanus)* found on dry sites increased their proportion and were later from now on supported because of the expected high returns and financial yields.

A relative homogeneous pure stand of the same age was developed through the facility of a felled system consisting of one or less tree species (Ash, Common Oak, Elm). Tree species that were left to grow on their own shot up from the lower up into the top storey (ash, elm).

The next large human intervention, which sustainably influenced the development of the tree species composition, was the drop of the periodical floods due to the river regulation measures undertaken on a large scale especially in the 1930s. Floods were taking place only sporadically in some parts (e.g. 1954).

There was increase of plants that did not have a great flood tolerance. This affected in the tree storeys Sycamore (*Acer pseudoplatanus*) and Norway maple (*Acer platanoides*). Recent analysis carried out by scientists from the University of Brno concerning the natural regeneration reveal partial quota of the tree species on the most found alluvial site in the floodplain forest, which is characterized by dry conditions with an enormous alluvial loam layer (Table 5).

Table 5: Partial quota of the tree species on the most found alluvial site (Klimo et al. 1996)

Tree species	**Species Proportion (%)**
Sycamore Maple *(Acer pseudoplatanus)*	74.40
Norway Maple *(Acer platanoides)*	12.30
Ash *(Fraxinus excelsior)*	7.98
Lime *(Tilia spec.)*	1.48
Hornbeam *(Carpinus betulus)*	0.44
Elm *(Ulmus spec.)*	2.10
Field maple *(Acer campestre)*	0.02
Elder *(Sambucus nigra)*	1.28

The Fungi *Ophiostoma ulmi*, which firstly made its appearance in 1919 in Holland and two years later in Leipzig led to the dying of elms (also called Dutch elm disease) in the 60s at a considerably rate. The reason for this sudden, extreme and rapid dying is certainly complicated but is connected with the appearance of the new aggressive germ *Ophiostoma novo ulmi*. This has led to a fall of the quota in the Elm species from the upper storey of Leipzig's floodplain forest. While in 1958, the percentage of elm trees was 13 %, today it is has dropped to around 0 %.

Considerable bomb damages appeared during the 2nd world war in the vicinity of the city and near strategically important targets (rail lines). This can be presently observed by the existing explosion craters. The damaged trees were cleared in the post war period. Large areas were besides cleared so that the citizens could be supplied with firewood. An average of about 15,000 m^3 woods in Leipzig's city forest was cut in the first post-war years. The reforestation especially with the maple and ash species took place after the 2nd world war on the large laid out exposed areas. This led to an increase of the proportion of these tree species and to a development of widely spread, of the same age and relatively homogeneous stock.

The cultivation of several poplar species was intensified since the 1960s in the course of so called "poplar program". This came into being so that the people's demand of mass wood could be met. The areas that were previously stocked with the elm were often reforested with poplar. A relatively high part of poplar hybrids in Floodplain Forests was therefore attained.

The changes that occurred in tree species composition; age class structure and forest picture in the last 130 years can be summarized as follows:

- The quota of the ecological important Common Oak (*Quercus robur*) tree species sank considerably. If one analyses the age class structure, it is foreseeable that this tendency would continue, if measures were not taken to make up a sustainable oak quota or increase its quota. The perishing of this tree species is likely to be a possible consequence.
- The Elm is disappeared in the tree storey.
- The Ash and Maple quota has considerably shot up. If the age class structure and the regeneration situation is analysed, it is apparently noticeable that there is a tendency to

(at least at the moment) an absolute dominance arising from these tree species. A succession in the direction of a Maple-Ash-forest is at the moment taking place without human intervention.

- A considerable quota of the tree species alien to this site especially hybrid poplar (*Populus canadensis*) was brought in by man.
- An increased uniformity of the stocks that were at one time fitted the site mosaic took place. Important differential species were dropped. Tree stocks on a large area arose with less floodplain's hardwood type of tree species that were often of the same age Sycamore *(Acer pseudoplatanus*) and Ash *(Fraxinus excelsior).* The quota of the area with a high number of different floodplain's hardwood type of tree species of not the same age decreased.
- The tree stands became poor in their structure with less marginal lines and all in all darker in the interior.
- The important tree species do not a show a regular age class distribution. A high age classification prevails within the Common Oak *(Quercus robur)* and a low one within the Norway Maple (*Acer platanoides*) and Sycamore Maple *(Acer pseudoplatanus*).

There would be a considerable decrease in the tree species variety and with it also the variety of the plant and animal species if the tendency continues as yet. They would be a perishing of species, especially those only found in the area of Leipzig's floodplain forest.

It is therefore an imperative task to counteract against the impoverishment of the biodiversity through proper interference in order to secure and to promote the biodiversity.

The forest management - one of the precise possibilities to control the tree species composition and structure of Leipzig's floodplain forests – has a crucial role to play. One of the main tasks of the forest management is to influence the tree species composition with its available means economically, wisely and of course under observation and utilisation of the natural conditions. This is aimed at maintaining Leipzig's floodplain forest stock's biodiversity, its high ecological and economical value and its landscape beautifulness.

FOREST FUNCTIONS

In 1995 a mapping of forest functions was carried out for Leipzig's Floodplain Forest. A corresponding factor of 5.3 demonstrates the huge importance of Leipzig's Floodplain Forest. Consequently a very sensitive management system was needed.

Leipzig's Floodplain Forest accomplishes three imported functions:

- Protection of natural resources (water, air, soil, biodiversity).
- Recreation;
  Since most parts of Leipzig's Floodplain forest are located near densely populated settlements, it is very important to provide the forest for recreational activities by Leipzig's citizens.
- Production;
  Every year10,000 solid cubic metres timber are harvested for industry and private purposes.

The objective of the forest management is the maximal benefit of all functions.

MANAGEMENT

The forest management applies a special form of the high forest system in order to protect and to develop a tree species composition and a crop structure aiming at the sustainable preservation of the species richness of the hardwood floodplain.

This is a very demanding task for the forest management, since esthetic and economic aspects and aspects of landscape management have to be taken into consideration. The “ideal target stands” were formulated as basis for all plannings and management measures.

The “ideal target stand” defines the tree species composition and consequently the stand mixture in a way that the continued existence of the respective biotope is sustainable saved under the afterwards dominating conditions.

The “ideal target stand” is a long term objective for the development of the forest stands, which has to be taken into account as base for all management and maintenance measures, even when in fact the objective will be reached after a very long period or never.

The following ideal average target stand for the hardwood floodplain forest was defined by historical studies, mathematical models and comparisons with other floodplain forests (Table 6).

Table 6: Ideal average target stand

Tree species	**Species Proportion (%)**
Common Oak *(Quercus robur)*	40
Elms *(Ulmus spec.)*	5
Hornbeam *(Carpinus betulus)*	10
Ash *(Fraxinus excelsior)*	20
Sycamore Maple *(Acer pseudoplatanus)*	5
Small-leaved Lime *(Tilia cordata)*	10
Field maple *(Acer campestre)*	5
Fruit trees	5

Ideal target stand was modified for all forest communities, sub-communities and variations of the landscape protection area in order to optimal adapt the conditions to the respective micro-site.

In order to calculate the regeneration areas, which are necessary for a sustainable development as well as for the protection of the ideal target stand, the rotation age for the different species were determined (Table 7).

Table 7: Rotation age for different species

Tree species	**Rotation age (years)**
Common Oak *(Quercus robur)*	240
Sessile Oak *(Quercus petraea)*	240
Ash *(Fraxinus excelsior)*	140
Small-leaved Lime *(Tilia cordata)*	140
Hornbeam *(Carpinus betulus)*	140
Field Maple *(Acer campestre)*	140
Sycamore (*Acer pseudoplatanus*)	140
Elms *(Ulmus spec.)*	140
Wild Cherry *(Prunus avium)*	140
Common Alder *(Alnus glutinosa)*	120
Willow *(Salix spec.)*	100
Bird cherry *(Prunus padus)*	80
Crap Apple *(Malus sylvestris)*	140
Common Pear *(Pyrus communis)*	140
Rowan *(Sorbus aucuparia)*	140
Birch *(Betula pendula)*	120
Aspen *(Populus tremula)*	120
Black Poplar *(Populus nigra)*	120

The aim is a evenly distribution of the aging classes among all tree species. Using the target values and the rotation age the annual regeneration area for the most important tree species can be calculated, for example for Common Oak *(Quercus robur)*:

Area of Leipzig's Floodplain Forest: 1,700 ha

Rotation age for Common Oak: 240 years

Targest value for Common Oak: 40 %

Averaged annual regeneration area = X

$$X = \frac{1{,}700 ha * 40\%}{240 years * 100\%} = 2.83 \text{ ha/year}$$

That means that for a period of a forest management, in fact for ten years about 28 ha regeneration area needs to be planned. The target values and rotation ages were already taken into account in the last forest management for Leipzig's city forest in the Floodplain Forest.

The forest management has to take into account many factors realizing these results. Three of the most important ones are:

- The different light demands of the floodplain tree species and the different light transmission ability, e.g. it is not possible to plant Common Oak under the canopy of maples.
- The different growth during the juvenile phase;

  Therefore it is possible to mix Common Oak and limes. A mixture of Common Oak with Sycamore Maple or even Smooth-leaved Elm is not possible cause by its fast juvenile growth.
- The existing potential on fruit developing trees and natural regeneration;

  While an artificial regeneration of Sycamore and partially also of Ash is mostly not necessary, there is no potential for a natural regeneration of Common Oak under the given circumstances.

In order to regulate the degree of mixture first of all a thinning will be realized onto the total plot.

During this cut a selection of phenotypes and a regulation of growing space by reduction of the number of trunks are carried out to a large extent.

If there are Common Oaks in the plot they can be promoted if their share needs to be increased. This offers the opportunity to increase the share of this species – also in the higher age classes. For semi-light-demanding tree species, especially for Common Oak, the group selection method of cutting is applied to create small clear cuts for regeneration. These small clear cuts must have a minimum diameter of 30 – 50 metres to cover a sufficient light supply for the young trees. After clearing away the timber the possibly existing natural regenerated trees are maintained and promoted. Subsequently Common Oak *(Quercus robur)* and, if necessary, Common Alder *(Alnus glutinosa)* will be planted. To realise to aim it can be necessary to establish Ash as well. In this case small clear cuts with a diameter of less than 30 metres should be used. Otherwise the semi-tolerant timber tree species to be promoted like Small-leaved Lime, Hornbeam, Field Maple, and Bird Cherry are planted on existing cleared spots and under the pervious canopy. They will be maintained during the next years.

In our work the following heights of the plants used are well-tried (Table 8). Common Oaks are planted using a plant spacing of 2x1m.

Table 8: Heights of the plants

Common Oak *(Quercus robur)* Small-leaved Lime *(Tilia cordata)* Hornbeam *(Carpinus betulus)*	30 – 50 cm
Field Maple *(Acer campestre)* Sycamore Maple (*Acer pseudoplatanus*) Ash *(Fraxinus excelsior)* Bird cherry *(Prunus padus)* Elms *(Ulmus spec.)* Others	100 – 150 cm

ECONOMICAL ASPECTS

In the previous years cutting, setting trees, establishment of paths and fences were almost completely carried out by private companies, whereas the maintenance and the dismantling of the fences were done by workers of the City of Leipzig.

Table 9: The costs of the forest enterprise of the City of Leipzig

Costs for overhead incl. management staff	35,988 €
Costs for personnel (workers)	64,108 €
Costs of taxes, material, machines etc.	51,525 €
Sum output in 2007	151,621 €
Awaiting input in 2007	>155,000 €

From this it follows that the forest management is possible without any subsidies despite considerable restrictions.

COOPERATION WITH NATIONAL NGO'S AND NATURE PROTECTION AUTHORITIES

The cooperation with the authorities for nature protection and NGOs can be evaluated as good and constructive. This can be proved in the way that newer guidelines for the landscape protection area and the nature protection area take into account the group selection method of cutting for a sustainable maintenance and protection of Common Oak. Therefore it is possible to say that the forest management of Leipzig's Floodplain Forest is demanded by law.

There is also a well-tried round table "city forest", where nature protection authorities, NGOs and scientists come together twice or three times a year to discuss and communicate planned forestry measures. This is also an opportunity to consult the staff of the City Forest Department directly and unbureaucratically. Public relations are quite important for the City Forest Department as well as to communicate its plannings.

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II. BLOCK: REGENERATION OF FLOODPLAIN FOREST SITES

EFFECT OF THE SIZE OF REGENERATION ELEMENTS (CLEARCUT AREAS) ON THE GROWTH OF PEDUNCULATE OAK (*QUERCUS ROBUR* L.) IN ARTIFICIAL REGENERATION

Pavel Hobza, Oldřich Mauer, Pavel Fibich, David Jirman

Abstract

Growth dynamics and vitality of pedunculate oak plantations growing on clearcut areas of different size (0.10 ha, 0.20 ha, 0.50 ha, 1.00 ha and 2.00 ha) were studied on floodplain sites. On each of five established research plots 2 marginal transects and 1 middle transect were laid out. Plants were assessed for 2 measured parameters, 3 derived parameters and for a total of 5 visually evaluated traits. The survey showed that the pedunculate oak is not such an orthodox light-demander as traditionally claimed. Clearcuts sized 0.10 ha and 0.20 ha are inadvisable for planting, and even the clearcut sized 0.50 ha may represent a certain risk. In contrast, clearcuts of 1.00 ha and 2.00 ha provide favourable conditions for the successful growth of pedunculate oak plantations. Statistically significant differences were demonstrated to exist in the growth of plants on marginal transects and on the transect situated in the middle.

Key words

floodplain forest, pedunculate oak, lighting

INTRODUCTION AND OBJECTIVES

Pedunculate oak is one of the most important commercial tree species of our floodplain forests. Natural distribution of pedunculate oak is mostly of zonal character in the Czech territory, which is given by the course of large rivers. Pedunculate oak used to occur on sites with only short lasting spring inundations (so called hardwood forest of lowland rivers). However, according to Úradníček and Chmelař (1998) it never produced pure stands and in the zone of hardwood floodplain it was growing in a mixture together with ash and elm. Areas with the occurrence of pedunculate oak have experienced great changes under the influence of humans. These sites were at all times most fertile for farming and the natural floodplain forests were therefore gradually felled. At the same time, the inundations were restrained and the groundwater table lowered by the controlled regulation of water courses (Mráz 1979). The measures resulted in a pronounced change of site conditions and in the changed species composition. In these anthropogenically disturbed localities the pedunculate oak has a severe competition in other tree species which massively regenerate under conditions of alluvial plains (field maple, linden and hornbeam).

Natural regeneration of pedunculate oak is rather complicated in our conditions, the supply of self-seeding being extremely low and the regeneration being too lengthy (Vyskot et al. 1978). A great threat is also seen in the precocious mass regeneration of undesirable tree species (field maple, hornbeam and linden). Possibilities for the natural regeneration of pedunculate oak in Czech conditions were studied in detailed by Houšková (2004).

Regarding the above acts, artificial regeneration is the most commonly used method for regenerating pedunculate oak in the Czech Republic. The pedunculate oak being a distinctly light-loving species, the artificial regeneration is made by planting or sowing on a clearcut area. In the case of natural floodplain sites the Czech legislation even provides for an exemption in establishing the clearcut area size at final intentional felling with an anchored possibility of large-scale clearcut area up to 2 ha with no limitation of width. And it was exactly the size of the clearcut area that has become a subject to many discussions among foresters because the contemporary principles of near-natural forest management try to curb the size of clearcut areas. However, a question remains to be asked whether it is really useful to force in the trend also in floodplain forests for the regeneration of pedunculate oak.

The objective of this paper is to compare the growth dynamics and vitality of pedunculate oak plantations on clear-felled areas of different size and to evaluate the impact of regeneration element size on the growth of pedunculate oak plantations. Moreover, the work should give an answer to the question what is the smallest clearcut size for the successful growth of plantations on the floodplain sites.

MATERIAL AND METHODS

In 2005, a total number of 8 permanent research plots were established in the territory of Litovelské Pomoraví Protected Landscape Area (PLA) – Natural Forest Region 34 - Hornomoravský úval Graben, for a continual monitoring and evaluation of the growth of pedunculate oak plantations. The research plots were established on clearcut areas after final felling. The paper includes results from 4 research plots. Other plots were not included since the character of their establishment does not correspond with the set up objective of the paper. The size of clearcuts is 0.10 ha (1 plot), 0.20 ha (1 plot), 0.50 ha (1 plot) and 1.00 ha (1 plot). The research plots are situated at an altitude of about 230 m a.s.l. in air-pollution danger zone D. Typologically the sites are classified in forest type 1L2. A control plot in this experiment was a clearcut area of 1.98 ha (hereinafter 2.00 ha) in the territory of Židlochovice Forest Enterprise LČR, s.p. (Natural Forest Region 35 - Jihomoravské úvaly Grabens). Altitude 160 m a.s.l., air-pollution danger zone D, FT 1L1. All plots are fenced.

The individual research plots contain 3 transects. On each plot a primary transect was alligned which determined the centre of the clear-felled area (middle) and 2 marginal transects which were designated by their aspect to cardinal points (northern and southern). The marginal transects reach to a distance of ca. 15 m from the clearcut edge. Starting point for this division was an effort to capture differences in the growth of individuals occurring in the most insolated middle transect and in the marginal transects where the clear-felled area is in some cases sheltered by the wall of surrounding stands (see the characterization of research plots).

Field surveys were carried out in 2005 and 2007. Each transect was laid out so that a minimum amount of 100 plants could be monitored. The measurements were focused on a total loss from the time of planting to the given year of measurement. Each plant was then measured for 2 basic growth parameters and for 5 visually assessed traits. Three derived growth parameters were calculated for a mutual comparison of the research plots.

<u>Characterization of research plots</u>

- Stand 768D 1a (0.10 ha); forest district Střeň, LS Šternberk LČR, s.p.

  A clear-felled area sized 0.10 ha was created in the mature stand, on which the pedunculate oak (DB) was planted in the spring of 1999. The clearcut is of rectangular shape (33x30 m) and is from all sides sheltered by the mature stand, av. height 32 m, stocking 1.0.

- Stand 770B 12/2 (0.20 ha); forest district Střeň, LS Šternberk LČR, s.p.

  A clear-felled area sized 0.20 ha was created in the mature stand, on which the pedunculate oak (DB) was planted in the spring of 2003. The clearcut is of circular shape (diam. ca. 50 m) and is from all sides sheltered by the mature stand, av. height 31 m, stocking 1.0.

- Stand 35B 16/7y (0.50 ha); LS Březová, Lesy města Olomouc

  A clear-felled area sized 0.50 ha was created in the mature stand, on which the pedunculate oak (DB) was planted in the spring of 2003. The clearcut is of rectangular shape (125x40 m) and its longer side is situated in the E-W aspect. The clearcut is sheltered from all sides by the surrounding mature stand, height 28 m, stocking 1.0.

- Stand 33D 12/7x (1.00 ha); LS Březová, Lesy města Olomouc

  A clear-felled area sized 1.00 ha was created on which DB was planted in the spring of 2003. The clearcut is of rectangular shape (200x50 m) and its longer side is situated in the E-W aspect. The clearcut is sheltered from the south, east and west by the mature stand of 30 m in height and 0.9 in stocking, and from the north it is sheltered by a young stand of 13 m av. height and 1.0 stocking.

- Stand 917B 10 (2.00 ha); Forest District Tvrdonice, LZ Židlochovice LČR, s.p.

  A clear-felled area sized 2.00 ha was created and subjected to whole-area site preparation (slash removal, removal of stumps by AHVI rotary tillers and subsequent loosening of soil to a depth of 20 cm), after which DB was planted in the autumn of 2003. The clearcut is of rectangular shape (220x90 m) and its longer side is situated in the N-S aspect. The clearcut is sheltered from the south, east and west by the mature stand, av. height 32 m, stocking 0.9, and from the north by a young stand, height 15 m, stocking 1.0.

<u>Assessed parameters and traits of plants</u>

Total height (cm) – measured from the ground surface up to the tip of terminal bud.

Root collar diameter (mm) – gives the stem diameter of the plant at height of 10 cm above the ground surface.

Mean annual height increment (cm) – derived growth parameter; it is calculated as mean periodical increment for 2005-2007, expressing mean annual terminal bud increment for the period of time.

Mean annual diameter increment (mm) – derived growth parameter; it is calculated as mean periodical increment for 2005-2007, expressing mean annual stem diameter increment for the given period of time.

Slenderness ratio – derived growth parameter; it is calculated as mean value of the ratio of total height (cm) and root collar diameter (cm) for each plant.

Stem form – is classified according to a scale of three degrees:

- cylindrical stem – unbranched stem with only one shoot; in the case of other shoots, these must not be of diameter greater than a half diameter of the terminal shoot
- fork – stem forked into two shoots with none of them being of diameter smaller than a half diameter of the other one
- multiple – stem branched into three and more equal shoots of the same diameter

Crown form – is classified according to a scale of three degrees:

- crown shape

    1. elliptical (E) – crown of regular shape, crown length is greater than crown width
    2. spherical (K) – crown of irregular shape, crown length is approximately same as crown width
    3. one-directional (J) – crown of irregular shape, crown branches spreading in one direction

- number of branches (pcs) – average number of branches of diameter > 3 mm on each plant
- diameter of the sturdiest branch (mm) – average diameter of the sturdiest branch on each plant

Vitality of plants – 2 categories:

- colour of assimilatory organs – two basic colours
    1. green – plant without any changes due to deficiency disease, assimilatory organs are green (colour 100 %/100 %, p. 3 in the VÚP colour table)
    2. yellow – plant shows changes due to deficiency disease, assimilatory organs are yellowish to yellow (colour 100 %/89 % and less, p. 3 in the VÚP colour table)
- average leaf size – assessed was the mean length of the leaf blade (mm) and the mean width of the leaf blade (mm). Leaves for sampling were taken at about 2/3 of the total plant height

Stem injury – damage to the stem or to the terminal shoot or bud

- dry terminal – expresses the dieback of terminal bud, a part of or a complete shoot
- nipping by rodents – expresses injury by nipping on the stem and lateral branches

Damage to assimilatory organs

- infestation by oak mildew (*Microsphaera alphitoides* Griff. et Maubl.) – shows in pale stains up to white coat on leaves, at a more advanced stage by necrotic spots, drying leaf margins and Lammas shoots. To be registered, the damage needs be greater than 50 % of the plant's foliage
- insect feeding – damages caused by insects from the families of Tenthredinidae, Tischeriidae, Geometridae and Chrysomelidae – feeding on leaf margins, mining and skeletonizing. To be registered, the damage needs be greater than 50 % of the plant's foliage

In the tables of results, the growth parameters of total height and root collar diameter are expressed by the arithmetic mean with the standard deviation. These parameters were then subjected to a statistic comparison (one-factor ANOVA, level of significance $\alpha = 0.05$) at two basic levels as follows:

- Differences between the individual transects were determined on each research plot. Significance of statistic variances was assessed by using Dunnett's test with the control. The control was the middle transect. The + sign in the table of results (in the first column behind the numeral) indicates a statistically significant variance, the -sign is for a statistically insignificant variance.

- Differences were determined between the individual research plots. Significance of statistic variances was assessed by using Dunnett's test with the control. The control was Plot 917B 10 (2.00 ha) and a mutual comparison was made of transect groups (middle, northern, southern). The +sign in the table of results (in the second column behind the numeral) indicates a statistically significant variance, the –sign is for a statistically insignificant variance.

Other growth parameters and traits in the tables of results or in diagrams are expressed as arithmetic means or in percentage of the occurrence in the total count of individuals (with slenderness ratio being the only dimension-less variable).

On 28 August 2007, a benchmark measurement was made of lighting of the individual part of clear-felled areas by calibrated luxmeter PU 550. The measurements were carried out only on the plots situated in Litovelské Pomoraví under sunny weather at the time from 10.30 to 11.30. On each plot, the lighting was determined in the stand whose density was 1.0, in the shaded margin, in the partly insolated margin (diffuse light through tree crowns), and in the insolated middle of the clearcut.

Table 1: Lighting of the respective clearcut parts

Place of measurement	**Average lighting (lux)**	**Number of measurements**
Stand (stocking 1.0)	733 ± 240	8
Clearcut margin (shade)	2,900 ± 1,112	8
Clearcut margin (diffuse light)	16,467 ± 3,004	8
Clearcut middle (light)	45,000 ± 5,132	8

RESULTS AND THEIR EVALUATION

Evaluation of total losses since the reforestation (Tab. 2)

The highest losses were recorded on plots sized 0.10 and 0.20 ha. In 2007, the average loss was 86 % and 56 %, respectively. This indicates a 15 % increase on the plot sized 0.10 ha and even a 47 % increase on the plot sized 0.20 ha. Other plots exhibited markedly lower losses to 2007 with the highest average loss being 26 % with the increase of 14 % in the studied period of 3 years (Plot 33D 12/7x – 1.00 ha). It should be pointed out that no serious damage due to biotic factors was recorded on the research plots, which would have affected the dieback of plants. Thus, the total losses can be considered as a result of the influence of site and stand conditions.

Evaluation of height and diameter growth

a) Mutual comparison of individual research plots according to the clearcut size (Tab. 2)

The greatest differences in the growth of plants can be seen namely in the comparison of root collar diameter in 2005 and 2007, in which the best results were achieved by the plot sized 2.00 ha. Plants growing on this plot reached the highest mean values and as compared with the other plots the differences in 2007 are mostly highly significant (being insignificant in 2005). Contrary to these findings, the least mean values were recorded in plants growing on the plots sized 0.10 ha, 0.20 ha and 0.50 ha. From the comparison of total height it can be stated that mean values recorded in the plots sized 0.50 ha, 1.00 ha and 2.00 ha were relatively balanced in the two years of research. The lowest figures in 2007 were measured in the plot sized 0.20 m. While the height differences were not expressive in 2005, the figures of 2007 are already statistically highly significant. Although the highest values are reached by plants growing on the plot sized 0.10 ha, the age difference of 4 years has to be taken into account in the evaluation.

Growth dynamics of plantations on the respective plots can be best understood from Fig. 1 and Fig. 2 which present a comparison of mean annual height and diameter increments. Fig. 2 shows that the greatest diameter increments were observed in plants growing on the clearcuts sized 2.00 ha and 1.00 ha. On the other hand, the least diameter increment values were recorded in the clearcuts sized 0.50 ha, 0.20 ha and 0.10 ha. Fig. 1 shows the evenness of height increments on the plots 0.50 ha, 1.00 ha and 2.00 ha and the retarded growth on the plots 0.10 ha and 0.20 ha. Apart from that, the plot sized 0.10 ha has to be again taken into account as that with the plantation of greater age, and as a plot with extremely high losses, in which only the most vital plants survived the end of the experiment.

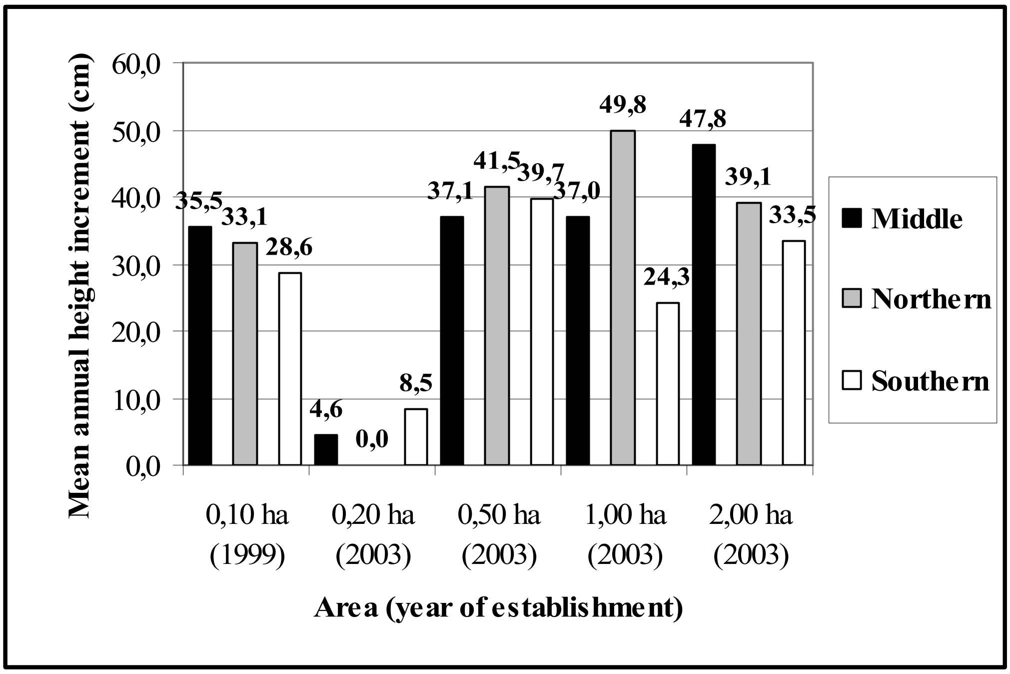

Fig. 1: Mean annual height increment (cm) on the respective transects of research plots

b) Comparison of transects within the respective research plots (Tab. 2)

Negative impact of clearcut shading by the surrounding mature stand was unamibugously demonstrated on plots sized 0.10 ha and 0.20 ha with the average height of plants on the middle transects being greater than the average height of plants on the marginal transects. The differences are in a majority of cases statistically highly significant both in 2005 and in 2007. In small clearcuts, the marginal part may constitute up to 90 % of the total clearcut area (with the margin breadth of 15 m). In some cases, (if the surrounding stand is high-grown), certain parts of the clearcut may be shaded whole day and height differentiation of plants may occur between them. Root collar diameter was less succeptible to reflect the impact of shading on the respective transects of small-sized clearcuts. In spite of the fact that the values of root collar diameter of plants growing on the middle transects were highest, differences between them were not statistically significant.

No differences between the respective transects were found on the plot sized 0.50 ha. The marginal part of the clearcut still constitutes more than 50 % of the total clearcut area. If the surrounding stand is high-grown, most of plants grow in the clearcut sections with impaired light treat.

The plots of 1.00 ha and 2.00 ha exhibited differences between the middle transect and the marginal transects. Although the size of these clearcuts provides during the daytime for a greater light treat also for plants growing on the marginal sections (marginal part of the clearcut constituting less than 50 % of total clearcut area), the shelter of surrounding stand is again an important factor. If the clearcut neighbours with the stands of lower height which do not cast greater shade (in this case northern transects), the average height of plants in the marginal transects is approximately identical and sometimes even greater than the height of plants growing in the middle transects. Nevertheless, if the variances occurred, they were not statistically significant. In contrast, the average height of plants in the middle transect on the plots the margins of which are strongly shaded by the mature stand (in this case southern transects) is 5 to 6 years after planting again higher than the height of plants growing in the marginal transects. The difference was in 2007 again highly statistically significant in most of the cases. The trend of diameter growth was similar to that of height growth.

The different light conditions are documented in Table 1 which brings the values of mean lighting in the respective clearcut sections. Lighting in the middle of the clearcut is up to 15-times greater than in the shaded marginal part and nearly 3-times greater than in the partly insolated marginal part (diffuse light through tree crowns).

c) Growth dynamics comparison according to the slenderness ratio (Tab. 2)

The worst slenderness ratio was recorded on the plot of 0.10 ha (in both years of research) and on the plot 0.50 ha (in 2007). The increased values of slenderness ratio indicate a faster height growth at a cost of diameter growth (growth for light). The increasing slenderness ratio leads to the impaired mechanical stability of plantations (stem bending, risk of breakages at snowhung). Similar results were arrived at by Bártová (2002). This means that in the future, most threatened may be exactly the stands which were growing up on shaded small-sized clearcuts (in our case the clearcuts sized 0.10 ha, 0.20 ha and 0.50 ha). The best result were achieved by plantations on the plots sized 2.00 ha and 1.00 ha with the slenderness ratio values on these plots being by up to 30 % lower than on the plot of 0.10 ha.

Evaluation of stem form (Tab. 3)

The evaluation of the stem form in the respective years of measurement shows that clearcut size has no direct link to the shape of plants on the research plots. Neither a functional dependence was found between the percent representation of determined stem forms on the respective transects within each of the plots. The youngest plantations are likely to have the stem form most affected by the planting stock quality. Stem form is also directly affected by the potential injury. The percentage of injured plants on some plots is up to 30 % (see Tab. 4).

A mutual comparison of values from 2005 and 2007 indicates that the percentage of plants with the cylindrical stem increased on all plots and also on all transects (with the exception of plot 0.50 ha where the highest percentage of plants with stem injuries was recorded).

Evaluation of crown form (Tab. 3)

The growth of crown is closely related to also by the trait of crown form which was assessed in 2007. The worst results (spherical and one-directional form) was recorded on the plot sized 0.20 ha with the least mean height increments. If the plants reduce their height growth, the crowns tend to spread and negative crown forms (so called wolf trees) are produced.

The number of branches in the crown is increasing with the increasing clearcut size. The plot sized 2.00 ha exhibits nearly 3-times more branches than the plots of 0.10 ha and 0.20 ha. The higher number of branches in the crown apparently relates to the greater lighting of the clearcut. On the other hand, values of the parameter diameter of the sturdiest branch are relatively equal on all plots with the exception of plot 0.20 ha that markedly lags behind the other. A question is whether the shading would not impair the good shape of crown and stem in the further development.

Evaluation of vitality (Tab. 4)

The largest mean leaf size was observed on plots 1.00 ha and 2.00 ha, the smallest leaf size was recorded on plots 0.20 ha and 0.10 ha. The size of assimilatory apparatus is increasing with the increasing clearcut size. The finding was demonstrated only on the plots in Litovelské Pomoraví.

No dependence was found between the colour of assimilatory organs and the clearcut size. Neither there were any differences found in the vitality of plants growing on the middle transects and plants growing on the marginal transects. Yellow colour of assimilatory organs was recorded only in plants injured by small rodents nipping, and in plants excessively infested by mildew or plants injured during the protective treatment of plantations.

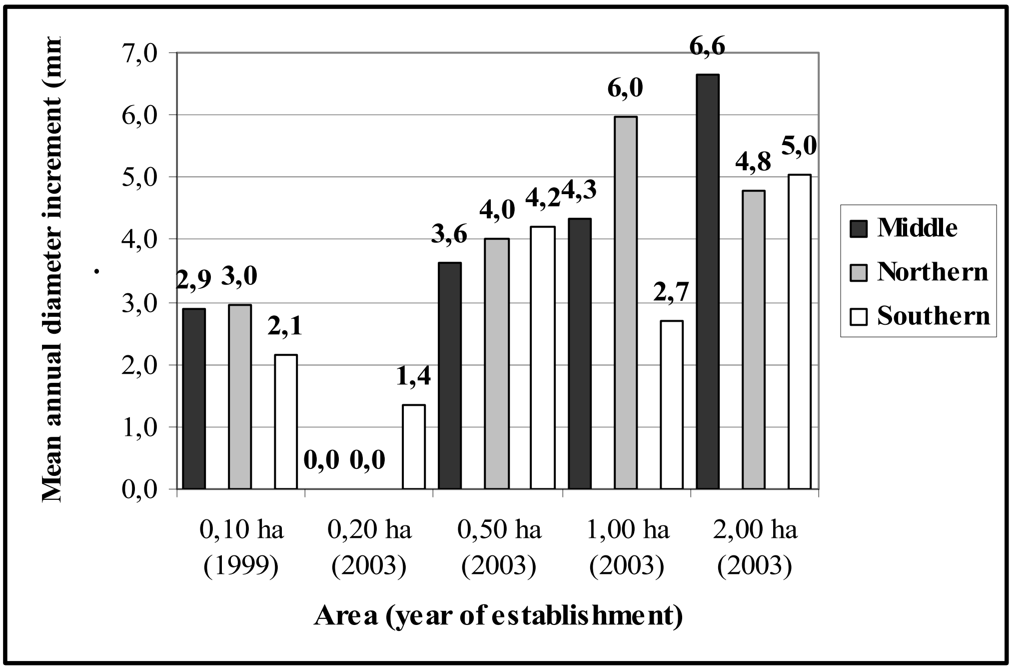

Fig. 2: Mean annual diameter increment (mm) on the respective transects of research plots.

Table 2: Total losses, total height, root collar diameter and slenderness ratio on the respective research plots and transects

Plot (clearcut size)	Year of reforestation	Transect	Total losses (%) Until 2005	Total losses (%) Until 2007	Total height (cm)* 2005		Total height (cm)* 2007		Root collar diameter (mm)* 2005		Root collar diameter (mm)* 2007		Slenderness ratio 2005	Slenderness ratio 2007
768D 1a (0.10 ha)	1999	Middle	72	89	131.2 ± 50.6	+	202.2 ± 85.7	+	11.7 ± 4.5	-	17.5 ± 6.3	+	113	115
		Northern	70	89	111.8 ± 43.3	+ +	178.0 ± 58.7	+ +	9.1 ± 3.2	- -	15.0 ± 4.2	- +	124	124
		Southern	71	81	117.1 ± 43.2	- +	174.3 ± 66.7	+ +	10.3 ± 3.9	- -	14.6 ± 6.5	- +	115	124
770B 12/2 (0.20 ha)	2003	Middle	11	58	82.1 ± 22.6	+	91.3 ± 26.9	+	10.3 ± 2.2	-	9.0 ± 1.6	+	80	101
		Northern	10	70	68.3 ± 21.6	+ -	65.6 ± 21.5	+ +	9.7 ± 2.3	- -	7.6 ± 1.1	- +	71	86
		Southern	5	40	72.7 ± 21.2	+ -	89.6 ± 25.6	- +	8.7 ± 1.8	- -	11.4 ± 1.2	+ +	84	87
35B 16/7y (0.50 ha)	2003	Middle	12	19	79.7 ± 31.0	-	153.8 ± 40.9	-	8.1 ± 2.1	+	15.4 ± 7.8	+	99	106
		Northern	9	23	81.7 ± 27.3	- +	164.7 ± 37.5	- +	8.6 ± 2.4	- -	16.6 ± 5.5	- +	96	105
		Southern	20	24	81.0 ± 19.0	- +	160.4 ± 40.5	- +	8.3 ± 1.9	- -	16.7 ± 5.6	- -	99	100
33D 12/7x (1.00 ha)	2003	Middle	12	28	77.6 ± 20.8	-	151.6 ± 45.3	-	9.5 ± 2.9	-	18.1 ± 5.2	+	85	84
		Northern	11	22	73.3 ± 21.7	- -	172.9 ± 53.1	- +	9.2 ± 2.9	- -	21.2 ± 8.4	- -	82	87
		Southern	14	29	70.5 ± 20.7	- -	119.0 ± 43.4	+ -	7.4 ± 2.0	- +	12.8 ± 4.2	+ +	96	93
917B 10 (2.00 ha)	2003	Middle	18	23	68.9 ± 27.3		164.5 ± 42.0		10.5 ± 3.9		23.8 ± 6.7		67	71
		Northern	14	16	68.1 ± 29.5	-	146.2 ± 52.1	+	10.0 ± 3.8	-	19.6 ± 7.2	+	68	77
		Southern	16	30	60.5 ± 25.4	-	127.4 ± 39.8	+	9.1 ± 3.5	+	19.2 ± 6.7	+	67	68

*Dunnett's test: The first column behind the numeral contains results from the statistical comparison of transects on the respective plots (control being the middle transect) and the second column behind the numeral presents results from the statistical mutual comparison of the plots (control being Plot 917B 10 – 2.00 ha).
The +sign is for the statistically significant difference, the –sign is for the statistically insignificant difference.

Table 3: Stem form and crown form on the respective research plots and transects

Plot (clearcut size)	Year of reforestation	Transect	Stem form (%)						Crown form in 2007								
			2005			2007			Crown shape (%)			Number of branches* (pcs)			Diameter of the sturdiest branch* (mm)		
			Cylindrical	Fork	Multiple	Cylindrical	Fork	Multiple	E	K	J						
768D 1a (0.10 ha)	1999	Middle	5	81	21	34	57	9	93	7	0	3.9 ± 1.7		+	7.4 ± 1.6		-
		Northern	17	78	14	34	58	8	90	10	0	3.1 ± 1.2	-	+	7.0 ± 1.8	-	-
		Southern	13	71	27	32	68	0	96	4	0	2.8 ± 1.5	+	+	6.9 ± 1.6	-	-
770B 12/2 (0.20 ha)	2003	Middle	29	59	15	48	39	13	39	59	2	3.6 ± 1.8		+	4.0 ± 1.1		+
		Northern	23	61	17	28	54	18	31	66	3	3.7 ± 1.7	-	+	4.1 ± 0.7	-	+
		Southern	23	59	23	48	49	3	77	13	10	3.8 ± 1.5	-	+	4.8 ± 1.2	-	+
35B 16/7y (0.50 ha)	2003	Middle	49	44	9	30	67	3	95	5	0	7.3 ± 2.6		+	7.0 ± 2.2		-
		Northern	55	35	11	38	57	5	80	15	5	6.9 ± 2.5	-	+	7.3 ± 2.5	-	-
		Southern	52	39	11	28	67	5	79	13	8	7.8 ± 2.6	-	-	6.7 ± 1.6	-	-
33D 12/7x (1.00 ha)	2003	Middle	16	59	26	31	54	15	69	31	0	5.4 ± 2.7		+	6.1 ± 1.5		-
		Northern	16	63	27	26	69	5	88	6	6	7.8 ± 1.8	+	+	8.2 ± 1.1	+	-
		Southern	35	52	15	34	58	8	65	28	7	4.2 ± 1.9	+	+	5.1 ± 0.9	-	+
917B 10 (2.00 ha)	2003	Middle	31	59	19	41	47	12	82	18	0	10.5 ± 3.3			7.3 ± 2.0		
		Northern	21	71	17	37	57	6	72	26	2	11.3 ± 3.6	-		6.9 ± 1.7	-	
		Southern	23	66	17	37	55	8	70	22	8	8.0 ± 3.1	+		7.6 ± 2.7	-	

*Dunnett's test: The first column behind the numeral contains results from the statistical comparison of transects on the respective plots (control being the middle transect) and the second column behind the numeral presents results from the statistical mutual comparison of the plots (control being Plot 917B 10 – 2.00 ha).
The +sign is for the statistically significant difference, the –sign is for the statistically insignificant difference.

Table 4: Vitality, stem injury and damage to assimilatory organs on the respective research plots and transects

Plot (clearcut area)	Year of reforestation	Transect	Vitality								Stem injury (in % of total number of individuals)				Damage to assimilatory organs (in % of total number of individuals)			
			Mean size of leaves in 2007* (mm)						Colour of assimilatory organs (green/yellow) (%)		Dry terminal (%)		Nipping by rodents (%)		Mildew (%)		Insect feeding (%)	
			Leaf blade length			Leaf blade width			2005	2007	2005	2007	2005	2007	2005	2007	2005	2007
768D 1a (0.10 ha)	1999	Middle	105.9 ± 11.8		-	65.2 ± 9.3		-	100/0	100/0	17	3	0	1	9	9	8	0
		Northern	109.2 ± 12.2	-	-	65.0 ± 9.0	-	-	100/0	100/0	31	1	1	2	10	6	7	3
		Southern	105.3 ± 15.1	-	-	62.0 ± 10.0	-	-	100/0	97/3	6	4	1	3	13	19	8	1
770B 12/2 (0.20 ha)	2003	Middle	105.3 ± 15.1		-	55.5 ± 8.4		+	92/8	99/1	47	10	3	2	59	8	2	0
		Northern	95.1 ± 13.3	+	-	48.5 ± 8.4	+	+	87/13	100/0	44	7	9	0	33	13	3	0
		Southern	107.8 ± 11.2	-	-	57.7 ± 7.7	-	+	97/3	92/8	24	7	6	8	40	9	3	0
35B 16/7y (0.50 ha)	2003	Middle	114.8 ± 10.1		+	66.3 ± 8.0		-	95/5	94/6	55	0	0	0	18	18	8	1
		Northern	110.1 ± 12.7	-	+	63.8 ± 10.7	-	-	94/6	93/7	63	0	0	0	19	22	8	0
		Southern	115.9 ± 13.5	-	-	68.3 ± 10.9	-	-	97/3	96/4	45	1	0	1	20	18	0	1
33D 12/7x (1.00 ha)	2003	Middle	119.5 ± 12.1		+	75.3 ± 11.6		+	97/3	100/0	16	0	0	0	24	7	0	0
		Northern	121.0 ± 13.7	-	+	73.9 ± 10.4	-	+	99/1	91/9	28	2	0	2	16	16	1	0
		Southern	117.6 ± 12.0	-	-	67.9 ± 11.8	-	-	96/4	95/5	8	2	0	2	63	8	3	0
917B 10 (2.00 ha)	2003	Middle	107.3 ± 11.5			63.9 ± 7.6			99/1	97/3	6	0	0	0	60	15	0	0
		Northern	102.5 ± 8.7	-		60.4 ± 7.1	-		98/2	100/0	4	0	1	0	65	14	0	0
		Southern	111.6 ± 10.0	-		65.0 ± 9.3	-		94/6	95/5	8	0	1	0	75	17	0	0

*Dunnett's test: The first column behind the numeral contains results from the statistical comparison of transects on the respective plots (control being the middle transect) and the second column behind the numeral presents results from the statistical mutual comparison of the plots (control being Plot 917B 10 – 2.00 ha).
The +sign is for the statistically significant difference, the –sign is for the statistically insignificant difference.

Evaluation of stem damage (Tab. 4)

Damage to terminal shoot is one of serious injuries which may result in the changed stem form and retarded growth of plants. Drying out of the terminal bud, in the worse case also of a part of the terminal shoot, is most frequently recorded on small-sized clearcuts (namely 0.20 ha and 0.50 ha), its occurrence on larger clearcuts (1.00 ha and 2.00 ha) being minimal. The significance of this injury is obvious in plot 0.50 ha where more than 50 % of plants with the dry terminal were found in 2005, which led to negative changes in the stem form (the representation of plants with the cylindrical stem decreased in 2007).

With respect to the fact that the percentage of plants with this type of injury exhibited a general decrease on all plots in 2007, it can be assumed that the drying of terminal occurs predominantly during the first years after planting. This is also corresponded to by the lower percentage of plants with the dry terminal on the clearcut sized 0.10 ha (established in 1999).

As to injuries due to the nipping of rodents, no expressive differences were found between the individual plots and it can be concluded that the clearcut size does not relate to the extent of this type of damage. The most severe damage by small rodents was recorded on plot 0.20 ha but its extent did not exceed 10 %.

Evaluation of damage to the assimilatory apparatus (Tab. 4)

Injuries due to the infestation of plants by mildew (namely the drying of Lammas shoots) contribute to growth retardation, too. The occurrence of this mould is relatively abundant in the region and there are no conclusions following out of the research that would point to relation with the clearcut size. The excessive insect feeding is observed only sporadically on the plots and has no influence on the growth dynamics of plantations.

CONCLUSIONS

Growth dynamics and vitality of pedunculate oak plantations growing on clear-felled areas of different size (0.10 ha, 0.20 ha, 0.50 ha, 1.00 ha and 2.00 ha) were compared on floodplain sites. Each of 5 established research plots contained 2 marginal transects and 1 middle transect. The plants were subjected to the evaluation of 2 measured parameters, 3 derived parameters and a total of 5 visually assessed traits. Conclusions following out from the research results are as follows:

- Pedunculate oak is not such an orthodox light-demander as traditionally claimed; the amount of light is apparently important during the first stages of the development of seedlings.
- Clear-felled areas sized 0.10 ha and 0.20 ha are not suitable for planting the pedunculate oak. These clearcuts had typically high losses (86 % and 56 %). Plantations on these clearcuts exhibited worse growth dynamics (minimum diameter increment and height increment lower than on the clearcuts of larger sizes). Slenderness ratio is high and hence the mechanical stability of trees is impaired. In the first years after planting, these plots showed a greater occurrence of plants with the dry terminal shoot. The marginal part constitutes up to 90 % of the total clearcut area (with the considered marging breadth of 15 m).
- Clearcut sized 0.50 ha represents a certain risk for the pedunculate oak planting (retarded diameter increment, negative values of slenderness ratio, higher share of plants with the injured terminal bud or shoot). The marginal part of the clearcuts

constitutes more than 50 % of the total clearcut area (with the considered margin breadth of 15 m), and a greater part of plants grow in sections with lower light treat.

- Clearcuts sized 1.00 ha and 2.00 provide favourable conditions for successful establishment of pedunculate oak plantations. Maximum losses on these clear-felled areas were 26 %. Diameter and height increments reached the highest figures. Also, the slenderness ratio was lower than on the small-sized plots. The marginal part of the clearcuts constitutes less than 50 % of the total clearcut area (with the considered margin breadth of 15 m).
- If the clearcut margin is shaded by the high-grown stand, statistically significant differences were demonstrated in the growth of plants on the marginal transects and on the middle transect. Plants growing on the clearcut margin wide 15 m (with the height of the surrounding stand being 30 m) exhibited lower average height than plants growing in the clearcut middle. In this respect it is important to choose the size and the shape of the clearcut (including the coordination of other fellings) so that the plantations could enjoy as much light as possible.
- During the first years after planting the stem form is not affected by the clearcut size.
- The increasing size of the clear-felled area results in the increasing number of branches in the crown. Negative crown forms are produced on plots with the least height increment.
- No dependence was observed of the colour of assimilatory organs on the clearcut size. However, the increasing size of the clearcut results in the increasing size of the assimilatory apparatus.

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POSSIBILITIES AND PROCEDURES FOR THE NATURAL REGENERATION OF PEDUNCULATE OAK (*QUERCUS ROBUR* L.) IN SOUTH MORAVIA

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Abstract

The paper informs about experimental verification of pedunculate oak natural regeneration on the alluvial site of Forest Enterprise Židlochovice (LZ LČR Židlochovice), for which extremely rich crop was used in 1999. Studied aspects were the effect of period for which the regeneration was sheltered by the parent stand of different stocking, the effect of soil preparation, and the effect of weed-control measures on the number and emergence of oak seedlings. It was experimentally demonstrated that oak seedlings develop best in the open ground while their increment is negligible under partial shade and full shade results in their kill in the second or third year. Sufficient light is a limiting factor for the survival of seedlings. The best method for regeneration of pedunculate oak stands is felling of the fully enclosed oak stand immediately after the fall of acorns. Weed-control measures are a must in the first three years. Natural regeneration of pedunculate oak after a rich seed year may be endangered and even made impossible due to biotic factors (rodents) and climatic extremes (spell of drought during germination and emergence of acorns).

Key words

natural regeneration, pedunculate oak, floodplain forest, light conditions, soil preparation, forest weed

INTRODUCTION AND OBJECTIVES

Stands dominated by pedunculate oak (*Quercus robur* L.) in floodplain forests of the Czech Republic are currently regenerated exclusively by artificial methods – planting or sowing, with intensive mechanical and chemical site preparation. Natural regeneration which is commonly used for example in Croatia and France is not applied in the Czech Republic the reason being until recently very sparse oak seed years and low crop of acorns. With the occurrence of more abundant crops and with the increasing efforts to apply near-natural management methods the issue gains ground for a possible natural regeneration of oak stands on alluvial sites. Certain references to its use in our country can be found in older works (Vyskot 1958) but the experience has been apparently lost during the long years of poor crop of acorns. It was therefore decided to propose and to experimentally verify methodological procedures for the natural regeneration of pedunculate oak on floodplain site and to establish limits of its use.

PROBLEM ANALYSIS

Seed years of pedunculate oak with abundant crop of acorns which could be a good groundwork for natural regeneration have been very rare in our country (Vacek et al. 2000). Even if some seedlings actually emerged from natural seeding, they died very quickly under the parent stand. The same response of the seedlings on the stand conditions was observed in other countries, e.g. in Belgium (Lust, Speleers 1990). Some authors can see the reason for dying oaks from self-seeding in the lack of light (Lüpke 1998), other considered a limiting factor to be also water (Löf et al. 1998). Moreover, floodplain forest is a very fertile site where stands are rapidly overgrown by weeds after just a moderate opening, which makes the natural regeneration difficult or entirely impossible (Plíva 2000). This is why foresters in Croatia and France advise a fast and intensive progress in the implementation of shelterwood felling for natural regeneration of oak in the floodplain, to increase access of light to oak seedlings and to make it possible for young plants to rapidly grow out of the impact of competing vegetation (Lararfouge 1990; Matič 2000 a.o.).

Success of natural regeneration can be enhanced by soil surface scarification. Foresters in France do not use soil preparation before regeneration but rather intensive protection of seedlings against weeds which are removed mechanically at the ground surface. Some experts recommend only shortening the weeds to equal the height of oak seedlings to prevent disturbance to the enclosed canopy of the self-seeded stand, which is important for sound tending of this species. In Croatia the to-be-regenerated site is prepared only in the case that the soil surface is infested by weeds prior to the fall of acorns, the weeds being controlled mechanically or chemically; hoeing is recommended in the case of compact soils, soils with accumulated raw humus or with the content of undecomposed litter. Similar intensive measures are taken to protect the seedlings against weeds.

Regeneration should be completed not later than 10 years from its beginning. Under favourable conditions the parent stand above the seedlings is felled much earlier – within up to 5 years. Some authors (Nesterov 1954 in Vyskot 1958; Larfouge 1990 and Duplat 1996) even recommend a complete removal of the parent stand in the autumn immediately after the fall of acorns in a rich seed year.

MATERIAL AND METHODS

Basic methodological approaches

Decisive for the successful natural regeneration of pedunculate oak is a sufficiently abundant crop of acorns to provide for such a number of plants that would enable rise of a qualitative stand. Two factors have an essential influence on the emergence and further growth of seedlings at juvenile stage: light and competition of herbaceous and woody vegetation. The two factors are very tightly linked on floodplain sites. Sufficient light can be provided to seedlings by removing the parent stand or by reducing its stocking, which however evokes an instant invasion of weeds which represent a serious competition to oak seedlings. Weed invasion can be delayed by mechanical site preparation which at the same time creates conditions favourable for germination of acorns and emergence of seedlings.

The extremely rich seed year of pedunculate oak in 1999 made it possible to establish trial plots in the forest district Lanžhot operated by LZ Židlochovice, on which all main aspects of natural regeneration of pedunculate oak were to be studied. Other experimental plots were established in 2005 and 2006 in the forest district Židlochovice operated by LZ LČR Židlochovice. As there was no seed year in the region in this period, the natural seeding was simulated by spreading collected acorns. Design of all plots was conceived so that it would be possible to assess the impact of soil preparation on the emergence of acorns and growth of seedlings, impact of weeds and methods of their control on the growth of seedlings, and the impact of time and intensity of parent stand shelter on the growth and development of natural regeneration.

Material

Experimental plots established in 1999 were situated in the forest district Lanžhot, and experimental plots established in 2005 and 2006 in the forest district Židlochovice LZ LČR Židlochovice. The Lanžhot plot came to existence by natural seeding of stand 806B 14, 804G 12. The plots in the forest district Židlochovice were established by using acorns collected in the forest district Tvrdonice.

With respect to the typological system developed by ÚHÚL all plots were situated on the site corresponding to the forest type 1L2 – Elm floodplain with goutweed on fluvisols, which was checked by phytocoenological relevés and in soil pits. Both localities are outside the reach of regular inundations.

The main tree species of regenerated stands is pedunculate oak; a considerable share is also occupied by narrow-leaved ash (*Fraxinus angustifolia* Vahl.), admixed species is small-leaved linden (*Tilia cordata* Mill.) often growing in abundant numbers in the lower storey which further includes field maple (*Acer campestre* L.) and common hornbeam (*Carpinus betulus* L.). Sporadically occurring are poplars (*Populus* sp.), wild pear (*Pyrus pyraster* L.) and other oak species such as Turkey oak (*Quercus cerris* L.) and red oak (*Quercus rubra* L.). The main species of the shrub layer is common hawthorn (*Crataegus laevigata* (Poiret) DC.).

Methods

<u>Scheme of experimental plots establishment</u>

To check up what conditions (light, humidity …) are best for the emergence of self-seeded pedunculate oak experiment plots were established as follows:

- with a complete removal of the parent stand shelter immediately in autumn after the fall of acorns,
- with a complete removal of parent stand shelter after 1 year of seedlings growth under full parent stand shelter,
- with parent stand reduced to stocking 0.5 after 1 year of seedlings growth under full parent stand shelter,
- with parent stand reduced to stocking 0.8 in seed year,
- with the full shelter of parent stand left.

To study the impact of soil preparation on the natural regeneration of stands experimental plots were established as follows:

- with the mechanical soil preparation (soil surface scarification by rotary cultivators) prior to the fall of acorns,
- with the mechanical soil preparation after the fall of acorns (acorns worked into the soil),
- with no mechanical soil preparation.

Methods of assessing the experimental plots

All experimental plots were in the first three years after the fall of acorns subjected to a detailed monitoring of vegetation on stationary laid-out transects 1 m wide and 15-35 m long. Total length of transects was 570 m.

The measurements were made twice a year, at all times in June – at the end of spring, approximately at the time of completed spring increment, and in September-October – at the end of the growing season, at the time of summer increment completion. Each current meter of the transect was surveyed for the number of oak, field maple, ash, hornbeam, linden and other tree species seedlings the height of which was measured on determined meters of the transect. Weeds were classified as "grasses" and "herbs" and their coverage was recorded on each current meter of transects.

Light conditions of seedlings were periodically monitored by measuring insolation above the seedlings (under the fully enclosed canopy, in the stand with the stocking of 0.5, and in the open ground) by luxmeter at intervals of max. 14 days. Soil moisture meters Virrib were installed in the soil on plots under the full parent stand shelter and without it, with soil moisture being measured by them at intervals of max. 14 days.

RESULTS AND DISCUSSION

One of serious factors limiting natural regeneration on floodplain sites are herbaceous and graminaceous weeds occurring in forest stands as soon as they are just slightly opened (stocking 0.8) and effectively hampering emergence of the fallen acorns. Our experiment showed that only a minimum of seedlings emerged on plots which were not prepared before the fall of acorns (Tab. 1). This corresponds to the information published by foreign authors that yield of acorns is low at natural regeneration (Matic 1996, 2000; Lust and Speleers 1990). According to Dengler (1972 in Korpel et al. 1991 and Nilsson et al. 1996) the emergence of acorns can be encouraged by mechanical soil preparation. Soil surface scarification increased the abundance of seedlings per square unit. A highest number of emerged acorns were however observed if they were worked into the soil (seeding under hoe). Scarification of the soil surface or working of the acorns into the soil help to create a better contact of acorns with mineral soil and partly prevent water loss from acorns, which is of conclusive importance in recalcitrant seeds for the maintenance of their vitality. Nevertheless, the opinions on time in which the scarification should be made rather differ. Most authors recommend to do the operation before the fall of acorns. The assessment of our plots demonstrated that if the crop is sufficiently high (fall of more than 20 acorns per 1 m^2), scarification is necessary only if the regenerated stand is infested by weeds and that it may be efficiently substituted by soil surface disturbance during parent stand logging, skidding and extraction of slash after seeding.

Beside the positive effect on the emergence of acorns the soil surface scarification suppressed also the emergence of weed tree species and reduced the weed coverage. The effect of scarification showed especially on plots in which the stand was removed immediately after seeding (Tab. 1). The effect was demonstrated to last three years in weed tree species, one incomplete growing season in herbs and one year in the case of grasses.

Tab. 1: Frequency of newly emerged seedlings of pedunculate oak and cover of weed on sample plots with the leave parent stand (stand density 0.8) or without it (stand density 0.0) in the spring of the first year of regeneration and with the various soil preparations for regeneration of the stand

Partition of sample plots per		Frequency of oak seedlings	Cover of weed
soil preparation	**parent stand density**	**(pcs. m^{-2})**	**(%)**
Without scarification	0.8	0.3	80
	0.0	0.4	65
With scarification	0.8	0.9	71
	0.0	7.3	11
Defraying of acorns to soil	0.8	0.6	100
	0.0	12.3	23

Presence of weeds in the first stage of seedlings emergence may also have certain positive effects. This was documented by a greater height of seedlings on the plot without scarification where the attendance of high-grown weeds stimulated oak seedlings to height growth immediately after the emergence (Tab. 2, Fig. 1). The beneficial effect on the seedlings growth was however ceasing with the progressing growing season and the following years showed the negative impact of weeds the shading of which from above hampered the further development of the seedlings (Fig. 2).

Tab. 2: Frequency and height of yearlings of oak (at the end of the 1st year of regeneration) on plots without parent stand and with different soil preparation

Partition of plots per soil preparation	Frequency of seedlings (pcs. m^{-2})	Height of seedlings (cm)
Without scarification	0.4	25.8
With scarification	5.5	24.1
Defraying of acorns to soil	12.8	30.4

As compared to sessile oak, the pedunculate oak has a higher demand of solar radiation. Its seedlings do best if fully exposed to light. Mortality of seedlings under a full shelter was high with nearly 50 % of individuals dying after the first year of growth, only a quarter of their initial count remainded after the second year, and only 4 % of seedlings were observed to survive the end of the 3rd growing season. Even under the shelter of reduced stocking (0.5) the seedlings stagnated in growth and exhibited impaired vitality (Fig. 3). The seedlings did best if the parent stand shelter was felled immediately after seeding and they could emerge already in the open ground. In the latter case the growth of seedlings is similar as in the autumn sowing which is of all possible methods of artificial regeneration most frequently used in the floodplain forest in the concerned region.

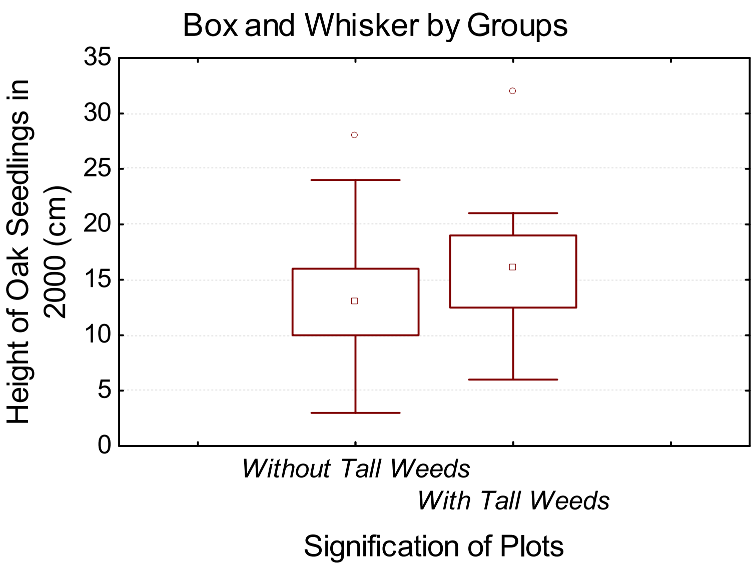

Fig. 1: Height of yearlings of pedunculate oak on the plots with various cover of weeds

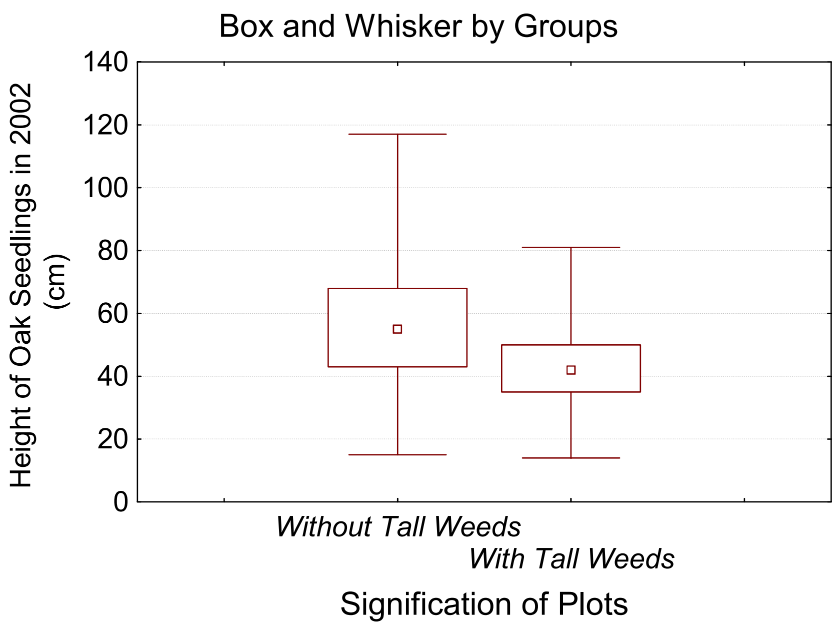

Fig. 2: Height of three year old seedlings of pedunculate oak on the plots with various cover of weeds

Reason to the rapid decay of pedunculate oak seedlings under shelter may be either the lack of light or deficient water and our further investigations were therefore focused on the two aspects. Pronounced differences were found in light conditions of seedlings under full shelter as compared with the plot with the parent stocking of 0.5 and with the open plot without any shading of seedlings. The amount of light penetrating under a fully enclosed canopy is negligible (1.4 % of light amount recorded in the open ground) and the amount of light under a half-stocked parent stand reached ca. 41 % of the open ground exposure. Soil moisture differences at the critical rooting depth of oak yearlings (15 cm beneath the ground surface) were not demonstrated and a similar development throughout the year was recorded in the open ground and under the parent stand (Fig. 4). The same results were published by Hadaš and Hybler (2003) on a locality near Lednice na Moravě in the vicinity of our experimental plots and further corroborated by soil moisture monitoring on the plot Knížecí les Forest (Forest District Židlochovice). The above facts indicate that the seedlings of pedunculate oak do not suffer with insufficient moisture under the parent stand shelter but are rather severely damaged by insufficient light which may be a limiting factor and a main reason to their kill.

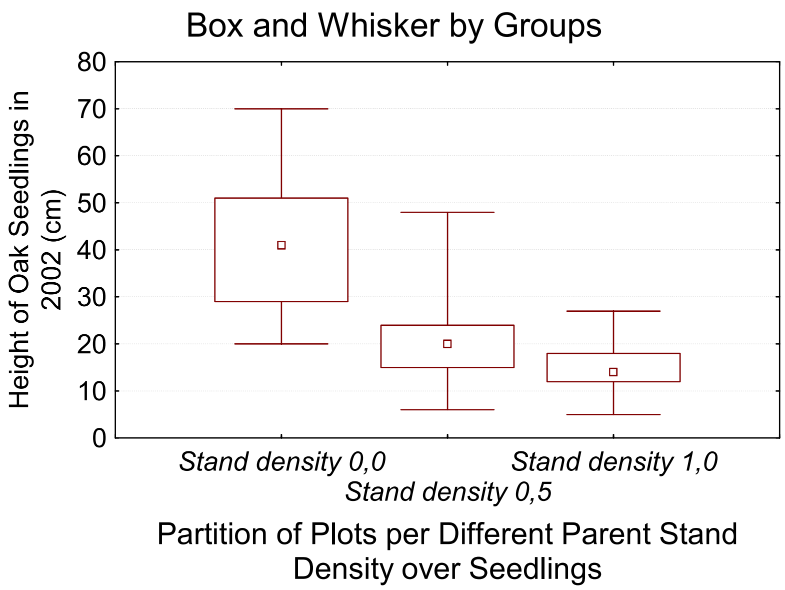

Fig. 3: Height of three year old seedlings of pedunculate oak under full shading of parent stand (stand density 1.0), under reduced shading of parent stand (stand density 0.5) and in open canopy (stand density 0.0)

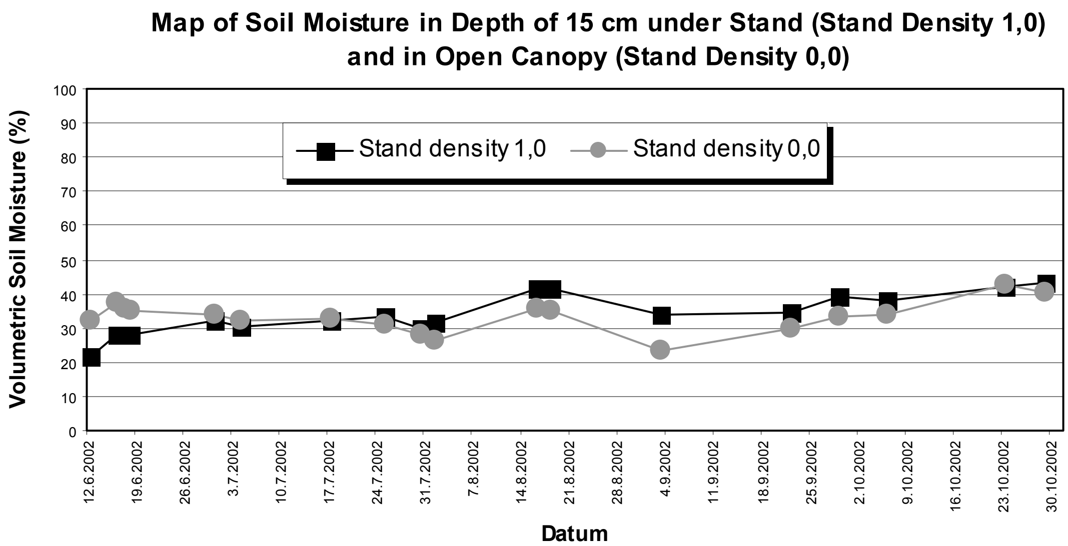

Fig. 4: Development of volumetric soil moisture in 15 cm soil depth from June to October 2002 under parent stand (stand density 1.0) and in open canopy (stand density 0.0)

Seedlings on plots with the shelter of parent stand completely removed after the 1st year of regeneration were established within 4 years (i.e. within three years after the removal of shelter). At places with the least number of emerged seedlings (4 pcs per sq. meter as an initial number of seedlings in the spring of the 1st year) the establishment had to be supplemented with additional transplants. However, none of the plots had to be repeatedly regenerated artificially. Best stand enclosure and growth were observed in seedlings on plots where the natural seeding was combined with the seeding of acorns under hoe, and where a total count of emerged seedlings was greater than 20 pcs.m^{-2}, which corresponded to the initial count of acorns (seedlings) recommended by Croatian foresters (Matić 2000).

Necessary condition for natural regeneration is fructification of the regenerated stand. Acorn crop for the natural regeneration has to be abundant as it is necessary to count with a low recovery of acorns, which is according to Matić (2000) approximately 20-30 % and according to Lust and Speleers (1990) only 6.4 %. Recovery of acorns at the extremely rich crop in 1999 was on our plots ca. 20 %. However, even the rich crop does not necessarily need to be a guarantee of success. Our further experiments showed that natural regeneration may be adversely affected by some other biotic and abiotic factors. In 2005, the trial plot of Knížecí les Forest was established in the Forest District Židlochovice, on which self-seeding was simulated by the spreading of acorns at an amount answering to 500 kg. ha^{-1}. Quality of acorns was satisfactory (germinating capacity 74 %), 1 kg contained 250 acorns, i.e. 13 acorns per 1 m^2. Checks made in the spring and at the beginning of summer 2006 revealed that seedlings occurred on the plot only very sporadically. Non-germinated acorns collected by random on the plot were sent to AZLSK for examination and detection of likely reasons to their low germinative capacity as compared with the germination percent before the simulated self-seeding. Health analysis disclosed the occurrence of *Penicillium* fungi and bacteria on the acorns, 17 % of acorns were infested by acorn monilia but even these acorns were exhibiting a greater damage by drought or frost. High amounts of empty pericarps from acorns on the plot became food for yellow-necked field. Damage to acorns by rodents was high probably also because the plot stayed unusually long under snow cover – from the end of November 2005 to the beginning of April 2006. This demonstrates that efficient measures to control small rodents are necessary, which was also confirmed by the Croatian foresters (Orsanic 2006 pers. com.). In the autumn of 2006, the self-seeding was repeatedly simulated in the Forest District Židlochovice LZ LČR Židlochovice and in the Forest District Bílovice n. Svitavou operated by Training Forest Enterprise Masaryk Forest (ŠLP ML) in Křtiny by spreading 600 kg of acorns per 1 ha, which answered to 15 pcs per square meter. Due to stand opening in 2005, trees on the plot brought a poor crop and a control counting revealed additional natural fall of about 10 acorns per 1 m^2. The spring of 2007 being extremely dry at the time of germination, the acorns were killed by drought.

CONCLUSION

In 1999-2006, possibilities were investigated on LZ Židlochovice LČR and ŠLP ML Křtiny of natural regeneration of pedunculate oak on alluvial sites. Results from the assessment of plots established after an extremely abundant crop in 1999 and plots established in years 2005 and 2006 through the simulation of natural self-seeding by spreading 500 kg and 600 kg, resp. of acorns per 1 ha can be concluded as follows:

- Stands of pedunculate oak have to be long prepared for natural regeneration – mature stands have to have suitable vertical and horizontal structure as well as favourable tree species composition (many of existing mature stands do not meet the criteria required for natural regeneration).

- Mechanical soil preparation facilitates the emergence of seedlings, for a short time suppressing infestation of the regenerated plot by herbaceous and germinaceous weeds and preventing the emergence of weed tree species.
- Mechanical soil preparation before the fall of acorns is necessary in the case that the stand is infested by weeds (not having a suitable vertical structure).
- Soil preparation is to be preferably carried out only after the fall of acorns that can be instantly worked into the soil, which would increase their emergence rate.
- Seedlings of pedunculate oak under a full shelter of the parent stand die within 3 years, their growth stagnating and their vitality decreasing under a reduced shelter (stocking 0.5).
- Seedlings did best on the plot on which the parent stand shelter was felled immediately after the fall of acorns where the seedlings could emerge on a fully sunlit open ground.
- Main reason to the kill of seedlings under the stand is the lack of light.
- Parent stand has to be removed rapidly (preferably immediately after the fall of acorns and within 1 year after seeding at the latest) and possible gaps are to be instantly filled with oak transplants.
- Successful can be considered natural regeneration with a minimum of 5 seedlings growing per 1 m^2 one year after seeding.
- Intensive protection of acorns and newly rising stand against weeds is a must.
- Intensive protection of acorns from damage by small rodents and wildlife is a must.
- Emergence of acorns may be endangered by extreme climatic effects (drought).

Natural regeneration of pedunculate oak cannot be fully relied upon in the Czech Republic due to the long-term absence of rich mast years and it is therefore necessary to continue in planning the artificial regeneration. Should a rich crop of pedunculate oak acorns occur, it is possible and adviceable to use it while adhering to certain rules of seeding in the floodplain forests. However, there will be always a certain risk that the natural regeneration would fail.

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NATURAL REGENERATION OF PEDUNCULATE OAK

Milan Oršanić, Ramie Drvodelić

Abstract

Forest management in Croatian lowland forests is generally based on the natural regeneration of forest stands and on the dynamics of natural forest. The paper brings an assessment of silvicultural procedures implemented in the natural regeneration of pedunculate oak. It includes description of site preparation and one of fundamental regeneration felling methods in which the new stand rises under protection of parent stand – shelterwood felling. Shelterwood felling is currently characterized by three stages in Croatia (preparatory felling, seed felling and final felling), which are described in details. Decisive for successful development of the follow-up stand is care of young growths and their tending.

Key words

natural regeneration, site preparation, shelterwood felling, preparatory felling, seed felling, final felling, young growth tending

INTRODUCTION

In the history of forest management in Croatia the regeneration of pedunculate oak has been at all times of major significance for forest experts concerned with floodplain forest management. As far back as at the first meeting of the Croatian-Slavonic association in 1846 a question was discussed how to manage old oakwoods of virgin forest character in order to bring them to rejuvenation of superb quality. Natural regeneration has been an interesting issue for Croatian foresters since time immemorial and has been long representing main problem for experts in the continental Croatia. Basic principle consisted in regeneration under shelterwood in two, three or more felling operations. During two centuries of the continual natural regeneration of oak forests in Croatia numerous problems emerged which were making it difficult – from poor crop of acorns, through sinking groundwater table to mass decline of stands, disturbance of their structure, etc.

At the beginning of the 19th century, oakwoods in Croatia were of virgin forest character and most of them were used for grazing and for rearing pigs. More than 70 % of the then Slavonia was covered by floodplain forests. Regeneration was made naturally with five years of protection. Five years before a good crop the stand was protected especially against acorn collection and grazing and then all stems were cut. This method of natural regeneration was described for ash stands also by Kozarac (1887) who mentions preliminary protection of ash woods for 1 year.

At some places, clear-felled areas were used in order to win high-quality soil for farming after which the plots were sown with acorns. The method is known as agroforestry (Divjak 1900). This affected the later condition of these stands, namely their species composition (pure stands), quality (crooked stems) and health condition. This method of regenerating oakwoods was later not recommended by some authors (Smilaj 1939).

Regeneration under shelterwood with two felling operations and a longer regeneration period in floodplain forests was advised by Petračić (1926).

SOME FEATURES OF CROATIAN OAKWOODS IMPORTANT FOR THEIR REGENERATION

Growing stock lower than normal is a general problem of pedunculate oak stands in Croatia. It results partly from decline and dieback of individual timber species in these stands but it is also a consequence of poor management practice namely in old stands. In spite of the fact that some stands are apparently low in growing stock, shelterwood felling is made at three stages. Intensity of preparatory felling is very often greater than 30 %, which brings ever more problems in regeneration reason being fact that the stands are infested by weeds and later water-logged, which makes the regeneration complicated or even impossible.

Preparatory felling is importantly in many cases replaced by soil preparation for regeneration. Soil preparation can be manual or mechanized and it must not lead to a complete removal of undergrowth and shrubs if the lower storey is missing. Undergrowth and shrubs control light amount within the stand, helping to maintain forest microclimate, protecting seedlings and young growths of pedunculate oak and preventing water-logging as well as severe occurrence of weeds and their development before the oak regeneration appears on the regenerated plot.

Stands in which the crop of acorns was hampered or made impossible due to any reasons require artificial regeneration either by sowing acorns under hoe, by manual seeding or by planting out transplants – at all times after the seed felling has been commenced. This means that apart from seed felling, final felling and site preparation it is necessary –if needed- to introduce acorns or oak transplants.

The crop of pedunculate oak acorns is very often considered one of main problems in floodplain forests regeneration. The fact is that the crop of acorns is not so certain in terms of its dynamics and abundance as it used to be in the autochthonous, site- and structurally balanced 300-year old pedunculate oak stands.

Tending of oak regeneration at the time of seed felling and particularly after its end is very important and conclusive for further development of young plants. This means that tending under canopy protection becomes every day more important especially if the stand's regeneration period is long. It is essential that light penetration is made possible in the course of stand regeneration to places where seedlings have already emerged because it is needed for a minimum but necessary process of assimilation. In the first two years of life, the pedunculate oak can normally exist under conditions of full shade and it can survive until the fourth year of life with 3-4 % of light (Matić 1979). In the following years it is however necessary to ensure a higher amount of light for pedunculate oak. We assume that the amount of light is to be increased to at least 15 % of normal light treat.

SILVICULTURAL PROCEDURES IN THE REGENERATION OF PEDUNCULATE OAK STANDS

Natural regeneration represents the most perfect way of regenerating any stand and this especially holds true for autochthonous stands of climax tree species among which the pedunculate oak occupies the first place in the Croatian forestry. This way of stand regeneration harbours natural continuity of all impacts which are inherent to stable and productive forest ecosystems capable of natural regeneration.

Natural rejuvenation or natural regeneration does not discontinue the mutual action and mutual impact of individual elements in the ecosystem (site and biocoenosis). And most importantly, this way of regeneration protects the forest soil as the most valuable, most susceptible and most important constituent of the ecosystem, in which the most abundant and most vital living world of our planet is concentrated.

Speaking of pedunculate oak stands regeneration we can distinguish two fundamental conceptions: natural and artificial regeneration.

Natural rejuvenation or regeneration gives rise to the young growth of pedunculate oak by natural way from seeds of the old parent stand which occurs on the regenerated area. Under favourable ecological conditions and at a suitable structure of floodplain forests the natural regeneration proceeds without any greater problems provided that the crop of acorn is sufficiently abundant. Felling operations to be made in the course of regeneration are gradual – preparatory felling, seed felling and final felling. If the seed crop is good and soil conditions optimal, they represent a set of activities which accelerate the rejuvenation and shorten the regeneration period at a simultaneous rational use of wood mass. This implies that no additional works should be required in the ideal stand conditions of floodplain forests for successful regeneration.

Regarding the above facts, the additional works referred to as site preparation for natural or artificial regeneration are currently a rule rather than an exception.

Site preparation for natural regeneration in floodplain forests is carried out only if necessary. Prior to start it is also necessary to assess the condition of forest soil and floodplain forest stands structure, namely the presence of lower storey, shrub layer and undergrowth in order to consider whether the site preparation is actually needed.

Site preparation for the regeneration of floodplain forests represents a lot of hard work which requires a considerable involvement of labour force and machinery. It is a set of work operations that have to be carried out on different sites under different stand conditions occurring in pedunculate oak stands. Site preparation activities for natural or artificial regeneration of pedunculate oak can be divided into following stages:

- removal of excessive undergrowth and bushes by hand or by mechanization,
- elimination of weeds by hand, chemically or mechanically,
- loosening of compacted soil or soil with accumulated raw humus or undecomposed litter,
- surface drainage of water-logged soil by digging out canals,
- construction of stationary or mobile fences before start of regeneration felling operations in order to protect seeds, seedlings and young plants of pedunculate oak and other tree species from game and cattle,
- laying of traps to prevent damage to acorns and young plants of pedunculate oak by rodents (mice etc.).

As mentioned above, the stands of pedunculate oak are rejuvenated by shelterwood or by successive fellings under shade provided by crowns of old trees in the parent stand – by the succession of three cuttings: preparatory, seed and final, or more frequently by the succession of just two fellings: seed and final fellings. Seedlings and young plants come to existence in the stand through the gradual felling of old stems, crop of acorns and soil fertility (Matić, Stojanović 1988). This way of regeneration answers best the biological properties and ecological requirements of acorns, seedlings and sprouts of pedunculate oak with respect to light conditions, air humidity and soil moisture, nutrient demands, relation to other competitor timber species etc. By this way, the transition from the old stand to a young stand of pedunculate oak occurs without any damage to soil and stand with site and stand conditions being maintained stable. Preparatory cutting (Petračić 1931) creates conditions in the stand, which are favourable for young plants. The stand canopy opens by felling stems which are genetically undesirable and redundant, the access of light is improved, the tree species representation regulated and high-quality and other trees are evenly distributed across the regenerated area. All this conditions a better crop of acorns, a greater light and warmth treat, improved soil moisture, accelerated mineralization and humification of soil organic matter and support to the germination of acorns and emergence of young plants. The felling is recommended to be made several years before an expected good crop of acorns (Petračić 1931).

Preparatory felling is normally used to cut up to 1/3 of existing standing volume but how much will be actually felled depends greatly on stand condition, vertical and horizontal structure, soil condition, current rejuvenation etc. It should be born in mind that preparatory felling is particularly important for successful regeneration. It is more important than seed cutting since it has to create conditions for the crop of acorns, their germination and for the survival of seedlings and young growths. If the stand is tended in a normal way, the preparatory cut can be omitted since the stand and the site have been already prepared for regeneration by thinning operations. Also, if the standing volume of the to-be-regenerated stand is lower than normal, the preparatory cut is unnecessary but the site has to be prepared for the regeneration.

Seed felling is to be carried out if conditions have been created for regeneration in the stand and in soil. It is most frequently made in the year of rich crop or a year or two after copious crop at the latest. Seed felling creates conditions for a sufficient penetration of light into the stand, which gives young plants a possibility of sound emergence. At the same time, tree crowns should provide a shelter for young plants to protect them from unfavourable ecological impacts. Intensity of this cut is ca. 50 % of current standing volume and a goal to be achieved is an even distribution of remaining trees across the area. The lapse of time between preparatory felling and seed felling is called rejuvenation period because during this time period the area is covered with young plants.

Final felling is to be carried out at the time when the entire regenerated area or its greater part shows emerging rejuvenation which does need any longer the protection by parent stand. The time between seed felling and final felling is 3 to 5 years in the stands of pedunculate oak. The time between preparatory felling and final felling in the stands of pedunculate oak with normal site and stand conditions is 6 to 10 years.

Regeneration fellings in pedunculate oak stands are carried out both on large and small plots. Small-scale cuts are made in strips or in circles. In the current intensive forest management and environment protection a preference should be given to circular small-scale fellings.

Pedunculate oakwoods are in Croatia found on two groups of alluvial microreliefs: on micro-elevations called “gredas” and in micro-depressions called “nizi”.

Forest communities of floodplain forests occurring on gredas are dominated by oak and hornbeam - *Carpino betuli-Quercetum roboris* (Anić 1959; Rauš 1969). According to Dekanić (1979), the natural regeneration of these stands is hampered by the attendance of hornbeam which is vital and intensively rejuvenating. Preference in regeneration is given to pedunculate oak. Preparatory felling is used to cut also large-diameter hornbeams together with poor oaks in order to reduce production of their seeds. Best time for the operation is summer to suppress hornbeam sprouting from stumps and to let the coppice shoots kill by frost in winter. Seed felling is carried out in the crop year or one-two years later so that about a half of oak stems is cut in order to increase light penetration to young plants. As soon as the young plants are self-sustained enough a time comes for final felling.

In regenerating stands of pedunculate oak on the gredas it is very important to make use of timber species capable of giving shade, i.e. hornbeam, beech and linden, and to regulate by them available light. This implies that they must not be all cut during the preparatory and seed fellings but rather left to provide shade to young plants and –what is even more important- to prevent wild growth of weeds. By this way the oak rejuvenation is encouraged and the tending costs curbed. If the risk of weed development is high and tending costs should be reduced, it is necessary to leave small-diameter stems of these timber species on the regenerated plot even after the final felling and to remove them in the course of regular tending operations only after their function has been fulfilled.

Most known of pedunculate oak stands occurring in terrain depressions is the oak floodplain forest with dyer's broom (*Genisto elatae - Quercetum roboris* Ht. 1938). According to Dekanić (1979), seed felling in these stands have to be made in such a way that the regeneration of pedunculate oak is encouraged, which is the weakest species from the silvicultural point of view. These stands often include small-leaved elm and white elm and the mixture may also contain ash, white and grey poplar, European aspen, black poplar and white willow. Lower storey of these stands is not so expressive as is the case of pedunculate oak and hornbeam stands, namely today, after the mass kill of elms due to Dutch elm disease. Ash and smooth elm regenerate readily in these conditions, growing faster at young age than the pedunculate oak.

Regeneration felling is made in two phases in these stands – seed felling and final felling. Seed felling is used to cut timber species that compete with the pedunculate oak in regeneration in order to encourage the emergence of pedunculate oak rejuvenation on the regenerated plot. Should the species composition of these stands be dominated by ash at a cost of oak, regeneration felling must be combined with artificial regeneration by introducing acorns or oak transplants.

TENDING BEFORE THE FIRST THINNING

It has been already explained above that in pedunculate oak the tending operations very often overlap with the regeneration works, a boundary between the two groups of works being non-existent or very weak. Reasons should be sought particularly in rather complex stand and site conditions in which the floodplain forests develop today. Improvement of edaphic conditions for the current stand and for the future young growth consists in loosening of compacted soil, accumulated raw humus and undecomposed litterfall. At the same time, the cultivation eliminates weeds endangering oak seedlings or rejuvenation. Surplus surface water accumulated in micro-depressions is taken away by means of digging out superficial canals. All these operations represent a continuation of works that were necessary in site preparation for the regeneration of floodplain forest stands. If the site preparation has not been made, the goal of these works is to create conditions most favourable for the development and rejuvenation of pedunculate oak seedlings. The works are normally carried out under the closed crown canopy of the parent stand which is at a stage of regeneration, which means that the works are needed and important in order to enable survival of the young growth which has in the enhanced edaphic conditions also better conditions for assimilation and biomass production.

Young growth (both seedlings and sprouts) is protected from the moment when a decision was made to adopt the shelterwood successive regeneration felling. By this way, the young growth is provided protection against frost and insolation. Tree canopy of the parent stand is to be maintained as required before the rejuvenated plants gain independence. At this place it is particularly relevant to emphasize importance of the lower storey which is in floodplain forests constituted by sciophilous or semi-sciophilous timber species such as hornbeam, linden and some other. These species are very important in the protection of young plants not only against unfavourable ecological conditions, but they also protect soil from severe weed infestation and maintain optimum soil moisture content. All this is to the benefit of pedunculate oak young growth protection. These trees may be kept until after final felling as long as the protection by them is needed, and felled at later stages of young stand tending.

Weed control measures consist primarily in mowing if the stand is at a stage of natural regeneration before and after final felling, and also at a stage of the development of seedlings or young growth. The same measures are taken to suppress other harmful tree species and weeds.

Protection against various biotic agents begins already in the first phase of regeneration felling when the regenerated plots are to be fenced. Young stems may be also coated with various chemical preparations to repel game and cattle and to prevent damage to young pedunculate oak growths. Reduction of wildlife populations or provision of required feed at sufficient amount and composition so that the animal metabolism would not have an urge to graze on young oak plants or bark seems the best protection against game damages. Protection against mildew is ever more needed and this protection measures should not be forgotten. Additional sowing or planting on regenerated plots in the floodplain forests is to be made in cases that it is needed on more than 20 % of regenerated area.

Enhancement can be made by spreading or sowing acorns, by planting both bare-rooted and containerized planting stock obtained from the excessively dense rejuvenation in the same stand or in the vicinity.

Tending of young plants after final felling is made by the elimination of injured individuals, by the removal of overtopping trees, shrubs and aggressive species threatening oak. Individual hornbeams may be partly left in the stand because in the future they will assume the tending function and will prevent the growth of weed. At the same time, weeds are to be controlled which endanger the oak seedlings and sprouts.

Main objective in this phase of tending is to provide a sufficient access of light to the young plants, to remove light treat suppressing individuals in order to accelerate the height increment of oak plants for them to quickly get out of the reach of weeds, shrubs and aggressive species. At this stage of works a time has arrived to start with the negative selection and to remove individuals of poor quality.

These necessary and costly operations are made mostly by hand using traditional manual tools (scythe, sickle, axe, machete and other). Possible is also the use of mechanization means such as rotary cultivator which can be raised above the young plants and which can remove anything that would steal light above the terminal bud.

Juvenile thinning are carried out at a stage of young growth and continue until the time of maximum height increment of the pedunculate oak stand, which is reached between 15 and 20 years of age.

Anything considered to be of low quality and unnecessary for the development of the future stand will be removed by negative selection. Declining, broken and otherwise injured trees will be cut out. Overtopping individuals and redundant pioneer species will be removed which also helps to control species composition in the stand. Juvenile thinning cannot encourage stems of the best quality because these cannot be precisely determined yet. However, it can be used to influence the representation of individual species and the spatial arrangement of the stand. In case of mixed stands, efforts are focused on the formation of group horizontal structure so that individual species are enabled to a mutual fair competition in their struggle for space above- and under ground. Through these efforts it is possible to achieve the stand variability and to avoid the felling of other timber species unless they put into danger the oak and if holding a position within the stand structure.

Regeneration of pedunculate oak stands is a long-lasting and expensive process which usually takes more than 10 years from the moment of its start. The natural regeneration can be sometimes lost after the final felling even in successfully regenerated stands if mildew control is neglected or mowing is not made. In the existing changed ecological conditions and with an ever greater impact of humans on the ecosystem of pedunculate oak there are many localities in which the pedunculate oak cannot be regenerated any more. The occurrence of neophytic plants such as the unintentionally introduced species *Amorpha fructicosa* which is currently spreading out of control represents at numerous places an irresolvable problem for the regeneration of pedunculate oak. Regeneration on extensive clear-felled areas is a matter of past, small-scale regeneration methods being today the only realistic possibility. Pedunculate oak continues to be the main commercial timber species in Croatia, and its natural regeneration will remain the main method of its regeneration also in the future; only it will have a far greater number of variants that have to be adopted in order to accommodate to newly arisen situations.

CONCLUSION

Natural rejuvenation represents the most perfect way for regenerating stands of pedunculate oak. Natural rejuvenation or natural regeneration does not discontinue the mutual relations and mutual impact of individual elements (site and biocoenosis) within the ecosystem.

Site preparation prior to natural regeneration is currently a necessary constituent of the regeneration procedure. One of basic regeneration fellings in which the new stand is arising under protection of the parent stand is shelterwood felling. Shelterwood felling is at the present time characterized in Croatia by three stages (preparatory felling, seed felling and final felling).

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EMERGENCE OF ABOVE-GROUND PART AND ROOT SYSTEM IN PEDUNCULATE OAK (*QUERCUS ROBUR* L.) AFTER WHOLE-AREA SITE PREPARATION BY PLOUGH AND ROTARY CULTIVATOR AND AFTER REGENERATION BY SOWING AND PLANTING

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Abstract

The work analyzes the development of above-ground part and root system of pedunculate oak (*Quercus robur* L.) aged 6-22 years after different whole-area mechanical methods of site preparation before and after their regeneration by sowing and planting on clearcuts of different size. Whole-area ploughing, agroforestry and whole-area surface rotary cultivation have no influence on the emergence of oak. Rotary cultivation to a depth of 40 cm showed a negative impact on root system development. Identical emergence of oak was recorded on localities sized two, five and more hectares also after regeneration by sowing and planting. Pedunculate oak is observed to produce at all times an ectomycorrhizal root system with substitute taproots, which reaches the groundwater table already at a shoot-height of ca. 4 m.

Key words

pedunculate oak, regeneration method, root system, above-ground part

INTRODUCTION

Elimination of weeds is one of the most serious problems in regenerating forests on alluvial sites. Weeds steel water and nutrients and restrict the access of light to the pedunculate oak which is a profusely light-loving tree species, the lack of which may very rapidly result in the kill of transplants (Lüpke 1998; Houšková 2004; Kühne and Bartsch 2005). Weeds occurring on alluvial sites may overgrow the transplants even severalfold. Elimination of this negative impact of weeds only after planting (mowing, application of herbicides) requires a good organization, must be often repeated and is costly (Stejskal 2001). Floodplain sites in southern Moravia have been for more than several tens of years now subjected to the mechanical preparation by whole-area ploughing prior to regeneration (Vybíral 2001). The measure suppresses the growth of weeds for up to 2 years while considerably contributing to the simplification of regeneration itself as it facilitates its mechanization. The extensive ploughed areas were long time used also for agroforestry which is a simultaneous growing of agricultural crops between the rows of forest tree species. In the last seven years the ploughing was replaced by another whole-area mechanical operation – rotary cultivation which differs from the ploughing by crushing the logging residues and by working them into the soil profile by various methods. Although a common visual assessment normally would not reveal any differences in the growth of plantations and stands established without the mechanical preparation and after the whole-area mechanical site preparation, there are voices increasingly heard (with no exact evidence provided) that the whole-area mechanical site preparation adversely affects the growth of young oak trees and namely of their root systems.

The very best method of regenerating the pedunculate oak would be natural regeneration. However, long unsatisfactory fructification (Kotrla 1999, 2000; Vacel et al. 2000) led to a greater use of artificial regeneration by planting. Again without any plausible evidence some opinions are presented that regeneration by planting has a negative impact on the emergence of pedunculate oak root system, which should be together with the mechanical site preparation also the reason to its decline in the region.

The objective of the paper is to bring an exact and complex analysis of the development of above-ground part and root system of pedunculate oak on sites after the whole-area mechanical preparation by ploughing and rotary cultivation, after agroforestry and without mechanical site preparation, and to compare the development of pedunculate oak root system from planting and sowing on identical sites. Another goal of the work is to answer the question of whether the emergence of oak can be affected in the concerned parameters by the clearcut size.

MATERIAL AND METHODS

Basic methodological procedures

- All measurements were made in the LČR (Lesy České republiky) territory, Forest Enterprise Židlochovice, forest districts Soutok and Tvrdonice on a very frequently occurring forest type 1L9.
- Regeneration after the whole-area mechanical site preparation by ploughing. The logged-over stand was subjected to removal of logging residues, stumps (by shooting) and to whole-scale autumn ploughing to a depth of about 40 cm. The plot was regenerated next spring.
- Agroforestry. The oak planting (sowing) was followed by the inter-row cultivation of agricultural crops (root-crops) such as potatoes, beet, maize, exceptionally sunflower. Agroforestry was practiced three years at maximum. Procedures agreed for the cultivation of agricultural crops included a simultaneous treatment of the regenerated oak.
- Regeneration after the whole-area mechanical site preparation by rotary cultivation. Logging residues were not removed but crushed into fractions of size to 5 cm. The rotary cultivation included also stumps of the logged trees. Superficial rotary cultivation – crushed logging residues were worked into the soil to a max. depth of 5 cm; deep rotary cultivation – crushed logging residues were worked into a depth of about 40 cm. Regeneration was carried out at a minimum time of 4 months after the rotary cultivation.
- Clearcut size. Pursuant to the existing legislation, the size of a clearcut in floodplain sites can be up to 2.00 ha; before 1995 it was 5.00 ha. The work analyses the two maximum clearcut sizes but also clearcuts over 5.00 hectares, which came to existence by the additional felling of stand remainders.
- Stands surveyed for the impact of mechanical site preparation by ploughing and by agroforestry were aged 17-22 years and sized 0.90 – 8.64 ha. Stands surveyed for the impact of mechanical site preparation by rotary cultivation were aged 6 years (the oldest stands established by this method of regeneration) and clearcuts were sized up to 2.00 ha. Stands analyzed for the impact of sowing and planting were of diverse age (in order to obtain a time series).
- Methodological procedures used to analyze the above-ground parts and root systems were identical in all surveys.
- Demonstrativeness of the measured parameters was tested statistically. Controls in the surveys of mechanical site preparation were plantations and stands established without mechanical site preparation, controls in the surveys of the impact of sowing and planting were plantations and stands established by sowing. Results of tests are in tables

differentiated graphically. In the case of significant variances the presented values (arithmetic mean and standard error) are added the +sign.

Above-ground part analyses

– All analyzed plantations or stands were of the same stocking.
– In every stand situation (clearcut size, without mechanical site preparation, whole-area ploughing, superficial rotary cultivation, deep rotary cultivation) two plantations or stands were measured with a minimum number of trees being 100.
– Above-ground part length. Measured was the stem length from the ground to the apex of terminal shoot.
– Stem diameter. Measured was the stem diameter at a height of 1.3 m from the ground surface.
– Crown setting height. Measured was the distance from the ground surface to the first branches with the green foliage.
– Crown width. The measurement was made at the widest place in the crown.
– Crown symmetry. S – symmetrical, M – slightly one-sided, V – distinctly one-sided.
– Crown form. E – ellipsoid, K – spherical, P – semi-spherical, O – other (flag-shaped, irregular).
– Stem form. J – cylindrical stem, D – one fork, DD – two forks, ND – more than two forks, V – multiple stem.
– Stem slantiness. Characterizes stem inclination at its foot. Measured was the angle between the perpendicular through the stem foot and the stem line.
– Stem waviness. Characterizes cylindrical growth of the stem: 0 – waveless, straight, 1 – waves up to 1 stem diameter, 2 – waves up to 2 stem diameters, 3 – waves up to 3 stem diameters, 4 – waviness greater than three stem diameters.
– Damage to stem. N – intact stem, Z – game damages (browsing, winter stripping), H – insect damages (*Buprestidae*, *Cerambycidae*), S – drought damages, J – other damages (most frequently during the treatment of young plantations and tending measures).

Root system analyses

– In establishing the impact of mechanical site preparation by ploughing and agroforestry on the root system development it was impossible to analyze all stand situations due to labouriousness but only the stand situations of decisive importance – Control (without mechanical preparation) on a clearcut area of 1.86 ha, whole-area ploughing on a clear cut area of 8.64 ha, agroforestry on a clearcut area of 4.54 ha. Through these analyses it is possible to establish demonstrably the effects of clearcut size and implemented mechanical site preparation. Each stand situation included analyzed 6 trees.
– In establishing the impact of mechanical site preparation by rotary cultivation stand situations analyzed were those without mechanical site preparation (control), superficial rotary cultivation and deep rotary cultivation – at all times up to an area of 2.00 ha. Each stand situation included 12 analyzed trees.

– The number of trees analyzed in establishing the impact of sowing and planting is presented in tables of results.

– Root systems of all analyzed trees were lifted manually by a so called archaeological method and analyzed according to methodological procedures developed by the Brno School of Rhizology (Mauer 1989). Trees chosen for the analyses in each stand situation were non-marginal, intact, with a cylindrical stem and identical length of above-ground parts.

– A closer explanation to some methodological procedures. Horizontal roots were assessed both for their total count and count in individual soil layers. The number of the branching of substitute taproots is to specify how many times in the course of their growth the substitute taproots further divided in dependence on rooting depth. The cylindrical shape of substitute taproots is to characterize their straight or undulated growth; 1 – waving to one diameter of substitute taproot, 2 – waving to two diameters, 3 – waving greater than two diameters. Index p (in tables of results also designated as Ip) is a calculated value to characterize the relation between the root system size and the size of above-ground part; it is a ratio of the sum of cross-sectional areas of all skeletal roots in mm^2 to the tree height in cm (the higher the Index p value, the larger the tree root system).

RESULTS

Impact of the whole-area site preparation by ploughing and agroforestry, impact of the clearcut size (Table 1, 2)

– No significant differences were found in any of monitored parameters and traits of above-ground part between trees growing on sites without site preparation, after whole-area ploughing or after agroforestry. Similarly, no significant differences were found in the impact of clearcut size on the studied parameters. A few variances resulted not from the method of site preparation but from the tending of these stands (crown symmetry, stem waviness) or from the method of their protection (game damage).

– No significant differences were found in any of the studied root system parameters and traits between trees growing on sites without soil preparation, after whole-scale ploughing or after agroforestry. No significant differences were either found in the parameters assessed in trees growing on clearcuts of various sizes. In all studied stand situation the oak produced tabular horizontal roots the profile of which very rapidly (up to a distance of 50 cm) changes into a circular one. Also, the termination of horizontal roots is identical – nodes, locks. All trees developed an equally large ectomycorrhizal root system with substitute taproots, identical architecture and rooting depth. Identical was also the growth response of horizontal roots in dependence on the depth of their rooting (layer 1/depth 5-30 cm, layer 2/depth 35-50 cm, layer 3/depth 70-90 cm). If the horizontal roots shoot from the outside of these zones, they would turn into them during their further growth.

– No significant differences were found in any of the studied above-ground part or root system parameters between trees growing on two- or five-hectare sized and larger clearcuts.

– Evaluation: Neither the mechanical site preparation by whole-area ploughing or by agroforestry, nor the clearcut size exhibited negative or positive influence on the growth of above-ground part and root system of pedunculate oak. A few recorded growth deviations were induced by tending measures.

Table 1: Emergence of the above-ground part of pedunculate oak after whole-area ploughing and agroforestry

Site preparation	**Clearcut size (ha)**	**Stand age (years)**	**Length of above-ground part (m)**	**Stem diameter in $d_{1,3}$ (cm)**	**Crown setting height (m)**	**Crown width (m)**	**Crown symmetry (in % of trees)**			**Crown form (in % of trees)**			
							S	**M**	**V**	**E**	**K**	**P**	**O**
No preparation (Contr.)	1.86	18	10.4±0.9	9.0±2.4	6.6±0.5	3.4±0.7	49	20	31	25	24	25	26
No preparation (Contr.)	2.00	22	10.5±0.9	9.6±2.4	6.7±0.4	3.2±0.6	48	25	27	25	23	35	17
No preparation (Contr.)	5.25	18	10.2±1.2	9.0±2.7	6.0±0.9	3.2±0.7	60	20	20	42	24	13	21
No preparation (Contr.)	3.72	20	10.2±1.3	8.1±2.7	6.5±0.7	3.2±0.7	58	12	30	40	24	16	20
Whole-area ploughing	1.89	20	10.6±1.2	10.0±3.1	6.4±0.4	3.5±0.7	47	27	28	24	29	28	19
Whole-area ploughing	0.90	21	10.4±1.1	9.8±2.9	6.4±0.6	3.4±0.7	40	20	40	23	20	28	29
Whole-area ploughing	6.30	19	10.9±1.4	10.7±2.2	6.9±0.8	3.6±0.6	52	20	28	18	38	33	11
Whole-area ploughing	8.64	18	9.6±1.5	8.3±3.1	6.3±1.0	2.9±0.9	59	26	15	36	24	18	22
Agroforestry	2.07	19	10.2±1.4	8.4±2.9	6.3±0.8	3.0±0.9	43	28	29	19	38	24	19
Agroforestry	6.27	18	10.2±1.4	9.3±2.7	6.4±0.8	3.3±0.9	60	24	16	39	22	17	22
Agroforestry	4.54	18	9.9±1.1	8.0±2.2	6.1±0.5	2.8±0.7	58	21	21	36	21	34	9

Table 1: continued

Site preparation	Clearcut size (ha)	Stem form (in % of trees)					Stem slantiness (in % of trees)				Stem waviness (in % of trees)					Stem damage (in % of trees)			
		J	D	DD	ND	V	0°	up to 10°	up to 20°	over 20°	0	1	2	3	4	N	Z	H	J
No preparation (Contr.)	1.86	46	34	14	2	4	33	58	8	1	25	26	31	7	11	96	3	1	0
No preparation (Contr.)	3.00	53	29	6	6	6	40	42	17	1	13	29	19	13	26	95	3	2	0
No preparation (Contr.)	5.25	65	25	3	4	3	43	40	14	3	20	32	24	10	14	82	17	0	1
No preparation (Contr.)	3.72	57	34	5	3	1	46	41	11	2	23	34	26	8	9	96	4	0	0
Whole-area ploughing	1.89	53	23	5	6	3	25	60	12	3	9	21	32	16	22	96	1	0	3
Whole-area ploughing	0.90	45	31	11	9	4	31	45	17	7	17	19	27	13	24	98	1	0	1
Whole-area ploughing	6.30	47	33	10	7	3	48	39	12	1	13	22	31	15	19	91	7	0	2
Whole-area ploughing	8.64	74	20	1	3	2	45	40	12	3	26	24	24	10	16	88	11	0	1
Agroforestry	2.07	50	31	10	6	3	26	53	19	2	15	17	25	16	31	93	1	0	6
Agroforestry	6.27	65	18	6	7	4	40	35	12	13	17	39	22	11	11	93	5	0	2
Agroforestry	4.54	38	36	16	8	2	31	48	21	0	13	20	36	18	13	96	1	0	3

Table 2: Emergence of the pedunculate oak root system after whole-area ploughing and agroforestry

Parameters and traits	No preparation (Contr.)	Whole-area ploughing	Agroforestry
Clearcut size (ha)	1.86	8.64	4.54
Above-ground part length (cm)	1,096±32	1,133±68	1,110±20
Stem diameter	90.6±11.0	97.3±3.2	94.0±12.2
Root system type (in % of trees)			
- taproot	100	100	100
- substitute taproots	0	0	0
No. of substitute taproots at a half of their length (pcs)	2.8±0.6	3.6±0.6	3.0±1.5
Length of subst. taproots – rooting depth (cm)			
- average length	131.3±17.0	126.0±24.0	123.7±8.9
- maximum length	134.3±20.5	143.7±25.4	137.0±12.9
Diam. of subst. taproots at a half of their length (mm)	31.3±13.0	28.3±11.1	25.1±12.9
No. of horizontal roots (pcs)			
- layer 1	16.3±1.5	17.7±3.5	11.3±3.5+
- layer 2	7.0±2.6	7.7±1.5	13.3±2.1+
- layer 3	5.0±2.0	7.7±1.2	7.0±3.5
- total	28.3±5.0	33.1±3.5	31.6±4.2
Diameter of horizontal roots (mm)			
- layer 1	17.5±8.6	18.3±8.5	12.9±13.2
- layer 2	14.1±5.6	12.5±3.6	12.1±6.1
- layer 3	7.6±2.5	8.8±2.7	5.8±2.4
- total	14.9±8.0	14.7±7.7	14.5±11.1
Length of horizontal skeletal roots (cm)	158±68	175±59	181±64
Max. angle between HSR (degrees)	25±13	23±6	27±6
Occurrence of anchors on HSR (in % of trees)	100	100	100
- number of anchors (pcs)	9.3±0.6	9.3±1.2	12.7±1.5
- diameter of anchors (mm)	12.6±5.6	10.9±4.0	9.4±2.3
- rooting depth of anchors (cm)	67.0±25.5	51.0±15.6	64.7±11.5
Number of subst. taproots branchings (pcs)	2.7±0.6	2.3±0.5	2.0±0.0
Cylindrical substitute roots (not tapered)	1.6±0.8	2.0±1.0	1.7±1.2
Index p - total	10.1±3.3	10.1±1.9	9.8±3.2
- % share of HSR in the Ip value	57.6±6.1	65.1±7.2	69.0±5.6
- % share of subst. taproots in the Ip value	30.8±9.2	26.0±5.6	23.1±4.4
- % share of anchors in the Ip value	11.6±4.4	8.9±2.5	7.8±2.4
Biomass of fine roots (g.100 ml earth^{-1})	0.045±0.002	0.047±0.004	0.047±0.003
Type of mycorrhiza	ekto	ekto	ekto
Root rots (in % of trees)	0	0	0
Infestation of roots by biotic agents (in % of trees)	0	0	0

Impact of the whole-area site preparation by rotary cultivation (Table 3, 4)

- No significant differences were found in any of the measured parameters and traits of above-ground part and root system between trees growing on sites without soil preparation and after superficial rotary cultivation.
- Deep rotary cultivation had no influence on the growth of above-ground part but affected the root system development. Following the deep rotary cultivation, the tree develops the same system of substitute taproots with the same rooting depth. However, the development of horizontal roots is different. After deep rotary cultivation the trees produce more horizontal roots whose diameter is by a half smaller, though. Therefore, the root system is smaller as compared with the Control (lower Index p value). Differences were observed namely in soil horizons worked by the rotary cultivator.
- Evaluation: Superficial rotary cultivation has neither positive nor adverse influence on the growth of above-ground part and root system of the pedunculate oak. Deep rotary cultivation does not affect the growth of above-ground part but shows a negative impact on root system emergence at the age of analyzed young plantations. Soil horizons worked by deep rotary cultivation start produce horizontal roots only now. Their number is high, and it is to be expected that the trees will catch up in both number and diameter of horizontal roots with trees growing on sites with no soil preparation (the worked layer of soil does not contain undecomposed wood mass any more). The inhibition of the production and growth of horizontal roots is induced inappropriate physical and hydric characteristics of the worked layer, which also result in higher losses after regeneration. This is why the deep rotary cultivation is no longer used in the concerned region.

- Impact of sowing and planting (Table 5)
- The traditional opinion that oak produces only the typical taproot system does not hold true. Oak from both sowing and planting produces a substitute taproot system with substitute taproots growing in a profusely positive geotropic direction. Taproot occurrence is more frequent (not 100 %) only in the initial stages of tree development, being rather exceptional at a later age.
- Trees from both sowing and planting produce a root system with the identical number of substitute roots, identical is also the depth of their rooting. Plants try to reach groundwater table as rapidly as possible, which occurs at their height of about 4 m. New plantations will not suffer from water deficiency after the groundwater table falls in consequence of the regulation of water course (older trees are incapable of responding fast to the fall of groundwater table any more).
- Trees from both sowing and planting produce a root system of the same size (Index p values).
- Evaluation: no differences were found in the architecture of pedunculate oak root system from sowing and planting that would speak against planting. The conclusions hold also to the emergence of root system from natural regeneration because in biological terms the natural regeneration and the sowing are identical. Additional surveys revealed that increased sowing density (overdense sowings) does not have any influence on root system architecture and rooting depth but inhibits the development of horizontal roots.

Table 3: Development of above-ground part of pedunculate oak after superficial and deep rotary cultivation

Site preparation	Clearcut size (ha)	Stand age (years)	Length of above-ground part (cm)	Stem diameter in $d_{1,3}$ (mm)	Crown setting height (cm)	Crown width (cm)	Crown symmetry (in % of trees)			Crown form (in % of trees)			
							S	M	V	E	K	P	O
No preparation (Contr.)	2.00	5	177.4±26.2	28.2±3.4	72.7±14.8	86.3±22.3	64	23	13	50	26	10	14
Superficial cultivation	1.97	4	150.0±18.0	25.0±2.7	47.4±14.2	61.9±11.3	50	30	20	43	25	13	19
Superficial cultivation	1.40	4	160.3±24.9	25.2±4.8	52.6±19.2	81.8±24.4	53	21	26	46	17	11	26
Deep cultivation	0.48	4	157.2±46.6	24.6±7.4	50.0±23.7	90.5±38.5	51	25	24	41	29	8	22
Deep cultivation	2.00	4	163.0±27.4	25.6±3.8	48.0±8.8	93.5±22.6	57	22	21	49	25	7	19

Table 3: continued

Site preparation	Clearcut size (ha)	Branches (pcs)	Diameter of the most long branch (cm)	Length of the most long branch (cm)	Stem form (in % of trees)					Stem slantiness (in % of trees)				Stem damage (in % of trees)			
					J	D	DD	ND	V	0°	up to 10°	up to 20°	over 20°	N	Z	S	J
No preparation (Contr.)	2.00	18.7±4.1	6.8±1.8	54.2±15.5	49	30	9	10	2	55	37	5	3	45	3	32	20
Superficial cultivation	1.97	16.8±2.4	6.2±1.2	48.0±7.7	43	25	13	9	10	55	39	6	0	39	1	30	30
Superficial cultivation	0.85	18.5±4.1	7.4±1.8	60.1±11.9	46	17	11	12	14	36	43	21	0	33	3	27	27
Deep cultivation	0.48	16.2±5.8	8.4±2.3	58.6±21.7	41	29	8	8	14	32	45	17	6	22	12	27	19
Deep cultivation	2.00	17.4±3.4	7.3±1.9	58.2±17.1	49	25	7	7	12	54	37	10	0	39	1	25	35

Table 4: Emergence of pedunculate oak root system after superficial and deep rotary cultivation

Parameters and traits	No preparation (Contr.)	Whole-area ploughing	Agroforestry
Clearcut size (ha)	2.00	0.85	2.00
Above-ground part length (cm)	179±4	171±8	161±9
Stem diameter	25.6±1.7	22.5±2.7	20.1±1.5
Root system type (in % of trees)			
- taproot	17	0	17
- substitute taproots	83	100	83
No. of substitute taproots at a half of their length (pcs)	2.6±0.5	2.2±0.4	2.7±0.5
Length of subst. taproots – rooting depth (cm)			
- average length	78.6±12.2	84.1±4.4	85.8±7.1
- maximum length	85.7±10.1	85.5±4.3	87.6±7.9
Taproot – substitute taproots diameter (mm)	12.4±5.0	10.9±3.0	9.4±3.8
Number of horizontal roots (pcs)			
up to the first branching of subst taproots	7.1±3.5	7.5±3.7	14.3±2.7+
on the taproot – on substitute taproots	9.9±4.0	10.2±3.8	8.1±2.5
total	17.0±2.9	17.7±2.0	22.4±4.8+
Diameter of horizontal roots (mm)			
up to the first branching of subst. taproots	5.5±2.7	5.2±3.6	2.7±1.7+
on the taproot – on substitute taproots	3.5±1.4	3.3±1.9	2.4±0.7
total	4.6±2.5	4.1±2.9	2.6±1.5+
Length of horizontal roots	94±36	105±41	43±21
Maximum angle between HSR (degrees)	42±17	51±11	40±11
Occurrence of anchors on HSR (in % of trees)	17	17	17
number of anchors (pcs)	1.0±0.0	2.0±0.0	2.0±0.0
diameter of anchors (mm)	8.0±0.0	7.0±1.4	7.5±0.7
depth of anchors rooting (cm)	37.8±0.0	35.0±5.6	35.5±12.0
Number of taproot – substitute taproots branchings (pcs)	1.7±0.9	1.5±0.8	2.0±0.6
Depth of the first branching (cm)	16.5±1.1	14.2±3.1	16.7±1.8
Cylindrical taproot – substitute taproots	2.8±0.4	3.0±0.0	3.0±0.0
Index p – total	4.28±1.04	3.65±0.86	2.58±0.76+
% share of HSR in Ip value	51.7±9.8	53.7±9.7	39.5±9.5+
% share of taproot – anchors in Ip value	47.6±10.4	44.5±11.5	64.5±13.2+
% share of anchors in Ip value	0.7±2.1	1.8±5.3	2.0±5.1
Biomass of fine roots (g.100 ml^{-1})	0.027±0.004	0.026±0.002	0.017±0.002+
Type of mycorrhiza	ekto	ekto	ekto
Root rots (in % of trees)	0	0	0
Infestation of roots by biotic agents (in % of trees)	0	0	0

Table 5: Emergence of pedunculate oak root system from sowing and planting

Method of regeneration	Number of analyzed trees (pcs)	Length of above-ground part (cm)	Stem diameter $d_{1,3}$ (mm)	Root system type of analyzed trees (pcs)		Number of subst. taproots at a half length[1)] (pcs)	Length of subst. taproots-taproot (rooting depth) (cm)	Depth of the first setting of subst. taproots[1)] (min. and max.) (cm)	Number of subst. taproots branchings[1)] (pcs)	Ip[2)] (%)
				Taproot	Subst. Taproots					
Sowing	21	73	-	11	10	2.7	31	11 až 24	1.0	100
Planting	20	69	-	3	17	2.8	35	13 až 18	1.0	95
Sowing	18	216	31	3	15	2.8	94	11 až 25	1.5	100
Planting	17	200	30	0	17	3.6	98	15 až 19	1.7	102
Sowing	11	290	44	0	11	3.7	112	13 až 33	1.9	100
Planting	6	300	55	1	5	3.8	114	15 až 18	2.1	104
Sowing	9	450	67	1	8	2.9	169	10 až 55	2.1	100
Planting	6	510	75	0	6	3.0	172	14 až 19	2.3	95
Sowing	6	1,090	91	0	6	2.8	184	18 až 36	2.7	100
Planting	6	1,110	94	0	6	3.0	187	14 až 24	2.0	108

Note: [1)] only in trees with substitute taproot system

[2)] Ip value in sowing

CONCLUSIONS

Main conclusions deduced from the implemented surveys are as follows.

– After whole-scale soil preparation by ploughing, agroforestry and whole-area superficial rotary soil cultivation the trees produce the same above-ground part and the same root system as in regeneration with no mechanical site preparation – mechanical site preparation by ploughing, agroforestry of superficial rotary cultivation has neither negative nor positive influence on the growth of pedunculate oak.

– Although the deep rotary cultivation does not affect the growth of above-ground part, it impacts the development of the root system. The root system type or the rooting depth do not change but the root system is weaker and has less fine roots due to the absence of larger-diameter horizontal roots in the worked soil layer.

– Trees growing on clearcuts up to two hectares in size and on clearcuts larger than five hectares produce the same above-ground part and the same root system – maximum clearcut size stipulated by legislation has no influence (negative or positive) on the growth of pedunculate oak.

– Trees emerged from sowing and planting produce the same root system.

– A general conclusion can be made that the pedunculate oak develops in all situations an ectomycorrhizal root system with substitute taproots and with a profusely geotropic growth of the substitute taproots (occurrence of typical taproot being more frequently observed only at earlier developmental stages of the tree, and exceptional in the further development). The pedunculate oak tries to reach with its root system rapidly the groundwater table, which happens at a tree height of about 4 m. The above-ground part and the root system of pedunculate oak exhibit a totally identical development on Forest types 1L9 and 1L1 (unpublished in the paper).

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IMPACT OF THE WHOLE-AREA SOIL PREPARATION BY PLOUGHING AND AGROFORESTRY ON SOME CHARACTERISTICS OF FLOODPLAIN ECOTOPES

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Abstract

The paper brings an analysis of the impact of whole-area site preparation by ploughing and agroforestry on undergrowth synusia, biological activity and physical and chemical soil characteristics. The analyses included twenty-year old stands of pedunculate oak (*Quercus robur* L.) on alluvial sites 1L9. Concurrent assessment was made of the impact of clear-felled area size. It can be deduced from the analyses that different site preparation or different clearcut size have no influence on the undergrowth synusia. Different site preparation or different size of clear-felled area has no influence on the biological activity of soil. Due to recurrent passes of machines, agroforestry was shown to have a negative impact on porosity and water retention capacity in the lower top soil (25-30 cm). Negative impact on the loss of C-substances due to accelerated mineralization was demonstrated after a single ploughing. The recorded differences are not of essential character with the measured values neither falling below critical limits nor affecting other monitored site parameters or development of root systems and above-ground parts of oak trees.

Key words

floodplain forests, mechanical site preparation, biological activity of soil, undergrowth synusia, physical and chemical soil analyses

INTRODUCTION AND OBJECTIVES

One of the most urgent problems in regenerating forests on alluvial sites is elimination of the negative impact of weeds which aggressively take hold of the ground and grow rapidly on these fertile sites even at a relatively low access of light (their height in the growing season being greater than the height of an adult man) and hamper or even make impossible regeneration of target species. In addition to chemical elimination of weeds (application of herbicides), other methods used in southern Moravia already for tens of years are whole-scale deep ploughing (depth of ca. 40 cm) and agroforestry (i.e. cultivation of forest trees and field crops at the same place and at the same time). In spite of the fact that differences in the growth response of pedunculate oak regenerated on plots after whole-scale soil preparation by ploughing (agroforestry) and on plots without mechanical soil preparation have never been demonstrated, and Mauer, Libus, Palátová (2007) did not find any significant differences in the growth of above-ground part or root system in this most spread tree species of pedunculate oak during exact analyses, a question remains whether these interventions into the forest ecosystem can eventually affect ecotope characteristics.

The objective of the work is to compare undergrowth synusia, biological activity of soil, and chemical and physical soil properties in pedunculate oak stands aged 20 years, differing from one another by clearcut size and by site preparation before forestation.

MATERIAL AND METHODS

Basic methodological approaches

- The experiment included 20-years old stands of pedunculate oak (*Quercus robur* L.) on sites 1L9, all stands of identical stocking 1.0. The stands differed by site preparation prior to regeneration: whole-area ploughing, agroforestry, no site preparation, and by size of the clear-felled area in regeneration: up to 3.00 ha (small clearcuts) and larger than 3.50 ha (large clearcuts). Detailed characteristics of analyzed stands see Tab. 1. The survey included 6 variants. For a better orientation in the tables of results the respective variants have been allocated a code of three characters: the first character (letter) is for soil preparation before regeneration: B – no site preparation, O – whole-area ploughing, P – agroforestry; the second character (letter) is for clearcut size : M – small clearcut, V – large clearcut; the third character (numeral) is to designate a concrete stand because some analyses were made with pairs of identical stands. The number of stands analyzed in all tests was not identical. However, a fundamental aspect was retained at all times – analyzed were different site preparations and different clearcut sizes.

Undergrowth synusia

- Determination of the forest type required to study typological maps from 1964 to 1999. Each stand was surveyed for a precise location of the concerned forest type 1L9 and for what development the given area experienced during the period of study. Reconnaissance of the stand included the demarcation of transects 20x20 m on which phytocoenological relevés were made. Vernal and summer aspects were monitored from 27 April – 2 May 2007 and from 24-27 August 2007, respectively. The survey included all variants in double repetitions.
- The phytological relevés were processed by using the programme Turboveg for Windows Version 2.57 (Hennekens, Schaminee 2001). Values presented in the table of results are those measured on the combined abundance and dominance scale.
- Plant communities were classified according to Ellenberg identification numbers which are empirically established values to express the species tolerance to some factors of environment (heat, light, continentality, soil reaction, availability of nutrients, humidity and salinity) (Ellenberg et al. 1992). Results were processed by using Juice Version 6.4 (Tichý 2002). Pairs of identical stands (site preparation, clearcut size) were consolidated in the evaluation.

Biological activity of soil

- One stand was chosen from each variant (BM2, BV1, OM1, OV1, PM1 and PV2). Soil was sampled on 20 June 2007 in each of the stands from three spots and a blended sample was prepared for analyses. The soil was taken from mineral depth of 5 - 10 cm under ground surface (without forest floor).
- The analyses were carried out according to methodological procedures developed by Foukalová and Pokorný (2006) with using the instrument Vaisala GMT 220.

Table 1: Characteristics of analyzed stands

Stand	Owner	Stand No.	Method of site preparation	Forest type	Altitude (m a.s.l.)	Clearcute size (ha)	Stand age (years)	Stocking
BM1	LČR f. district Tvrdonice	922F2a	No soil preparation	1L9	160	3.00	22	1.00
BM2	LČR f. district Tvrdonice	928A2	No soil preparation	1L9	160	1.86	18	1.00
BV1	LČR f. district Tvrdonice	914B2	No soil preparation	1L9	160	3.72	18	1.00
BV2	LČR f. district Tvrdonice	933B2	No soil preparation	1L9	160	4.25	17	1.00
OM1	LČR f. district Tvrdonice	922C2	Whole area ploughing	1L9	160	0.90	21	1.00
OM2	LČR f. district Tvrdonice	930B2	Whole area ploughing	1L9	160	1.89	20	1.00
OV1	LČR f. district Tvrdonice	914A2	Whole area ploughing	1L9	160	8.64	19	1.00
OV2	LČR f. district Tvrdonice	919C2	Whole area ploughing	1L9	160	6.30	18	1.00
PM1	LČR f. district Tvrdonice	926D2a	Whole area ploughing agroforestry	1L9	160	2.07	19	1.00
PV1	LČR f. district Tvrdonice	913B2	Whole area ploughing agroforestry	1L9	160	6.27	18	1.00
PV2	LČR f. district Tvrdonice	931D2	Whole area ploughing agroforestry	1L9	160	4.54	18	1.00

– Values of biological soil activity obtained from the analyses were as follows:
  - Basal respiration – designated as B. The higher the value, the greater amount of CO_2 respired by soil microorganisms;
  - Respiration after the addition of ammonium sulphate – designated as N. The higher the value, the greater amount of CO_2 respired by microorganisms after the addition of ammonium sulphate, i.e. they were short of soil nitrogen;
  - Respiration after the addition of glucose – designated as G. The higher the value, the greater amount of CO_2 respired by microorganisms after the addition of glucose, i.e. they were short of soil organic substances.

- Coefficients (ratios) calculated from these values were as follows:
  - Physiological availability of soil nitrogen. The higher the value, the lower the physiological availability of soil nitrogen. If the amount of available soil nitrogen is sufficient, the further addition of nitrogen would not increase the respiration and the value approximates 1. The coefficient is designated as N:B in the tables of results;
  - The amount of readily available soil organic substances. Higher values point to a lower amount of available organic substances. The coefficient is designated as G:B in the tables of results;
  - An idea about the mutual proportion of available soil carbon and nitrogen provides the coefficient designated in the tables of results as G:N. with respect to the fact that carbon use is at all times of great extent than that of nitrogen, the G:N ratio is equal to about 5 at a balanced physiological condition of these two elements. If the ratio is lower, soil microorganisms in the soil sample are relatively better nourished with organic substances than with nitrogen, and vice versa;
  - The factor of complex effect is designated in the tables of results as FKP. Its deviation from 1 indicates to what measure the other (namely physical) factors enable full utilization of carbon and nitrogen in complex effect as compared with the product of their effects in the case of separate application.

Physical and chemical properties of the soil

- Reason being their labouriousness, the analyses were made only in variants BM2, OV1 and PV1 (sites on which Mauer, Libus, Palátová (2007) simultaneously studied development of above-ground part and root system of pedunculate oak).
- Soil pits were excavated by hand down to groundwater table in all analyzed stands.
- Representative character of the place of excavation was established mainly on the basis of bioindicators and benchmarking dug-outs. Soil sampling for chemical and physical properties was carried out in all diagnostic horizons of mineral earth according to standard procedures (Zbíral 2002).
- Grain size was established by the pipetting method according to Zbíral (2004). Available nutrients phosphorus, potassium, calcium and magnesium were extracted from soil samples by Mehlich II solution on the nuclear absorption spectrophotometer. Sorption complex parameters were established by cumulative method, pH value was determined according to the methodology developed by Zbíral (2002), determination of hydrophysical soil characteristics was made according to Jandák et al. (1991).
- Statistic evaluation of physical soil properties was made by using one-factor ANOVA and multiple comparison by Scheffe’s test at a level of significance $\alpha = 0.05$.

RESULTS AND THEIR EVALUATION

<u>The impact of whole-area soil preparation by ploughing and agroforestry on the undergrowth synusia (Tables 2, 3; Fig. 1, 2)</u>

- Table 2 clearly demonstrates that the predominant types of undergrowth in the vernal aspect on the monitored plots were *Galium aparine* L., *Aster lanceolatus* Wild. and *Ficaria bulbifera* Holub. The neophytic species *Aster lanceolatus* Willd. dominated in the majority of stands after ploughing and agroforestry. In sites with zero soil preparation *Aster lanceolatus* Willd. occurred in smaller quantities, it nevertheless represented the dominant species in one stand with no soil preparation (BM2). The dominance of the other above mentioned species never depended on site preparation or clear-felled area size.
- As regards the other species, *Urtica dioica* L. and *Rubus caesius* L. had a frequent occurrence in the vernal aspect undergrowth. They were never predominant species but their degree of coverage often reached 10–20 %. Shrub layer species had a very low degree of coverage due to their level 1 stocking and it was even completely absent from some stands. Frequently occurring species of this layer were *Acer campestre* L., *Cornus sanguinea* L., *Prunus spinosa* L. and *Crataegus* sp. The tree layer was dominated exclusively by *Quercus robur* L. with the degree of coverage at 90 %.

Table 2: Phytocoenological relevés of stands, vernal aspect

Stand		BM1	BM2	BV1	BV2	OM1	OM2	OV1	OV2	PM1	PV1	PV2
Altitude (m a.s.l.)		160	160	160	160	160	160	160	160	160	160	160
Exposure		-	-	-	-	-	-	-	-	-	-	-
Gradient (°)		-	-	-	-	-	-	-	-	-	-	-
Aspect (vernal)		vernal	vernal	vernal	vernal	vernal	vernal	vernal	vernal	vernal	vernal	vernal
Total cover		95	100	90	100	95	100	90	100	90	85	100
Layer	Species name											
Tree	Quercus robur L.	+5	+5	+5	+5	+5	+5	+5	+5	+5	+5	+5
Shrub	Acer campestre L.	+		+	+	+	1					
	Acer pseudoplatanus L.											
	Cornus sanguinea L.		+	1	+	1				-		+
	Crataegus sp.	-	+		+				+	+	1	
	Fraxinus angustifolia Vahl.	+			1	-	-		-	+		-
	Prunus spinosa L.	+		+	1			1	-			
	Quercus robur L.									1		
	Sambucus nigra L.					1						
Herb	Aegopodium podagraria L.										+	
	Aster lanceolatus Willd.	+	-3		+	1	-2	+2	+3	+3	+2	+3
	Brachypodium sylvaticum Huds.	1	+	1			+					
	Carex riparia Curtis.	1			-2		-2	1	+		+2	
	Crataegus sp.			+								
	Deschampsia cespitosa (L.) Beauv.	+		+	+							
	Ficaria bulbifera Holub.	-3	-2	+3	+2	-2	+3		+2		1	+2
	Fraxinus angustifolia Vahl.	+		-			+		-	+		
	Galium aparine L.	-2	+2	-2	+3	-3	+2	-3	+2		+	+2
	Geum urbanum L.			+		1	+				+	
	Glechoma hederacea L.	+	+	-2	1	+	1			1	+	
	Impatiens parviflora D.C.	1			+							
	Iris pseudacorus L.	-	-		1				-	-	+	-
	Lamium maculatum L.										-	
	Lysimanchia nummularia L.									1		
	Rubus caesius L.	+2	+	-	+2	1	1	-3	1	+2	+2	-2
	Rumex sanguineus L.	-	+	-				+	-			
	Stachys sylvatica L.	+						+	-			
	Symphytum officinale L.	-	-									
	Urtica dioica L.	1	-2	+2	1	-3	-2	1	+	+2	-2	

– The summer aspect was not as plentiful as the vernal aspect with regard to species richness (Table 3). *Aster lanceolatus* Willd. was the dominant species on all sites after soil preparation and on one site with zero preparation. The terrestrial species *Ficaria bulbifera* Holub. which dominates in the vernal aspect and the omnipresent *Galium aparine* L. are absent in the summer aspect. Their dominance was replaced by the species *Rubus caesius* and *Urtica dioica* L. It is noteworthy that one site without soil preparation is dominated by the very low species *Glechoma hederacea* L. Another species which had a more frequent occurrence in the summer aspect was *Carex riparia* Curtis. Other species were represented only by a few individuals.

Table 3: Phytocoenological relevés of stands, summer aspect

Stand		BM1	BM2	BV1	BV2	OM1	OM2	OV1	OV2	PM1	PV1	PV2
Altitude (m a.s.l.)		160	160	160	160	160	160	160	160	160	160	160
Exposure		-	-	-	-	-	-	-	-	-	-	-
Gradient (°)		-	-	-	-	-	-	-	-	-	-	-
Aspect (vernal)		summer	summer	summer	summer	summer	summer	summer	summer	summer	summer	summer
Total cover		95	100	85	100	95	100	100	100	90	100	100
Layer	Species name											
Tree	Quercus robur L.	+5	+5	+5	+5	+5	+5	+5	+5	+5	+5	+5
Shrub	Acer campestre L.	+		+	+	+	1					
	Acer pseudoplatanus L.											
	Cornus sanguinea L.		+	1	+	1				-		+
	Crataegus sp.	-	+		+				+	+	1	
	Fraxinus angustifolia Vahl.	+			1	-	-		-	+		-
	Prunus spinosa L.	+		+	1			1	-			
	Quercus robur L.									1		
	Sambucus nigra L.					1						
Herb	Aegopodium podagraria L.										+	
	Aster lanceolatus Willd.	1	+3	-	1	+2	+2	+4	+4	+3	-3	+4
	Brachypodium sylvaticum Huds.	1	+	1			+					
	Carex riparia Curtis.	1			-2	-2	-2	+	+		+2	
	Crataegus sp.			+								
	Deschampsia cespitosa (L.) Beauv.	1		+	+							
	Ficaria bulbifera Holub.											
	Fraxinus angustifolia Vahl.	+		-			+		-	+		
	Galium aparine L.											
	Geum urbanum L.	1		+			+				+	
	Glechoma hederacea L.	1	1	+3	1	-2	1			+	+	
	Impatiens parviflora D.C.											
	Iris pseudacorus L.	-	-		1				-	-	+	-
	Lamium maculatum L.											
	Lysimanchia nummularia L.									1		
	Rubus caesius L.	-3	-2	-	-3	+2	1	-2	-2	+2	+2	-2
	Rumex sanguineus L.		+									
	Stachys sylvatica L.								-			
	Symphytum officinale L.	-	-									
	Urtica dioica L.	-3	+2	+2	+2	1	+2	1	+	-2	1	

– Fig. 1 describes undergrowth requirements for light, continentality and soil reaction. Vertical columns leading from the points which designate the individual averages indicate the 95% confidence intervals. It can be deduced from the figure that undergrowth herbs had very similar requirements for soil reaction. This variable now includes a significant statistical variance between the undergrowth synusia in individual stands despite the very low confidence intervals. It can be stated that herbs in all stands require relatively high pH. Undergrowth requirements for light reached average values. Mean values are again balanced in all stands – confidence intervals overlap. The figure further shows that undergrowth herbs do not require climatic conditions associated with the location in the centre of large continents. Average values of Ellenberg continentality index do not show any statistically significant difference.

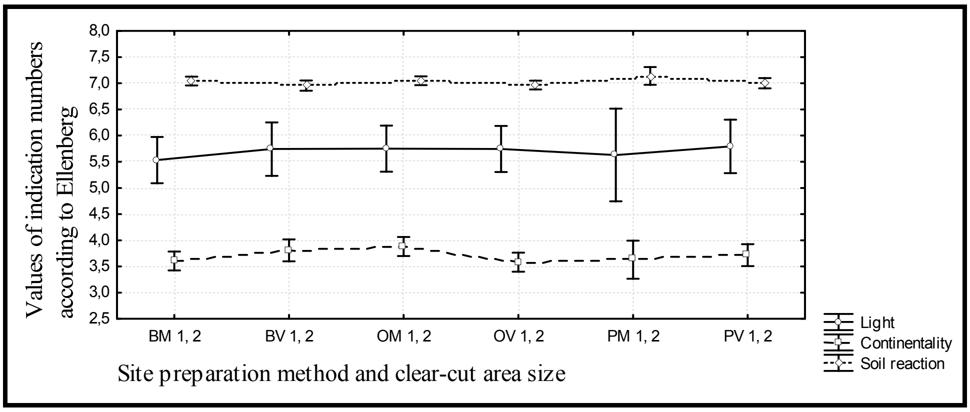

Fig. 1: Undergrowth requirements for light, continentality and soil reaction

– Fig. 2 specifies undergrowth requirements for temperature, moisture and nutrients. Considering that the investigation was conducted in floodplain forests, it is obvious that all herbs were relatively very nutrient-demanding - Ellenberg indexes arithmetic averages reach the value of roughly 7 but there is no statistically significant difference between them. Undergrowth synusia requires high moisture. There is no statistically significant variation between index mean values which stand for temperature.

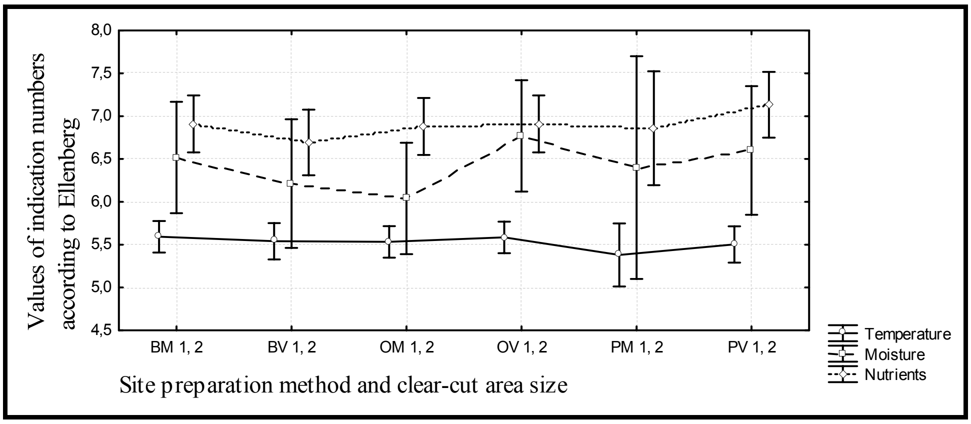

Fig. 2: Undergrowth requirements for temperature, moisture and nutrients

The impact of whole-area preparation by ploughing and agroforestry on biological activity of the soil (Table 4)

– It follows out from Table 4 that the values of soil samples basal respiration that we acquired vary. Statistical conclusiveness by means of a multifold comparison by Scheff test at the level of significance $\alpha = 0.05$ showed that variance does not exist only between the stands OM1 and PV2. Most intensive activity of soil edaphon was recorded in BM2 stand (0.805 mg $CO_2 \cdot 100g^{-1} \cdot h^{-1}$) and the lowest value of basal respiration was detected in stand BV1 (0.644 mg $CO_2 \cdot 100g^{-1} \cdot h^{-1}$). However, compared to the data specified in the professional literature, our results have a different information value. Růžek et al. (2006) specify that the basal respiration average value for Fluvisols is 0.46 mg $CO_2 \cdot 100g^{-1} \cdot h^{-1}$. Novák (1969) states that the basal respiration values in layers from 3 to 13 cm amount to between 0.60 and 1.36 mg $CO_2 \cdot 100g^{-1} \cdot h^{-1}$ and Šantrůčková (1993) cites the value range from 0.11 to 1.23 mg $CO_2 \cdot 100g^{-1} \cdot h^{-1}$.

- Judging by N:B coefficients, the physiological availability of soil nitrogen is high and balanced in all stands (majority of values approximate 1). Lhotský et al. (1987) cite coefficient values ranging from 1.19 to 1.34 in forest soils in the seventh year after ploughing which indicates that the monitored stands have a very good physiological availability of soil nitrogen and that, in the majority of cases, the values that we acquired are more balanced than the figures specified by Novák (1969) in illimerized soils.
- The quantity of readily available organic substances (G:B) is high when compared with literature and relatively balanced in all stands. Lhotský (1987) cites the range from 4.50 to 7.69 after seven years in ploughed forest soils, Foukalová and Pokorný (2006) specify a value ranging from 3.72 to 16.32 in a layer of up to 15 cm.
- The calculated values of the G:N coefficient show that soil micro-organisms in the monitored stands are better supplied with organic substances than with nitrogen and with the exception of the OV2 stand the values are very balanced. Foukalová and Pokorný (2006) measured the G:N value range between 2.32 and 7.93.
- The factor of complex effect in the stands monitored by us ranges between 1.22 and 2.16. These values indicate lower utilization of carbon and nitrogen in complex effect as compared with the corresponding product of their effect in the case of separate application. The values are nonetheless similar in all stands when compared with the data cited in the literature – 1.74 to 10.43 (Foukalová and Pokorný 2006).
- It can be generally concluded that despite partial variations the whole-area ploughing and agroforestry, similarly to the different size of a clear-felled area, do not have an influence on the soil activity.

Table 4: Values of basal and relative respiration

Stand	**B (mg $CO_2 \cdot 100g^{-1} \cdot h^{-1}$)**	**N:B**	**G:B**	**G:N**	**FKP**
BM2	0.805	0.894	2.276	2.546	1.740
BV1	0.644	1.040	2.551	2.454	1.648
OM1	0.735	1.027	2.300	2.239	1.460
OV2	0.712	0.711	3.036	4.268	2.161
PM1	0.665	0.863	1.977	2.291	1.397
PV2	0.732	1.019	2.286	2.243	1.236

<u>The impact of whole-area preparation by ploughing and agroforestry on physical and chemical soil characteristics (Tables 5, 6, 7)</u>

- The basic presumption assuming that the forest type 1L9 would have an identical soil subtype was not confirmed. The monitored stands (BM2, OV1, PV1) are characterized by different soil subtypes. Sites with the zero soil preparation (BM2) – gleyed eubasic Fluvisol, soil horizons: 0–1.5 cm – L horizon, 1.5–3 cm F horizon, 3–8 cm Ah_1 horizon, 8–25 cm Ahm horizon, 25–52 cm Mg_1 horizon, 52–85 cm Mg_2 horizon. Site with a whole-area ploughing (OV1) – gleyed eubasic Fluvisol, soil horizons: 0–3 cm L+F horizon, 3–17 cm Ahp horizon, 17–38 cm Ap horizon, 38–68 cm Mg_1 horizon, 68–98 cm Mg_2 horizon, 98–128 cm Mg_3 horizon. Agroforestry site (PV1) – gley eubasic Fluvisol, soil horizons: 0–2 cm L+F horizon, 2–11 cm Ahp horizon, 11–29 cm Apg horizon, 29–43 cm Mg_1 horizon, 43–72 cm Mg_2 horizon, 72–110 cm Mg_3 horizon. Basic differences lie in the fact that the local site conditions affect the development of gleyed soil subtypes to gley subtype of Fluvisol (elicited by the vicinity of a secondary water course). Another significant difference was determined in the zero site preparation stand (BM2) which shows deep salination (Cl^- and SO_4^{2-}) in the form of slightly crystallic fractions in the bottom layer starting 40 cm deep and significant salination at 60 cm and deeper (salination is not caused by anthropogenic factors).

– Specific weight does not show high fluctuations and it corresponds to the level of common mineral soils (2.5–2.7 $g.cm^{-3}$) which means that it is neither influenced by C-substances, chiefly by their fermentation and humification fractions, to a greater degree. This is confirmed also by high intensity of mineralization defined for example by the C:N ratio which is very low in all soil pits and fluctuates within the framework of individual horizons only in the range from 8 to 11:1.

– Reduced bulk density is one of the criteria for evaluating the soil environment quality, namely with respect to aerobic and respirating edaphon. The boundary value of the optimum top limit (1.6 $g.cm^{-3}$) was exceeded in partial horizons very exceptionally. Relatively the worst situation was recorded on the whole-area single ploughing site (OV1), in which the average value starting from 70 cm deep amounted to 1.7 $g.cm^{-3}$. This is however not due to whole-area preparation but because of the effects of site and soil-forming processes.

– Table 5 further illustrates that porosity on the treated plots does not decrease in any horizon below the risk level of 35 %. A different and generally considerably negative impact of both whole-area preparations was registered in the top soil horizon within the framework of treated plots with upper soil horizons in relation to the intact profile. As regards the applied technologies for organomineral horizon, no difference was determined. The agroforestry process presented a greater risk for more shallow subsoil of 25 – 35 cm as this process statistically greatly reduced its porosity. Porosity values of around 42 % on plots treated by agroforestry and characterized by stronger hydric influence get slightly below the optimal limit of 45 %. Such sites are already classified in the compacted soil group. Lower horizons on sites with whole-area technologies treatment then reach levels which approach risk values of very compacted soils (P–35 %). This trend was not registered in soil profiles on the zero preparation sites but the differentiation can be caused also by a specific edatope of this locality.

– High sorption and swelling capacity of soils on an untreated control plot – intact profile plot – markedly reflected in the evaluation of a very important quantity of minimum air capacity. The values in deep horizons from roughly 40 cm approximate zero. This problem does not occur in other plots.

Table 5: Physical soil parameters

Stand	Depth (cm)	Actual moisture (%)	Field moisture capacity (%)	Maximum water capacity (%)	Water retention capacity (%)	Reduced bulk density ($g \cdot cm^{-3}$)	Specific weight ($g \cdot cm^{-3}$)	Porosity (%)	Minimum air capacity (%)
BM2	10 - 15	38.89 ± 0.15	41.42 ± 1.11	39.21 ± 0.99	33.18 ± 0.80	**1.24 ± 0.05**	2.64 ± 0.06	**52.94 ± 1.28**	13.73 ± 1.55
	25 - 30	39.32 ± 1.17	**53.08 ± 2.10**	**48.39 ± 2.01**	**38.41 ± 1.31**	1.40 ± 0.03	**2.73 ± 0.01**	48.60 ± 0.89	**0.22 ± 2.76**
	50 - 58	**36.73 ± 1.32**	**53.33 ± 2.19**	**48.10 ± 2.17**	**38.20 ± 2.28**	1.53 ± 0.01	2.75 ± 0.01	**44.54 ± 0.05**	**0.15 ± 2.11**
	80 - 85	**37.10 ± 1.21**	**54.99 ± 2.43**	**48.94 ± 1.95**	**38.17 ± 1.50**	**1.54 ± 0.02**	2.68 ± 0.08	**42.61 ± 2.31**	**0.09 ± 1.31**
OV1	10 - 15	39.57 ± 2.61	41.03 ± 0.60	38.94 ± 0.51	32.03 ± 0.44	1.33 ± 0.03	2.61 ± 0.01	48.92 ± 1.24	9.98 ± 1.65
	25 - 30	39.50 ± 2.00	43.21 ± 0.75	40.19 ± 0.35	33.28 ± 0.17	1.38 ± 0.03	2.58 ± 0.05	46.68 ± 1.98	6.49 ± 2.33
	50 - 58	**31.66 ± 0.91**	39.48 ± 1.34	36.93 ± 1.19	29.21 ± 0.98	1.63 ± 0.03	**2.68** ± 0.01	**39.12 ± 0.90**	2.24 ± 1.27
	80 - 85	27.92 ± 0.92	35.96 ± 0.74	33.22 ± 0.62	25.67 ± 0.53	1.71 ± 0.02	2.65 ± 0.01	**35.50 ± 1.18**	2.28 ± 1.33
PV1	10 - 15	37.20 ± 0.90	39.97 ± 0.59	37.76 ± 0.63	31.83 ± 0.56	**1.39 ± 0.03**	2.63 ± 0.03	47.07 ± 1.22	9.31 ± 1.78
	25 - 30	.32.49± 3.99	38.04 ± 4.12	35.41 ± 3.60	**28.06 ± 3.20**	**1.53 ± 0.03**	**2.67 ± 0.03**	**42.72 ± 0.85**	7.31 ± 2.74
	50 - 58	32.63 ± 1.91	38.19 ± 0.91	35.57 ± 1.25	28.26 ± 1.28	1.59 ± 0.02	2.74 ± 0.02	42.12 ± 2.51	6.56 ± 1.53
	80 - 85	30.44 ± 0.58	39.96 ± 1.08	35.78 ± 0.62	28.24 ± 0.55	1.67 ± 0.01	2.72 ± 0.01	38.60 ± 0.30	2.82 ± 0.36

Note: Values in bold letters statistically significantly differ from values in the same horizon

- The level of soil reaction in the surveyed plots corresponds to moderately acid soils. As a consequence of sodium influence on the soil bsorption complex in deep horizons of the intact plot (BM2), its value for exchangeable soil reaction increases to the level of neutral limits. In this case it is rather an inhibitory factor (Table 6).
- The best quality decomposition with the highest production of humification fractions (1.53 %) was determined in the upper soil layer of genetically undisturbed horizons (BM2). The lowest values were registered in both technologically prepared plots.
- Nitrogen is an important element of nutrition. The acquired data on C:N correspond to the ideal state of its availability and they can entirely compete with the values of intensively managed plots of Agricultural Land Resources (ZPF).

Table 6: Chemical soil parameters

Designation		pH (H_2O)	pH (KCl)	Oxalates $g \cdot kg^{-1}$		%			Sodium pyrophospate				2M-HNO3
									%	%	%	%	$mg \cdot kg^{-1}$
Stand	**Depth (cm)**			**Fe**	**Al**	**C**	**N**	**C:N**	**C-CHL**	**C-HK**	**C-FK**	**HK/FK**	**Mn**
BM2	10 - 15	6.50	5.24	9.80	1.64	3.45	0.42	8.21	1.53	0.76	0.79	0.96	611.00
	25 - 32	6.92	5.49	14.00	1.58	1.95	0.17	11.47	0.52	0.25	0.27	0.93	720.00
	50 - 58	7.00	5.78	12.50	1.57	0.96	0.12	8.00	0.34	0.15	0.19	0.79	825.00
	80 - 88	7.09	6.08	4.72	1.61	0.71	0.07	10.14	0.18	0.09	0.09	1.00	381.00
OV1	10 - 15	6.60	5.15	9.29	1.90	1.87	0.24	7.79	0.78	0.34	0.43	0.79	619.00
	25 - 32	6.70	5.09	9.52	1.95	1.60	0.21	7.62	0.69	0.29	0.41	0.71	681.00
	50 - 58	6.83	5.38	6.14	1.33	1.18	0.08	14.75	0.21	0.11	0.10	1.10	463.00
	80 - 88	6.95	5.55	5.22	1.01	0.59	0.06	9.83	0.16	0.10	0.07	1.43	307.00
PV1	10 - 15	6.18	4.95	7.95	1.82	3.30	0.29	11.38	0.88	0.44	0.43	1.02	449.00
	25 - 32	6.45	5.18	8.10	1.86	1.98	0.18	11.00	0.56	0.22	0.33	0.67	344.00
	50 - 58	6.64	5.35	4.79	1.41	0.74	0.08	9.25	0.22	0.09	0.13	0.69	387.00
	80 - 88	6.71	5.54	6.76	1.26	0.71	0.06	11.83	0.19	0.09	0.09	1.00	488.00

- Accessible nutrients in profiles reach above-standard or very high values on the surveyed plots. Primarily magnesium values are very high and correspond to roughly a quintuple of very high reserve in entire profiles. They reach twice as high values than it is common for very high reserves in arable lands. High and nearly risky values were determined in lower soil horizons on the zero preparation plot (BM2) which is specific by its partial salination caused most likely by groundwater contamination. Correlative values of Cl^- and SO_4^{2+} further support this hypothesis (Table 7).
- Soil salination of over 0.2 mS/cm can be considered as slightly higher. It even reaches the values typical for saline soils ($0.7\ mS \cdot cm^{-1}$) in the depth of 80 cm. One of the essential components determining salination is also the increased presence of sodium. Precipitated salts in these horizons were apparent also in the course of reconnaissance evaluation of partial characteristics.
- Potassium is a chemical element which ensures cell growth and division (e.g. in the root system) and its deficiency causes hypertrophic development of parenchymal tissues. It also influences plant water regime and enzymatic activity. It is an important nutrition macro-bioelement. The ratio of potassium and magnesium can be dangerous and in some cases very dangerous. If the Mg:K chemical equivalent ratio exceeds the level of 10:1, the input of K in nutrition becomes suppressed on the basis of an antagonistic relation. If there is a sufficiently developed biomass in the upper rhizosphere, this risk can be eliminated chiefly in an intact soil profile site without soil preparation.

Table 7: Chemical soil parameters

Desigantion		Water extract 1 : 5			Mehlich II				Melich KVK - cumulative m.							
Stand	Depth (cm)	$mg \cdot kg^{-1}$	$mS \cdot cm^{-1}$	$mg \cdot kg^{-1}$	$mg \cdot kg^{-1}$				$mmol.chem.ekv. \cdot kg^{-1}$					suma		
		Cl^-	Conduct.	$S\text{-}SO_4$	P	Mg	Ca	K	H+	Mg	Ca	K	Al	KVK	Mg:K	v (%)
BM2	10 - 15	6.20	0.070	36.50	5	679	6,893	302	56	55.90	344.00	7.70	0.80	464.40	7.20	87.80
	25 - 32	30.90	0.088	57.30	< 1	789	8,133	202	42	64.90	405.80	5.20	0.40	518.40	12.50	91.80
	50 - 58	63.00	0.229	61.30	< 1	851	8,262	139	34	70.00	412.30	3.60	0.40	520.30	19.70	93.40
	80 - 88	80.30	0.572	90.40	< 1	964	8,493	107	30	79.30	423.80	2.70	0.00	535.90	28.90	94.40
OV1	10 - 15	6.70	0.052	12.80	< 1	696	6,490	212	42	57.30	323.90	5.40	1.60	430.20	10.50	89.90
	25 - 32	6.60	0.048	17.70	< 1	692	7,362	164	47	57.00	367.40	4.20	1.20	476.70	13.50	89.90
	50 - 58	10.30	0.050	47.90	< 1	592	5,083	102	30	48.70	253.60	2.60	2.80	337.80	18.60	90.30
	80 - 88	6.10	0.072	54.10	< 1	501	4,041	90	27	41.20	201.60	2.30	1.20	273.40	17.90	89.70
PV1	10 - 15	11.40	0.050	28.60	6	668	6,180	215	56	55.00	308.40	5.50	4.40	429.30	10.00	85.90
	25 - 32	12.10	0.054	34.60	< 1	652	6,723	151	42	53.70	335.50	3.90	0.80	435.80	13.90	90.20
	50 - 58	12.50	0.064	42.40	< 1	599	5,433	105	31	49.30	271.10	2.70	1.20	355.30	18.30	90.90
	80 - 88	24.60	0.100	83.90	< 1	606	5,590	96	28	49.90	278.90	2.50	0.80	360.10	20.30	92.00

CONCLUSION

The paper brings an analysis of the impact of a whole-area site preparation by ploughing and agroforestry on the undergrowth synusia, biological activity and physical and chemical soil characteristics. The surveyed sample included twenty-year old stands of pedunculate oak (*Quercus robur* L.) on alluvial sites 1L9. Concurrent assessment was made of the impact of clear-felled area size. The following conclusions can be drawn from the conducted analyses:

- Different site preparation or clear-cut area size do not influence the undergrowth synusia.
- Different site preparation or clear-cut area size do not influence the biological activity of the soil.

– Agroforestry as a result of recurrent passes of machines negatively affects the porosity and water retention capacity in the lower part of topsoil (25–30 cm). Single ploughing exerts negative impact on the decrease of C-substances due to accelerated mineralization. The recorded differences are not of essential nature, the values did not fall below critical limits and they did not influence other monitored site parameters or development of root systems or above-ground parts of oak trees in none of the cases.

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ELIMINATING THE NEGATIVE INFLUENCE OF FOREST WEEDS IN THE PEDUNCULATE OAK (*QUERCUS ROBUR* L.) REGENERATION ON ALLUVIAL SITES BY MOWING TO "HIGH STUBBLE"

Oldřich Mauer, Petra Mauerová

Abstract

The paper analyses possibilities of eliminating the negative influence of forest weeds by mowing to "low stubble," to "high stubble," during the treatment of "high stubble" by wick applicator for herbicides and by the application of varied planting density with subsequent mowing to "low stubble" during regeneration of pedunculate oak by sowing or planting on alluvial sites 1L1 and 1L9. Main conclusions from the survey are as follows. The plantations and the young stands of oak grow up best if their crown is in the sun and their stem is in the shade. Mowing to "high stubble" has several advantages over traditional "low stubble" mowing: It reduces loss, stimulates growth of the above-ground part, accelerates the stand establishment, ensures better quality of the stem and crown, and reduces the number of weed control treatments by up to two times, decreases damages by game, frost and solar radiation. Use of wick applicator for herbicides on "high stubble" is not appropriate as it rapidly changes the weed composition in favour of grasses and there is a risk that the oak trees might be affected by herbicide as well. Planting 20,000 pcs of transplants.ha^{-1} has positive effects on the growth of oak compared to planting 10,000 pcs of transplants.ha^{-1} combined with subsequent mowing to "low stubble." It cannot however compete with mowing to "high stubble." Principal difference is in the production of forks which is elicited by significant lateral insolation. Leaving regenerated oaks without weed control treatment is possible only in the first year after regeneration. In the following years, weed induces unacceptable losses and causes inappropriate stem form. Seedlings from sowing are more sensitive to weed pressure and light treat restriction than transplants from planting.

Key words

pedunculate oak, regeneration, weed control

INTRODUCTION AND OBJECTIVES

One of the most serious problems (technological and economic) during regeneration of pedunculate oak in generally very fertile alluvial sites is the elimination of negative weed impact. The competitive relations in the sites in question do not so much concern uptake of nutrients, but rather water uptake and limitation of light treat. Indirect negative influence of the weed is of significance (Mauer 2002). Alluvial forest sites are very rich in high and dense weeds which respond by lush growth also to very small amounts of light. Weed in clearcut areas, where oak is regenerated by sowing or planting, makes use of full light and quickly exceeds the height of an adult person and can considerably affect the species composition of the future stand and its quality.

Two stages can be distinguished in the development of advance growths: The shade development stage and light development stage (Vyskot 1958; Hees 1997; Niinemets 1998; Welander, Ottoson 1998). Natural seeding of oak bears shading from above for maximum two years but the deficiency of light presents a limiting factor for its survival in the subsequent years. Shading reduces not only height increment but also increases the number of stems and large-diameter branches. High intensity of insolation has a similar effect (reduction of vertical as opposed to horizontal growth). Completely shaded and fully lighted plants have a shrubby growth tendency. Shaded plants are characterized by asynchronous growth. Sudden removal of shading brings about heliosis and deep growth shock.

Sufficiency of water is equally a factor which affects the growth of pedunculate oak (Collet, Frochot 1996; Löf et al. 1998; Prpić, Anić 2000; Bergmann 2001). The plant can successfully survive climatic variations provided that its root system is outside the zone of allelopathic relations of the weed root system (chiefly grasses) and quickly reaches the groundwater table. With grass degree of coverage higher than 60% the germinating acorns are not able to take roots. Water competition can be eliminated by a complete or partial removal of weed. Minimization of competition for water provides oaks also with a higher uptake of nutrients.

The objective of the paper is the analysis of the possibility of applying an untraditional technique of weed control after pedunculate oak regeneration by means of mowing it to "high stubble" in the Czech Republic. It is a procedure that should provide the plants with insolation from above, lateral cover and which should lead to the prevalence of positive effects of weed on oak growth over the negative influence.

MATERIAL AND METHODS

- Basic methodological approaches. In the 4-year period following the stand establishment by sowing or planting, differences in the growth of oaks treated by whole-area mowing of weed to "low stubble," to "high stubble" and without any weed control measures were monitored. The impact of varied density of the new stands was also analysed. In the process of performing sub-experiments, mowing to "high stubble" was replaced by the use of a wick applicator for herbicides (mechanical attack on weed was replaced by chemical attack). All regenerated plots had the surface area of maximum 2.00 ha and had not been treated in any way prior to the regeneration.
- Verification was realized in the most wide-spread forest types – 1L1 (field maple site) and 1L9 (nettle site).
- Sowing was carried out into ploughed furrows – manually by point sowing in order to reach the amount of 10,000 emerged seedlings per 1 ha at spacing of 1x1 m.
- Planting was performed manually by slit planting method without previous site preparation at spacing of 1x1 m (10,000 $pcs.ha^{-1}$) and 1x0.5 m (20,000 $pcs.ha^{-1}$); two-year undercut transplants with the shoot length of 50 to 60 cm without lateral branches (spikes) were planted.
- Neither sowing nor planting were treated in the process of verification except for different ways of weed control.
- Mowing to "low stubble" – whole-area cutting of weed to a height of roughly 10 cm above the ground surface was performed manually by means of a motor scythe.
- Mowing to "high stubble" – whole-area cutting of weed to a height of roughly 5 cm above the oak plants was performed manually by means of a motor scythe.
- Wick applicator use – whole-area attack on weeds at a height of approximately 5 cm above the oak plants was carried out manually by wick applicator for herbicides; the applied herbicide was Roundup.

- At the end of every growing season, the losses (mortality) and biometric parameters of the above-ground part of surviving oak plants were assessed. Light treat was evaluated after mowing to "low" or "high stubble".
- The length of the above-ground part was measured from the ground surface to the terminal bud tip (in cm).
- Root collar diameter was measured 2 cm above the ground surface (in mm).
- Crown setting height was measured from the ground surface to the highest set branch (in cm).
- Number of branches – number of all branches growing from the stem was determined (in pcs).
- Branch length – length of all branches growing from the stem was measured (in cm).
- Branch diameter – diameter of all branches was measured 2 cm from the point of setting (in mm).
- Fork formation – the occurrence of forks and multiple tops was assessed according to the standard CSN 482115.
- Light treat – light intensity was measured by luxmeter at 2/3 height of the oak plants.
- For better orientation, the results for many measured parameters in the tables are expressed relatively (proportionally) to the whole-area mowing to "low stubble."

RESULTS AND THEIR EVALUATION

<u>Sowing – elimination of the negative influence of weed by different forms of mowing (Tab.1)</u>

- Losses. Mowing to "high stubble" induces a loss by up to 10 % lower than whole-area mowing to "low stubble". If the plot is left untreated for weed control, the loss in the first year does not exceed the loss sustained by treated stands. The loss however significantly increases from the 2nd year and reaches nearly 100 % values 4 years after the sowing.
- Above-ground part length, root collar diameter. Mowing to "high stubble" from the 2nd year significantly stimulates the length growth of oak plants in regular intervals (4 years after sowing, oaks are up to 60 % higher than on the plot with mowing to "low stubble"). The same response was observed also in oaks surviving on the untreated plot. Oaks on the plot mowed to "high stubble" however fall behind in the root collar diameter (their slenderness ratio deteriorates). An equal effect (with a greater negative difference) was determined also on the untreated plot.
- Crown setting height, number of branches. Oaks growing on the plot mowed to "high stubble" are characterized by a significantly higher set crown and a lower number of branches as compared with the plot mowed "to low stubble." The same trend was observed also on the untreated plot; number of branches and oak plants on this plot is however considerably lower than on the "high stubble" plot.
- Branch length, branch diameter, formation of forks. Oak plants on the plot mowed to "high stubble" have a remarkably shorter branch length and diameter starting from the 2nd year of growth. Formation of forks is up to 10 % lower than on the plot mowed to

"low stubble". The monitored parameters on the untreated plot reach values even twice as high as on both treated plots.

- Oak mildew damage. Oak mildew had a 100 % occurrence on all monitored plots (regardless of the method of weed elimination).
- Light treat at 2/3 height of plants. The higher the retained weed, the lower the lights treat. The light treat value on the plot mowed to "high stubble" is roughly 70 to 80 %; untreated plot values fall in the interval between 30 to 40 %.

Planting–elimination of the negative influence of weed by different mowing methods (Tab. 2)

- Losses. Mowing to "high stubble" causes by up to 10 % lower loss than whole-area mowing to "low stubble." No differences were determined in the process of planting 10 and 20 thousand plants per hectare with subsequent mowing to "low stubble." If the plot is left untreated, the losses starting with the 1st year reach three times higher levels as compared with the treated plots.
- Above-ground part length, root collar diameter. Mowing to "high stubble" from the 3rd year significantly stimulates the length growth of oak plants in regular intervals (4 years after sowing, oaks are up to 30 % higher than on the plot with mowing to "low stubble"). The same effect can be observed with the densification of outplanting to 20,000 pcs.ha^{-1} mowed to "low stubble." A similar effect was determined also with the oak plants surviving on the untreated plot. Oaks both on the plot mowed to "high stubble," the outplanting being 20,000 pcs.ha^{-1}, and on the untreated plot have a considerably smaller diameter of the root collar (worse slenderness ratio).
- Crown setting height. Oaks on the plot mowed to "high stubble" as well as on the untreated plot have a remarkably higher set crown than on the plot mowed to "low stubble." Denser plantation mowed to "low stubble" affects the concerned parameter much less only from the 4th year after planting.
- Number of branches, branch length, branch diameter. Oak plants mowed to "high stubble" as well as oak plants on the untreated plot have a considerably lower number of branches already from the 1st year and a significantly shorter length and smaller diameter from the 2nd year of growth. Plant densification in the course of cutting to "low stubble" shows in a similar way only from the 4th year after planting.
- Fork formation. Mowing to "high stubble" reduces the proportion of forks by more than two times (from the 4th year from 45 to 17 %); planting densification at mowing to "low stubble" reduces the share of forks approximately by 10 %. The same number of forks was determined on the untreated plot and on the "low stubble" plot.
- Oak mildew damage. Oak mildew occurred on all monitored plots (regardless of planting density and weed control method).
- Light treat at 2/3 of plants height. The higher the retained weed, the lower the light treat. Light treat on the "high stubble" plot amounts to roughly 70 to 80 % and around 50 to 60 % on the untreated plot. The light treat also decreases by roughly 20 % when 20,000 pcs.ha^{-1} are planted.

Table 1: Pedunculate oak – sowing – elimination of the negative influence of weed by means of different mowing methods (forest type 1L1)

Parameters and traits	Whole area mowing to low stubble				High stubble				Without treatment			
	Years				Years				Years			
	1.	2.	3.	4.	1.	2.	3.	4.	1.	2.	3.	4.
Losses (in % of plants)	5	14	27	31	3	9	16	22	5	47	68	96
Above-ground part length (in % of Control)+	100	100	100	100	112	126	141	156	128	137	152	-
Root collar diameter (in % of Control)+	100	100	100	100	101	86	84	115	112	73	62	-
Crown setting height (cm)	-	17	21	32	-	27	48	66	-	48	62	-
Number of branches (in % of Control)+	100	100	100	100	106	94	91	83	87	72	37	-
Branch length (in % of Control)+	100	100	100	100	100	86	71	65	105	127	148	-
Branch diameter (in % of Control)+	100	100	100	100	105	84	76	71	117	142	145	
Fork formation (in % of plants)	-	25	29	31	-	18	19	24	-	33	59	-
Damage by oak mildew (in % of plants)	100	100	100	100	100	100	100	100	100	100	100	100
Number of treatments per year (pcs)	3	3	3	2	2	2	2	1	0	0	0	0
Light treat at 2/3 of height plants (in % of Control)*	100	100	100	100	83	72	64	81	41	44	38	32

Note: + Control – 100% whole-area mowing to low stubble, 10,000 pcs.ha^{-1}
* Control – 100% – direct insolation

Table 2: Pedunculate oak – planting – elimination of the negative influence of weed by different mowing methods (forest type 1L1)

Parameters and traits	Whole-area mowing – low stubble								High stubble				Without treatment			
	10,000 pcs.ha^{-1}				20,000 pcs.ha^{-1}				10,000 pcs.ha^{-1}				10,000 pcs.ha^{-1}			
	Years				Years				Years				Years			
	1.	2.	3.	4.	1.	2.	3.	4.	1.	2.	3.	4.	1.	2.	3.	4.
Losses (in % of plants)	16	21	28	32	12	23	29	33	11	14	17	21	28	35	47	59
Above-ground part length (in % of Control)+	100	100	100	100	100	105	116	131	105	109	129	130	107	108	117	126
Root collar diameter (in % of Control)+	100	100	100	100	98	106	92	108	102	87	81	96	104	81	74	64
Crown setting height (cm)	-	16	18	18	-	15	23	27	-	25	46	72	-	31	54	66
Number of branches (in % of Control)+	100	100	100	100	105	101	96	88	85	81	83	76	89	86	81	80
Branch length (in % of Control)+	100	100	100	100	105	102	98	98	87	76	70	64	92	81	76	70
Branch diameter (in % of Control)+	100	100	100	100	97	98	91	85	97	85	81	82	105	88	86	75
Fork formation (in % of plants)	0	17	31	45	0	12	25	35	0	6	14	17	0	7	34	48
Damage by oak mildew (in % of plants)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Number of treatments per year (pcs)	3	3	3	2	3	3	2	1	2	2	2	1	0	0	0	0
Light treat at 2/3 of height plants (in % of Control)*	100	100	100	100	undet.	undet.	85	77	86	75	71	73	52	56	62	65

Note: + Control – 100% whole-area mowing to low stubble, 10,000 pcs.ha^{-1}
* Control – 100% – direct insolation

Table 3: Pedunculate oak – planting – elimination of the negative influence of weed by use of wick applicator on high stubble (forest type 1L9, 10,000 $pcs.ha^{-1}$)

Parameters and traits	**Whole-area mowing low stubble**				**Wick applicator for herbicide**			
	Years				**Years**			
	1.	**2.**	**3.**	**4.**	**1.**	**2.**	**3.**	**4.**
Losses (in % of plants)	14	15	21	23	10	12	18	19
Above-ground part length (in % of Control)+	100	100	100	100	95	103	115	108
Number of treatments per year (pcs)	3	3	3	2	1	1	1	0

Note: + Control – 100 % – whole-area mowing to low stubble

Table 4: Change in the weed composition after diverse elimination methods (Site 1L9 – Nettle)

Treatment method	**1st year after treatment**		**3rd year after treatment**	
	% of grasses and bedstraw	**% of herbs**	**% of grasses and bedstraw**	**% of herbs**
Low stubble	75	25	95	5
High stubble	5	95	35	65
Wick applicator for herbicides	5	95	65	35

<u>Planting–elimination of the negative influence of weed by the use of wick applicator for herbicides on "high stubble"</u>

– It follows out from Table 3 that the use of wick applicator for herbicides compared with mowing to "low stubble" did not affect the oak growth with respect to loss and height of the above-ground part. The positive aspect of using this method should be however considered the number of weed control operations reduced by about two thirds.

– The reason is a different change in the weed composition after individual treatments (Table 4). When the method of cutting to "low stubble" is used, herbs recede considerably on the plot and become replaced by grasses. The same effect was determined during the use of wick applicator for herbicides (the applied herbicide eliminates high-grown herbs). The decline of herbaceous vegetation is far lower when mowing to high stubble and a positive aspect of this method is the densification of herbaceous vegetation after cutting.

<u>Evaluation of results</u>

– The survey confirmed that pedunculate oak is not such an extremely light-loving tree species as it is often claimed and that for oaks after regeneration, too applies an old truth that oak grows best with the crown in the sun and the stem in a "furcoat" (in the shade).

- As compared with mowing to “low stubble”, mowing to “high stubble” which respects the above forestry true statement features a range of advantages:
    - it reduces the amount of losses,
    - it stimulates growth of the above-ground part and accelerates the stand establishment,
    - oak plants have a better stem quality,
    - it reduces the number of weed control treatments by up to two times,
    - with respect to the fact that the plants are sheltered by weed cover, damages caused by game, frost and solar radiation become reduced.
- Mowing to “high stubble” can be fully implemented by means of special mowing equipment mounted on a tractor. Wolf trees can be also cut short in the process of mowing to “high stubble” which will ensure the tending function for other oaks in the next stage of development. Although the mowing to “high stubble” can be applied also in the traditional artificial regeneration, its merit should be primarily weed control after natural regeneration.
- Leaving plots with no weed-control measures is acceptable only in the first year after regeneration (weed does not induce losses and stimulates height growth seedlings from sowing). In the following years, the overgrown weed has very negative effects more so in the sown plants than in transplants. Positive influence of weed in the first year applies only to clearcut areas. Light treat of plants from sowing and artificial regeneration under the stand is markedly lower and oak plants suffer already during the first year after regeneration.
- The surveys showed that the formation of forks and crown form are affected by light treat, too. The more lateral light oaks have, the more frequent is the formation of forks and the occurrence of spreading crowns. Common creation of forks and irregular crowns on untreated plots is caused by the fact that some branches of oaks which overgrow the weed “grow through” for sun.
- Compared with the planting of 10,000 pcs.ha^{-1}, denser planting (20,000 pcs.ha^{-1}) combined with the method of mowing “to low stubble” has a positive influence on the growth of oak plants but it cannot equal mowing to “high stubble.” It can be nevertheless inferred that the oak density will also assure its higher quality in the further growth.
- Ideal light treat for the growth of oak would be 100% at the top part of the plants, 60 % of insolation at a half of their height and 20 % of insolation at the ground surface.
- Wick applicator use is less successful than mowing to “high stubble” because it significantly modifies the weed species composition in favour of grasses and there is a risk of oak plants being affected by herbicide. Its usefulness can be seen only in a single treatment.
- The survey demonstrates that plants from sowing grow up better and faster than transplants from planting which “sit” up to 2 years. As regards the operational perspective, the surveys proved that plants from sowing do not require treatment against the negative impact of weed in the first year and that older species need not be treated for weed control when weed overgrows oak plants by 25 % of their height. In both cases the measure must be nonetheless executed at the end of the growing season to prevent

the suppression of oaks by weed in winter. A similar operation at the end of the growing season is necessary also when dense grass weeds reach the height of the oak plants.

CONCLUSION

The paper analyses the possibilities of eliminating the negative impact of weed by means of mowing it to "low stubble," mowing to "high stubble," using the wick applicator for herbicides on "high stubble" and the application of diverse planting densities with subsequent mowing to "low stubble" for regeneration of pedunculate oak by sowing and planting on alluvial sites 1L1 and 1L9. The principal conclusions of the survey are as follows:

- Also the plantations and the young stands of oak grow best up if their crown is exposed to the sun and the stem is in the shade.
- Mowing to "high stubble" has a number of advantages over the traditional "low stubble" mowing: It reduces the amount of losses, stimulates the above-ground part growth, accelerates the stand's establishment, assures better quality of the stem and crown, reduces the need for weed control treatments by up to two times, decreases the damage due to game, frost and solar radiation.
- Use of wick applicator for herbicides on "high stubble" is not appropriate as it quickly modifies the weed species composition in favour of grasses and there is a risk that the oak plants will become impacted by the herbicide as well.
- As compared with the planting density of 10,000 pcs of plants.ha^{-1} combined with subsequent mowing to "low stubble", the planting of 20,000 pcs of plants.ha^{-1} has a positive impact on the growth of oak, it nevertheless cannot equal the high stubble mowing. The essential difference consists in the formation of forks which is provoked by profuse lateral insolation.
- Leaving the regenerated oak plants untreated for weed control is possible only in the first year after regeneration. In the following years, weeds would induce unacceptable losses, causing also stem malformations. Plants from the sowing are much more sensitive to weed pressure and restricted light treat than transplants from planting.

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THE QUALITY OF ACORNS AND THEIR STORAGE

Zdeňka Procházková

Abstract
The paper presents some basic information on methods used for the determination of acorn quality and describes conditions related to the storage of acorns. In brief summarised results from studies focused on the occurrence of *Ciboria batschiana* (Zopf) Buchwald) on acorns collected from the forest floor or from nets suspended above the forest floor for the 2000-2002 in the Czech Republic are given.

Key words
Quercus, black rot, *Ciboria batschiana* (Zopf) Buchwald , short and long term storage

DETERMINATION OF ACORN QUALITY

In the Czech Republic the quality of acorns (seeds of *Quercus* species) is determined according the Czech Technical Rules (ČSN 48 1211 1997). Among the most important evaluated parameters are purity, germination, moisture content and acorn health, especially the occurrence of pathogens. In purity tests the species of tested seed or the seed prevalent in a sample, representing the whole seedlot, is determined. However, it is nearly impossible to determine with certainty the species of oak seeds based on the morphology of acorns (and even of seedlings). Consequently, for acorns only the genus (*Quercus* sp.) of pure seeds is reported in the results of purity tests.

Germination of acorns which are recalcitrant seeds can be negatively influenced by a long-term decrease in moisture content below 40 %. When evaluating acorn quality the moisture content determination provides information important to seed owners and nursery managers. Germination tests for acorns take 4 weeks. A laboratory procedure for English oak includes removing the pericarp, soaking the acorns in water for 24 hours and cutting off a third of the acorn at the cup scar end. This method speeds up the germination of acorns. A standard germination test of intact acorns would take much longer – up to 2 months. Freshly-collected acorns have epicotyl dormancy and only the root and hypocotyl are developed. Chilling is necessary to break the epicotyl's dormancy and allow the acorns to develop into seedlings. Germinable acorns (both fully developed oak seedlings and acorns with well developed roots and intact cotyledons) are reported in germination test results.

An important part of the quality evaluation of acorns is health testing which focuses mainly on the determination of "black rot" caused by the fungus *Ciboria batschiana*. Initial infection of acorns occurs in forest stands where the pathogen develops on old, already-infected acorns with cotyledons transformed (mummified) into pseudoclerocium. Ascospores released from such fruiting bodies infect new acorns in the autumn when the acorns are mature and fall to the ground. The pathogen can enter through a mechanically damaged pericarp, or the hillum (Delatour, Morelet 1979; Men 1976 in Delatour, Morelet 1979; Neff, Perrin 1999). Most acorns are infected after they fall to the forest floor but they can also be infected while still on the parent tree (Men 1976 in Delatour, Morelet 1979; Stocka 1994; Procházková, Pešková 2006). Small, yellow, orange-yellow to cinnamon coloured spots appear on the surface of acorns in the early stage of infection. These spots later coalesce and finally the cotyledons become mummified, i.e. change into a black porous mass formed by densely matted hypha and reminders of cotyledon tissues. The pericarp cracks along a longitudinal slot in which the dark brown to black, mummified cotyledons (sometimes covered with a dark olive dust) can be seen.

COLLECTION AND STORAGE OF ACORNS

Acorns are usually collected after they fall onto forest floor or from nets spread below acorn-bearing oaks. It is recommended to float acorns in water after collection. Floating helps to remove acorns infested with insects, infected with *Ciboria* or undeveloped seeds. Floating can also increase the low moisture content of acorns caused by dry weather at the time of autumn collection or if the collection is done from nets. After harvesting it is necessary to transport the acorns as soon as possible to the seed centre for processing (cleaning and preparation for storing) or nurseries for autumn sowing. It is important to avoid either drying or over heating of acorns. Post harvest ripening can also increase acorn germination.

The recommended moisture content of acorns for short and long term storage is 45 – 50 %. Short term storage of acorns is done for one winter at 5 °C when the acorns are kept in open boxes. These conditions are favourable for secondary spread of the *Ciboria* fungus. Under moist conditions at above – 1°C a cinereous to dark olive aerial mycelium develops on already-infected acorns in a few days and quickly spreads to healthy acorns. *Ciboria* can completely destroy all the stored acorns. The first record of *Ciboria* in the Czech Republic was in 1923 (Klika 1923), but the first economically important damage on stored acorns, up to 60 %, was reported in the first half of the 20th century (Urošević 1956, 1957, 1961). In France 90 % of stored acorns were destroyed in 3 to 8 months in 1973 and 1974 (Delatour, Morelet 1979). In our nurseries acorns are mostly sown in the fall immediately after collection. Short term storage (over one winter) and long term storage (up to 3 winters) of acorns represents only a small part of all our sown acorns. However, even acorns sown after harvest in the fall can suffer from *Ciboria*, especially if they are not treated by thermotherapy. Fungicide application only prevents spread of the aerial mycelium and infection of healthy acorns in storage, but it can not prevent killing of already-infected seeds. In our country there are no data on the impact of *Ciboria* on autumn sowings in nurseries.

However, important damage to autumn-sown acorns has been recorded in Poland; e.g. in 1993 the acorns on 401 ha were destroyed; initially it was thought that the acorns were damaged by frost but *Ciboria* was finally determined as the causal agent (Siwecki 1994; Kowalski, Kowalczyk 1997; Kowalski 1999; Stocka 1994).

Acorns can be stored over two to three winters at – 1 to – 3°C. Acorns with a moisture content of 45 % at least have to be stored in closed boxes (e.g. plastic barrels) with an air access (e.g. by a perforated pipe). In Poland it is recommended to mix acorns with sawdust that soak up the water from respiration and keeping them in boxes with perforated lids.

PROTECTION OF ACORNS

Successful storage of acorns is not possible without using effective protective measurements against the pathogenic fungus *Ciboria batschiana* which is widely distributed in the Czech Republic. The level of *Ciboria* infection varies according the weather conditions at the time of acorn ripening in September to November each year. Fungicide application mostly slows down or eliminates spreading of aerial mycelium of the fungus on stored acorns, but it does not prevent destruction of already-infected acorns. Presently the only treatment that can save infected acorns is thermotherapy (Delfs-Siemer 1993; Delatour 1978; Delatour et al. 1980).

The principle of this treatment is the use of temperatures lethal to the pathogen but not affecting germination and vigour of the seeds. The soaking of seed in warm water or steam treatment is the most used practice. Soaking is considered as being more effective because of the interaction of leached phenol and tannin substances. After thermotherapy saprophytic fungi can appear on acorns (e.g. *Penicillium*, *Aspergillus*, *Trichothecium* and Mucorales). These species are not so sensitive to high temperature, i.e. they are thermo tolerant. Their activity is negligible, but it is best to dress acorns with some fungicides or add the fungicides to the water used for the thermotherapy.

Integrated protection that is most effective includes:

a) Cleaning of the forest floor to remove old, *Ciboria* infected acorns before acorn collection starts and use of nets that keep down or restrict acorns from the infection via contact with the soil,

b) Harvested acorns should be transported as soon as possible to the warehouse or nursery to avoid excessive drying or self-heating of acorns,

c) Before storage based on health tests apply thermotherapy, fungicides or both (soaking of acorns in warm water at 41 °C for 2-2.5 hours with the added fungicide) (Schröder et al. 2004; Procházková, Pešková 2006).

In the Czech Republic little information is available about acorn quality (mainly about germination and *Ciboria* infection) because most acorns are sown immediately after harvest and the seed owners or nursery managers check acorn quality by an acorn cutting method. The quality of acorns processed at the Tree Seed Centre Týniště n. Orlicí and prepared for either short or long term storage is evaluated according the CSN 48 1211 (1997). However, only a small part of all acorns collected and sown annually in this country is assayed for germination and *Ciboria* occurrence. In the research project NAZV QD 0173 "Factors influencing the quality of beechnuts and acorns during storage" studies were made on the quality of acorns and the occurrence of *Ciboria batschiana* on acorns of oaks (*Quercus*) in the Czech Republic in different years. Some of the results found following the evaluation of the 209 acorn samples collected from 2000 to 2002 are presented here.

Acorns of different oak species were collected either directly from the forest floor or from nets suspended below trees (to prevent the acorns from coming into contact with the forest floor) in oak stands around the country (Table 1). The occurrence of *Ciboria batschiana,* other fungi and insect infestation was determined for acorns incubated in wet chambers (Petri dishes with three layers of filter paper) kept at 15 (±2) °C for a maximum of 2 weeks. Moisture content (fresh weight basis – ČSN 48 1211 1997) and germination (done in conjunction with the health test) of the acorns was also determined.

Table 1: Oak species, number of samples, collection technique and crop year.

Year	**2000**	**2001**	**2002**
Total sample	100	62	47
Samples collected from forest floor	100	52	47
Samples collected from nets	None	10	None
Time of collection	Early September to late October	Late September to early November	Late September to early November
***Quercus* species**	*Q. robur, Q. petraea, Q. cerris, Q. rubra, Q. pubescens*	*Q. robur, Q. petraea, Q. rubra*	*Q. robur, Q. petraea, Q. rubra*

The highest incidence of *Ciboria batschiana*, but also the highest average germination and moisture content, was found on acorns collected in 2001, while the lowest number of infected samples was found in the 2000 crop (Fig. 1). The level of acorn infection with *Ciboria* coincides with weather, especially occurrence of precipitation in September. More rainfall occurred in 2001 than in 2000 and 2002 (Fig. 2) which facilitated the development of *Ciboria* fruiting bodies and the production and dispersal of ascospores, and consequently the infection of maturing acorns. In 2000, acorns ripened and were shed from mother trees from early September to late October and both months were dry (about 50 mm of precipitation – Fig. 2). In 2001, acorn maturation was delayed (as compared to the 2000 crop) to late September, October and early November. September was very wet (Fig. 2) and the conditions for development of *Ciboria* were the best for all three years. Precipitation in 2002 was similar to 2000 but acorns matured later.

In forest stand 207 D15, with the highest *Ciboria* incidence in 2000 (Fig. 3), acorns were collected both from the forest floor and from nets in 2001. However, the acorns collected by both techniques (i.e. from the forest floor and from nets) were infected with *Ciboria* even if the level of infection was higher on acorns from the forest floor. The use of nets for acorn collection can decrease *Ciboria* infection but not prevent it completely.

Germination and moisture content of *Quercus robur* and *Q. petraea* acorns were similar in three study years, but the lowest germination was recorded in English oak acorns collected in 2001 while in the same year the acorns of *Quercus petraea* germinated the best. However, in all three years higher incidence of *Ciboria* was found on *Quercus petraea* acorns (Fig. 4).

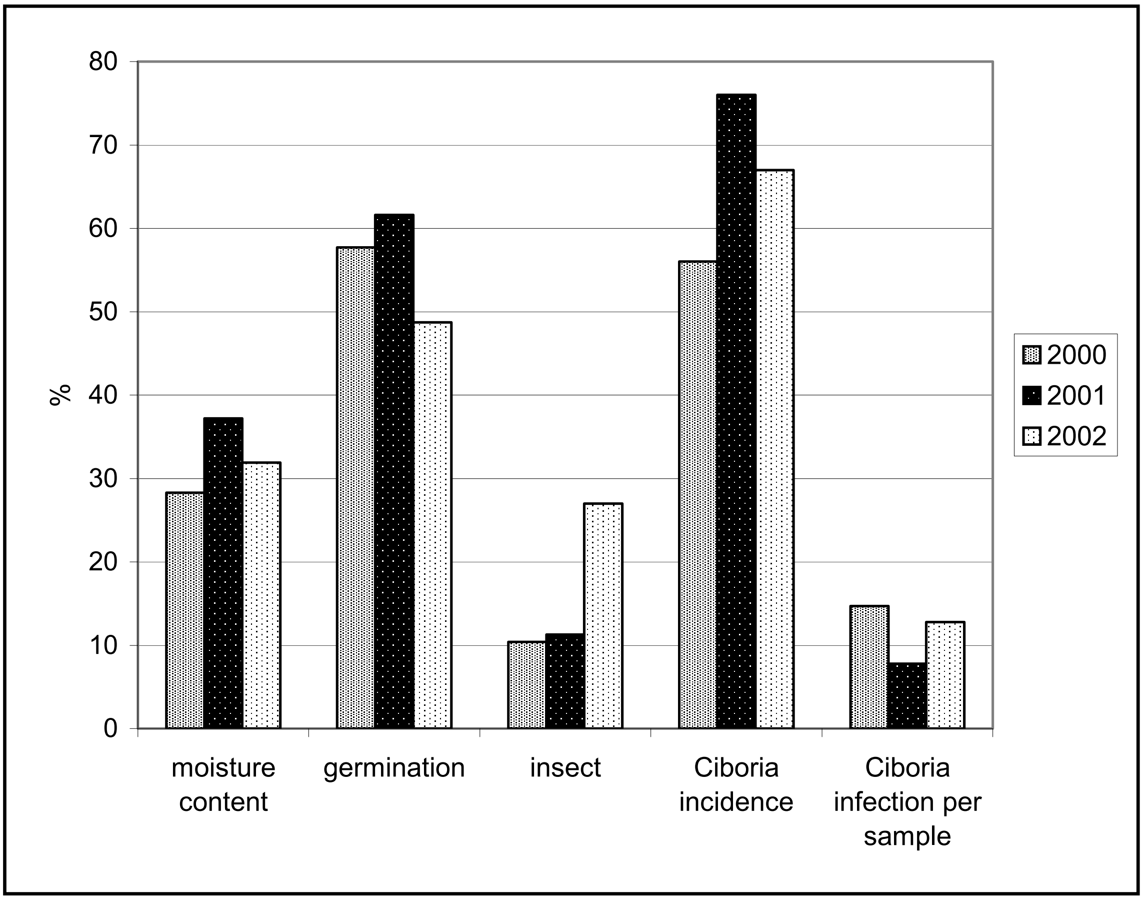

Fig. 1: Average quality of acorns and occurrence of *Ciboria batschiana* in years 2000, 2001. 2002

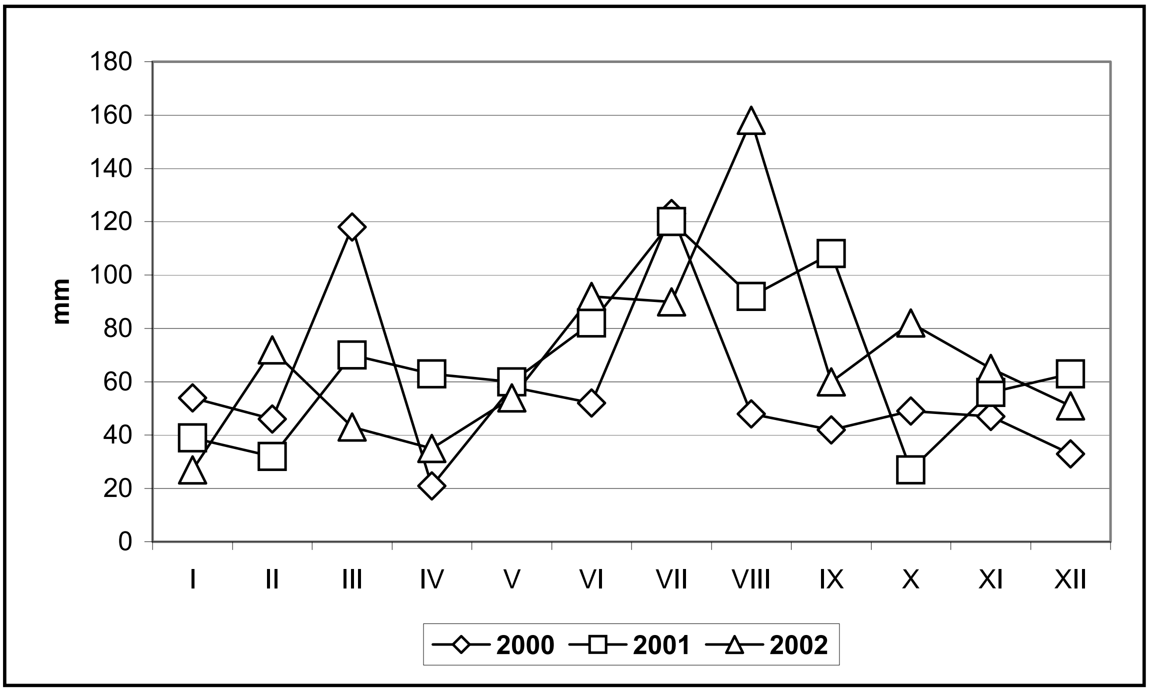

Fig. 2: Average month by precipitation in years 2000 - 2002

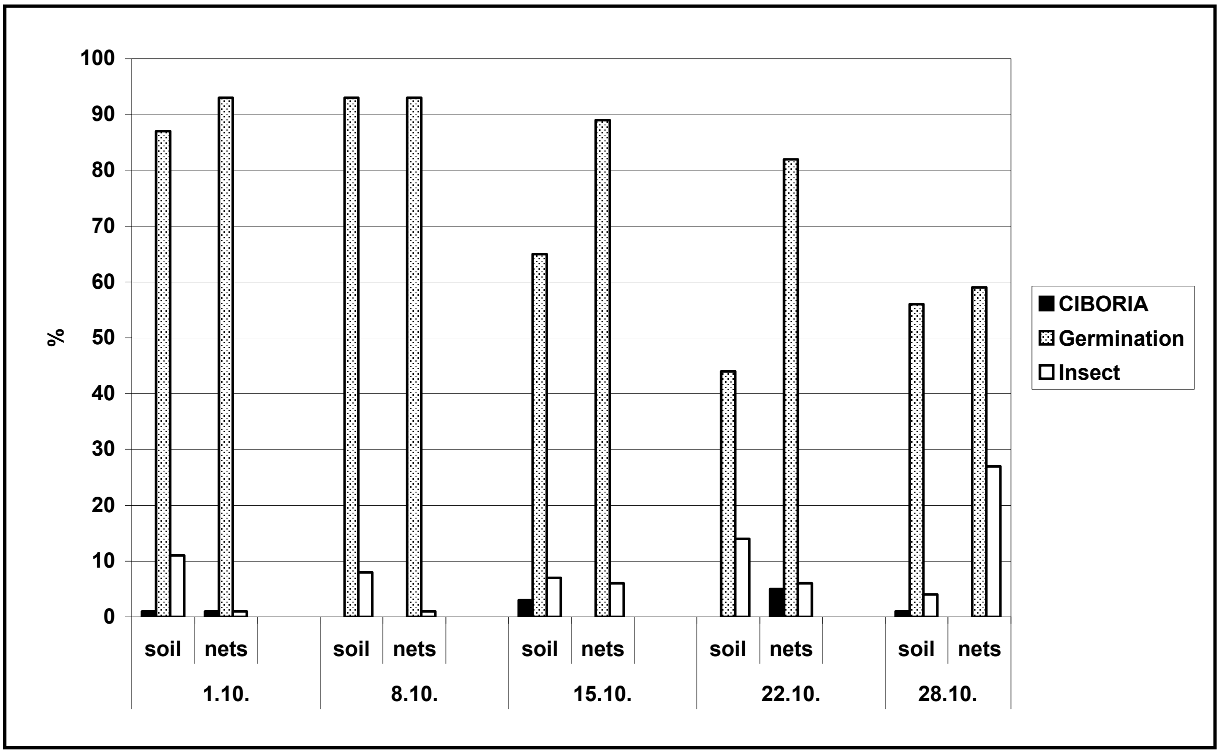

Fig. 3: Quality of acorns collected from the forest floor and from suspended nets in October, 2001, at Buchlovice, stand 207D 15

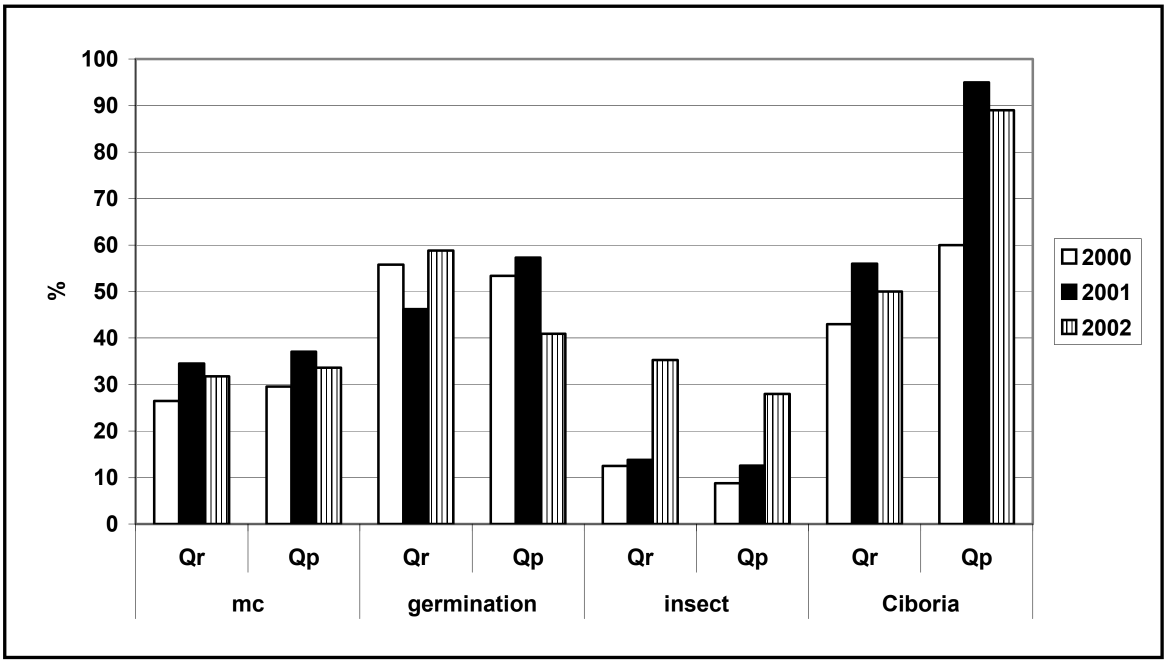

Fig. 4: Moisture content (mc), germination, insect infestation and *Ciboria* infection of *Quercus robur* (Qr) and *Q. petraea* (Qp) from 2000 – 2002 crops

CONCLUSION

1. *Ciboria* infection of acorns differs by year of collection and by forest stand.
2. There appears to be a positive relationship between the amount of acorn infection and abundance of rain in September of the collection year.
3. Infection also occurs on acorns collected from nets suspended above the forest floor, but infection is lower than for acorns collected from the forest floor.
4. Acorns of English oak were less often infected with *Ciboria*.

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ARTIFICIAL POPLAR REGENERATION

Ladislav Varga

Abstract
Plantations with bred poplars are established by artificial methods and regeneration can be realized according to valid act up to 5 hectares. Intensive cultivation systems are applied out of the flooded river territories where a decisive role plays a production capability of site and selection of convenient clone. The whole-area soil preparation and regular cultivation during the first years have positive influence on growth and stand health condition.

Key words
artificial regeneration, poplar, clone, whole-area soil preparation

INTRODUCTION

High production capacity characterizes the lowland forests in Slovakia. The task of an owner or forest manager is to improve this ability while securing other public-beneficial forest functions. Fast-growing tree species, of those the poplars are of a greatest practical importance, have rather broad range of utilization. Originally black poplar (*Populus nigra* ssp. *nigra*), white poplar (*Populus alba*) and grey poplar (*Populus canescens*) have been distributed in the lowland and hilly regions. At the beginning of the 20th century, the autochthonous poplar species were gradually substituted in the lowlands by spontaneous and artificial Euramerican hybrids, (*Populus deltoides* x *Populus nigra*), which overtook domestic poplars by growth intensity, resistance against biotic and abiotic agents, as well as by their wood properties (Table 1). Balsam poplars and their hybrids find practical application only on submontane regions.

Based on cultivation of certified poplars, the poplar biomass production has increased doubly and wood yield increased from 29 to 97 % during the last 50 years without the change of the area.

POPLAR CLONE SELECTION

The same rules as for other cultural plants are valid for poplars too. It is obvious that the higher stage of breeding a certain plants is on, the higher productivity it has, however the greater attention must be paid at it. Since poplars, except to *Leuce* spp., can easy be propagated by cuts-off, it is possible to establish the cultivation of poplars using a monoculture method, which means to pay attention only to one certified clone. This verifies a currently gained theoretical knowledge and practical experiences which showed that:

- a risk of fungal diseases and pests occurs within a monoculture of the same genetic composition,
- similarly as for agricultural crops (potatoes, beetroot) a degeneration should be taken into account,
- there exists, within the large-scale breeding works based mainly on new breeding, a permanent guarantee that for the needs of forestry a sufficient number of resistant and high productive poplar clones will be always available,
- the highest reserves represent multiclonal varieties.

For the selection of poplar clones for nature conditions in Slovakia are determined the permanent research plots as well as comparing plots on all types of sites, represented by forest types. The permanent research plots serve regular biometric measurement of heights, diameters, evaluating stem and crown form, as well as observing the health conditions. Of biometric factors there are monitored especially resistance against fungal (*Melampsora* sp., *Chondroplea populea*, *Marssonina brunnea*) and bacterial diseases (*Erwinia cancerogena*), further foliage pests (*Melasoma* sp., *Byctiscus* sp.) and technical wood pests (*Saperda* sp.). Clones reaching better growth parameters than standard poplar „*Robusta*“ which have the signs of resistance will be marked as so called promising.

For promising clones the analyses of mechanical (fibre length, specific weight) and chemical wood properties (wood pulp and lignin content) are performed. Clones which meet selection criteria (growth, health condition and have convenient wood properties) will be marked as registered (certified) and are approved for cultivation under the nature conditions in the Slovak Republic according to valid legislation. At present, 5 Euramerican hybrids can be cultivated (*I-214*, *Robusta*, *Pannonia*, *Gigant*, *Blanc du Poitou*), as well as one European black poplar (*Baka*), one white poplar (*Palárikovo*), one American (*Cifra*) and one balsam poplar (*Liptov*). Survey on poplar clone convenience for cultivation is given in the Table 2.

Table 1: Poplar basic characteristics

Domestic poplars	Euramerican poplars
- broad ecological amplitude	- broad ecological amplitude
- intensive growth only in juvenile stage	- intensive growth during the whole rotation
- low reproduction capability in propagation by cuttings	- excellent reproduction capability in propagation by cuttings
- low resistance against biotic agents	- easy crossability
- unsuitable mechanical and chemical wood properties	- resistance against diseases and pests
	- convenient wood properties

POPLAR PLANTATION ESTABLISHMENT

In Slovakia, bred poplars are cultivated on the area of 24,000 hectares, of those forest land resources make up 20,000 hectares. The highest concentration of poplars is in inundated territories of the watercourses in lower reach of rivers and on waterlogged, heavy gleyic soils in lowlands. Rather high distribution is also in the form of scattered high greenery (windbreaks, line and group plantings) on agricultural land in the lowland regions. The basic criteria of cultivation are considered an average annual volume increment, which may not decrease below 14 m^3 per hectare.

The establishment of poplar plantations depends on the method of cultivation which can be classified into two basic groups:

a) Traditional method of poplar cultivation or cultivation in silvicultures

b) Intensive method of poplar cultivation ad a) Establishment of poplar plantations in silvicultures

Inundation territories of rivers in lower reach have been regularly flooded. The period of floods varies in the interval from 2 (5) days to 3 weeks. Process of sedimentation and erosion has occurred during the floods in inundated territory. Sediments contain a high proportion of organic component which secures a regular fertilization of the whole inundation on a natural basis.

Considering a special character of the flooded territory, the whole-area of soil preparation is not applied. Vital shrubby and herbaceous undergrowth is removed by rolling brush chopper, heavy disks or by dozer blade before the regeneration. Holes are bored before planting using soil borers hung hydraulically on a tractor into a depth 60 to 80 cm. For plantings are used one (+2,5 m) or two-year seedlings with a minimum height of 3.0 m. Plantings are realized in spacing of 3x2 or 3x3 m. Commonly an individual conservation can be performed taking into account permanent damages caused by game (browsing, windbreak). The best method for protection the stands turned out reed fencing. Mowing are being done in the first 2 (3) years, as well as an adjustment of crowns aimed at removing of fork trees and forming of crown damaged by red deer. The first tending felling has a character of negative selection and is performed between 7th (10th) year. The basic data on poplar cultivation by traditional method are given in the Table 4.

ad b) Technological procedures of poplar plantation establishment using intensive system of poplar cultivation

A precondition for intensive system of cultivation is especially a suitability of nature conditions. Intensive methods of cultivation should principally be used in the areas which are not flooded. In the flooded regions there is still a risk of erosion by invading water and though a high danger of washing away a top humous soil layer.

The mentioned system of cultivation can be successfully applied within the forest types *Querceto-Fraxinetum*, *Ulmeto-Fraxinetum populeum* and on humid forest types within the group of forest types *Ulmeto-Fraxinetum carpineum*. From the soil point of view it is mainly soil types Euthric Fluvisol Pelic, Fluvi-gleyic Phaeozem and Verti-Haplic Chernozem. However, it is possible to apply intensive methods of cultivation also on heavy clayey loamy to loamy soils within the permanent whole-area soil treatment under the condition that no unfavourably acting layers (gravel, gleyic) occur in soil profile. Based on current knowledge, it is possible to characterize intensive methods of cultivation by a complex of measures as follows:

- whole-area soil preparation
- selection, plantings and cultivation of high productive poplar clones
- whole-area mechanical soil adaptation one to three times during the growing season in both directions if possible. Technological process is applied minimally for the first three years after plantings

Beforehand the own establishment of poplar plantations by intensive methods, the whole-area mechanical soil preparation as a precondition for application of the mentioned cultivation technology, is realized. The preparation consists of removal of stumps, field adaptation and soil disking. For this treatment there is available a set of various mechanisms (Table 3), while some operations can be performed at the same time. It is necessary to point out that by application of the whole-area soil preparation improves considerably water - air regime in the zone of root system and activity of technical wood pests significantly decreases.

Table 2: Survey of registered poplar clones suitable for cultivation under the nature conditions in Slovakia

	Hole planting															
	Forest type number											Commercial stands				
Clone name	**923**	**931**	**932**	**941**	**942**	**943**	**951**	**952**	**953**	**954**	**901**	**Silvicultures**	**Intensive plantations**	**Lignicultures**	**Pulp wood plantations**	**Energy stands**
I-214 (EU)				+	+	+	+	+				+	+	+		+
Robusta (EU)					+	+	+	+	+	+			+		+	
Blan du Poitou (EU)		+	+	+	+	+	+	+				+	+	+		
Pannonia (EU)		+	+	+	+	+	+	+				+	+	+		
Gigant (EU)			+	+	+	+	+						+	+	+	+
Cifra (D)		+	+	+	+	+	+					+	+			
Baka (AČ)	+	+	+	+	+	+						+				
Liptov (B)											+	+	+			
Palárikovo (TB)		+	+	+	+							+	+			
Deep planting																
I-214 (EU)								+	+		+		+	+		
Gigant (EU)								+	+		+		+	+		
Pannonia (EU)								+	+		+		+	+		

Note: + suitable for cultivation, EU - euramerican hybrid, AČ - autochthonous black poplar, B - balsam hybrid, TB - white poplar

Table 3: Recommended technology and mechanisms for the whole-area soil preparation

Operation	Recommended mechanisms	Necessary tractor power, rounds	Machine power	Information technical data
Stump removal	Stump driller TRITACEP-TI	74-118 kW, 750 rounds/min.	Remove 1 stump per 40 sec	
	Stump rotary tiller STUMP GRINDER TM 40	25-40 kW, 540 rounds/min.	Remove 1 stump per 40 sec	Roller bite width 330 mm
	Stump rotary tiller STUMP GRINDER TM 1 000	90-100 kW, 1,000 rounds/min.	Ø 60 cm stump per 14 sec	Roller bite width 635 mm
	Tooth grubber D-210, D-496, D-513, K-2A	55-74 kW	Ø 60 cm stump per 7 min.	
	Buldozer plough			
Terrain alignment	Buldozer plough	55-74 kW		Performed where necessary
Root burling	Root burler ERTI (Hung.)	74 kW	0.3 ha per hour	Bite depth 300-700 mm Width 288 mm, Weight 1,050 kg, Teeth number 2-6
Deep cultivation	Plough PPU-50 A	74 kW	0.2 ha per hour	Ploughing depth 600 mm, Weight 2 710 kg
	Deep cultivator ERTI (Hung.)	74 kW	0.3 ha per hour	Cultivation depth to 500-700 mm

Intensive systems of cultivation can be classified depending on commercial goal, length of rotation period and size of initial spacing into as follows (Table 4):

a) Lignicultures

b) Intensive poplar plantations

c) Plantations for pulp-wood production

d) Energy stands

ad a) Lignicultures

Lignicultures represent the highest level of intensifying poplar cultivation. Their goal is to grow the special quality logs (Ist, IInd class) with rotation period of 15-20 years. Therefore they are established into totally prepared soil in a definitive felling spacing, at least in 6x6 m. Strong saplings (½, 2/2, 2/3) with well-developed root system are used for plantings. Within an own afforestation there is valid a principle „from earth to earth". Survey of poplar clones convenient for establishment of lignicultures is given in the Table 2.

Within the ligniculture, each stem is target, therefore it is necessary intensively treat each stem from the point of view of cultivation and protection. Thinnings are not performed in lignicultures considering the application of felling spacing.

ad b) Intensive poplar plantations

Production goal in the intensive poplar plantations are roundwood assortments (Table 4). Rotation period is in the interval from 18 to 25 years depending on production capability of soil and growth of cultivated poplars. The same clones as were recommended for lignicultures are suitable for cultivation in intensive plantations.

Intensive poplar plantations are established in medium spacing 4 x 4 to 5 x 5 m. The whole-area mechanical cultivation of soil after the plantings is being realized for 4 to 5 years. Processing of soil in drier forest types within the group of forest types *Ulmeto-Fraxinetum carpineum* is performed minimally 10 years. During the first years it is necessary to ensure soil hoeing around individual trees. Regarding application of medium spacing, the thinnings of 25 to 50 % from the number of trees are realized in intensive poplar plantations.

Within the cultivation of poplars in intensive plantations, so called technology of deep plantings is applied in the sites with considerable decrease of ground water surface. The following principles apply for the mentioned technology:

-optimum initial spacing is 4x4 m, on sterile gravels can be applied spacing of 5x5 m

-only clones with tendency to create the so called total root system can be used for plantings (Table 2)

-factor of minimum is soil oxygen; maximum depth of plantings on gravel soil is up to 4 m and on coarse-grained sands to 3 m

-plantings are realized for average ground water surface during the growing season

-poplar cuts-off are used for plantings. The best for plantings have proved cuts-off with 3-year old root system and 2-year old aboveground part

-whole-area mechanical preparation and soil treatment are not performed

Technology of deep plantings has been commonly applied in forest practice. The lack of nutrients in sterile sandy and gravel berms are compensated by nutrients from ground water strongly mineralized. The whole system is based on a principle of hydroponics.

Table 4: Methods of poplar cultivation under the nature condition of the Slovak Republic

Cultivation method	**Spacing (m)**	**Rotation period (years)**	**Commercial goal (assortments composition in %)**	**Total volume production (m^3.ha)**
Traditional methods of cultivation				
Silvicultures	3x2 3x3	18 (25)	I., II. class 8 III. class 42 Pulp wood 50	350 (600)
Intensive methods of cultivation				
Lignicultures	5x5	15 (25)	I., II. class 15 III. class 50 Pulp wood 35	300 (450)
Intensive plantations	3x3 4x4 5x5	18 (25)	I., II. class 10 III. class 45 Pulp wood 45	300 (500)
Pulp-wood production plantations	3x3	12 (15)	III. class 15 Pulp wood 85	220 (250)
Energy stands	1.0x0.8 1.0x0.7 1.0x0.6	2 (4)	Energy chips	10 (13) $t.ha^{-1}year^{-1}$ in dry substance

ad c) Plantation for pulp-wood production

The production goal is pulp-wood. Rotation period varies from 10 to 15 years and depends on soil fertility and growth properties of cultivated poplar clones. From certified clones is suitable mainly poplar „*Robusta*“, which has the lengthiest fibres and the highest content of cellulose of registered clones (Table 2).

Since plantations for production of pulp-wood and energy chips are concerned, they are established on less fertile poplar sites within the set “c“. Spacing 3x3 m is commonly applied as an initial spacing. High quality one-year old seedlings (+2,2 m) are used for plantings into whole-area prepared soil. Soil cultivation is performed during the first four years. The basic data on the mentioned system of cultivation is given in the Table 4.

ad d) Energy stands

The main attributes for cultivation of poplars with very short rotation period (to 10th year) is a maximum woody biomass production. For plantings can be used clones which:

-intensively grow immediately after plantings

-easy propagate by winter axial cuts-off

-have excellent reproduction capacity from stump and root shoots

-are characterized by resistance marks

-proportion of bark on stem should be as small as possible

-create close or medium-wide crown

-have broad ecological amplitude

From registered poplar clones, the clones „*I-214*“, „*Gigant*“ and „*Pannonia*“ have proved to be best for establishment of energy stands. Some balsam poplars or clones from the group of interactive poplars have shown as perspective.

Energy stands should be established into substantially prepared soil (autumn ploughing, smoothing, disking) using winter axial cuts-off (30 cm) or one-year old poplar seedlings (+ 1,7 m) in spacing of 1,5x0,4 to 1,5x1,0 m. Average annual weight increment varies in the most productive plots around 12 (14) tons per hectare in dry condition. Cultivation of poplars with very short rotation period is efficient in case that the annual weight increment does not drop below 8 tons pre hectare.

CONCLUSION

In Slovakia, bred poplars have the greatest practical importance from fast-growing tree species. There are still available some high productive and resistant clones with suitable wood properties based on regular completing of approved poplar clones by new clones Within establishment of poplar plantations by intensive methods, an important role play the whole-area soil preparation, selection of suitable clone, protection and regular soil cultivation. Specific case of cultivation is energy stands for production of energy wood chips. However, the highest reserves in application of the mentioned technology are in agricultural land.

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REGENERATION OF POPLARS FROM COPPICE SHOOTS IN THE FOREST ENTERPRISE ŽIDLOCHOVICE

Zdeněk Vícha

Abstract

Growing of poplars has a long tradition in the Židlochovice Forest Enterprise (LZ Židlochovice). First records on the cultivation of poplars in the Židlochovice district date back to 1818. Intensive cultivation of poplars commenced in 1910 when *Populus deltoides* – var. *Monilifera* was brought from England and planted in the Vranovice forest district. Poplars are currently grown in the LZ Židlochovice on an area of 1,076 ha, i.e. on 7 % of total forest land area. The possibility of regenerating poplar stands from coppice shoots and root suckers was tested already in 1993. Total area of poplar stands established since then is 15.5 hectares and some of them had to be later artificially reforested. This method of regeneration is not a common and well-proven technology and it follows from its evaluation that it is not best for the intensive growing of poplars with respect to the expected production of technically utilizable wood mass at felling age. At the present time, the method is tested in the cultivation of poplar plantations intended for dendromass production for energy.

Key words

poplar, coppice shoot, dendromass, clone

INTRODUCTION

Regeneration of poplar stands by coppice shoots or by root suckers

Regeneration of a poplar stand by root suckers was first tried in the forest district of Velký Dvůr in 1993. The cultivar of black poplar and white willow was regenerated after intentional final felling and site clearing by dozer. First tending measure was carried out three years after regeneration.

Following the introduction of whole-scale site preparation technology by cutting stumps and clearing logging residues by rotary cultivators in 1998, the forest district of Velký Dvůr returned once again to the idea of regenerating the poplar stands, the reason being ten of thousands coppice shoots and root suckers emerging in the following growing season after the superficial rotary cultivation of the site. Total areas regenerated vegetatively in the forest districts of Velký Dvůr, Židlochovice and Diváky were 8 ha, 6 ha and 1.5 ha, respectively. In 2002, the technology was evaluated on 10 sample plots according to parent stand origin, regeneration age and forest type. The evaluation of the technology was the main subject of dissertation worked out by Ing. Milan Novotný, Head of the Židlochovice Forest District.

SELECTION OF PLOTS

The evaluation of stand regeneration involved the following procedures:

- assessment of the parent stand – mature growing stock, health condition, suitable clone, site,

- cutting and site preparation by rotary cultivator (must be made during dormancy – until mid-April at the latest), later processed plots exhibit lower height increments due to drying out roots and milled stumps,
- division of the renerated plot into strips (spacing of 3 - 4 m) by mulching aggregate attached to general-purpose wheel tractor (UKT) at the beginning of the 2nd growing season,
- thinning of sprouts in the strips by positive selection to 4 m between individuals (required spacing 4x4 m) with preference being given to root suckers; crown treatment in retained individuals (2/3 of above-ground part height),
- protection from wildlife,
- mulching of weeds in the inter-rows by UKT-mounted aggregate for 2-3 years after regeneration.

EVALUATION OF THE TECHNOLOGY OF NATURAL REGENERATION

Measurements on the sample plots revealed that not all clones were regenerating sufficiently. Best regenerating were *Robusta* and *Regenerata*, which however produced the least mature stock on the sites of the LZ Židlochovice. In contrast, *Marilandica* (with the second greatest mature stock) was regenerating on about a half of the prepared area, and the Italian clone *1-214* which exhibited the greatest mature stock of all poplar stands felled on the local sites hardly regenerated at all. One of reasons can be seen in the direct dependence between the mean-tree volume and the number of regenerated individuals on the plots. The greater the mean-tree volume, the lower the number of trees at felling age on the plot, and the lower the number of vegetativelly regenerated individuals (lower number of trees at felling age = lower number of stumps and roots = lower number of stump shoots and root suckers). Here, too, we can observe the dependence between the growth characteristics of individual cultivars. Clones *Marilandica* and *1-214* which produce a large spreading crown require more space than the narrow-crowned *Robusta* and *Regenerata,* and the number of their individuals at felling age on the plot is therefore lower.

Furthermore, height increment was shown not to have been essentially affected by forest type (the site division was likely to have been made too detailed). At the end of the 1st growing season, sprouts on all monitored forest types reached a height of about 2 m.

Total amount of regenerated individuals and their origin – coppice shoots and root suckers were monitored on four sample plots (different sites and clones). Sprouts of root origin grew individually or in tufts, most frequently of 6-8 individuals. The number of coppice shoots depends on the number of trees at felling age and ranged from 180-330 pcs.ha^{-1}. The number of coppice shoots on each stump ranged from 40-60. As already mentioned above, the numbers of individuals on the plot by clones varied and ranged from 40-70 thousand per 1 ha. More important than the total numbers of individuals is the fact that the spacing of 4x4 m is impossible to attain by individually growing root suckers the reason being a severalfold lower number of individual sprouts as compared with root tufts and the irregular character of their occurrence. Individuals of stump origin and root suckers growing in tufts are more succeptible to fungal diseases communicated from the parent stand or in the course of thinning the tuft, and are mechanically more instable (possible sporadic break-offs in the future). As compared with artificially regenerated stands, the plots also exhibited a higher incidence of insect pests.

A comparison of increments with other technologies used at LZ Židlochovice needs compare the age of individuals. Transplants in reforestation are of the same age as the regenerated individuals after the 1st growing season. Therefore, the increment values after the 2nd growing period in natural regeneration had to be compared with the increment values of artificial regeneration after the 1st growing period. The comparison showed that the height increment of naturally regenerated individuals can be competed with after the 1st growing period only by transplants of the same age, treated by agroforestry. Annual height increment in natural regeneration ranges about 100 cm. In the next growing season, the values of height and diameter increments of all technologies are already similar with the height increment ranging from 90 - 115 cm.

A negative featured by all assessed older rejuvenated stands are great height differences among individuals on the plot. The height starts to differentiate after the 2nd growing period and at the age of regeneration of 4 years the differences range from 200 - 250 cm. The height differences are entirely inappropriate for poplar which is one of the most light-demanding tree species, intolerant to be grown in sub-level, and whose further development is endangered by such height differences. Another disadvantage is the fact that in comparison with the artificial regeneration, any man-made improvement of dead sprout or sucker, or complementation of the plot with transplants in the case of insufficient regeneration is nearly impossible. The transplants would grow in the sub-level and would gradually die. The problem can be cured by enhancement with white willow which –although having the same increment after the 1st growing season as poplar- is less light demanding and can fulfil tending and soil-improving functions in the future. It should be pointed out that the larger reduced area improved with willow, the lower the total volume production of the stand. White willow does never reach poplar dimensions during the growth (not even at felling age) and its health condition is more instable. By this we cast doubts on the main reason for the intensive growing of cultivated poplars, i.e. the maximum production of high-quality wood mass at the shortest possible time. Another disadvantage is the expected lower share of valuable assortments (smaller tree size and worse health condition). Lower will be also the total stand volume production as compared with artificially established stands. Low forest (coppice forests) has a shorter rotation period and a lower wood mass production than high forest (Mottl, Špalek 1961).

If this technology is compared with other methods of regeneration for its economic demands, it comes out as one of extremely low-cost methods. Reforestation costs are zero but some costs are incurred for thinning sprouts and suckers.

Positive features:

- low total costs before establishment
- rapidly growing individuals (can be compared only with agroforestry)

Negative features:

- best rejuvenating are clones which do not produce the highest mature stock on local sites
- probability of fungal diseases communicated from parent individuals or during the thinning of individuals in the tuft
- instability of the stand – sprouts (possibility of frequent break-offs in the future)
- greater occurrence of insect pests
- unevenness of stand heights, larger differences are not desirable
- impossibility of enhancement by poplar

- total volume production lower than in artificially established stands
- low probability of the occurrence of valuable assortments.

It can be concluded that the method is not of the best ones for the intensive growing of poplars. The choice of rejuvenated clones is affected by the planting material used 30 - 40 years ago. Today, the clones are no longer used for planting stands in the LZ Židlochovice, being even identified as improper for the purpose in the List of recommended assortment of poplars for the Czech Republic due to their growth characteristics and health problems. Nevertheless, the method of regeneration might be used in special-purpose forests such browsing plots in game preserves. It can be also applied in reforesting smaller plots where artificial regeneration would be too costly, at places where the stands fulfil non-wood-producing functions of the forest (desuction, soil-conservation, etc.). The method is successfully used abroad in growing plantations intended for the production of pulp and dendromass for energy or other use.

Evaluation of the surveyed stands

The sample plots of natural regeneration were distinguished according to age, cultivar and site. The sample plots were subjected to the measurement of height and diameter increments and their comparison.

120B 05, sample plot no. 7 – Whole-area site preparation by superficial rotary cultivator (logging residues + stumps) in February 2000. Stand area is 1.17 ha, Forest Type 1L2. Vegetative regeneration was divided into rows in the spring of 2001 and the plot was supplemented white willow in March 2002. Tufts of root suckers were thinned to the required spacing 4x4 m. Protection against game damage individually by plastic tubes. The stand is considerably height-differentiated. A considerable share of suckers is infested by small poplar longhorn beetle (*Saperda populnea* L.). Weed control by mulching (in inter-rows by UKT-mounted aggregate). The current state of the stand is shown below in Fig. 1.

127B 04, sample plot no. 20 – Whole-area site preparation by superficial rotary cultivation (logging residues + stumps) in February 2001. Stand area is 1.07 ha, Forest Type 1L2. Vegetative regeneration failed and the whole plot has been forested artificially.

130C 08b, sample plot no. 23 – Whole-area site preparation by superficial rotary cultivation (logging residues + stumps) in February 2001. Stand area is 1.20 ha, Forest Type 1L9. Vegetative regeneration failed and the whole plot has been forested artificially.

123E 05b, sample plot no. 18 – Whole-area site preparation by superficial rotary cultivation (logging residues + stumps) in February 2001. Stand area is 1.60 ha, Forest Type 1L4. Vegetative regeneration failed and the whole plot has been forested artificially.

127A 04, sample plot no. 21 – Whole-area site preparation by superficial rotary cultivation (logging residues + stumps) in February 2001. Stand area is 0.30 ha, Forest Type 1L9.The vegetative regeneration was divided into rows in the autumn of 2001 and the tufts of root suckers were thinned to the required spacing 4x4 m in March 2003. Protection against game damage individually by plastic tubes. Weed control by mulching in inter-rows using a UKT-mounted aggregate.

129C 00b, sample plot no. 22 – This stand serves as a browsing plot in the game preserve. The site was not subjected to whole-area preparation after felling which was made in summer 1997. Root suckers and coppice shoots emerged in the following growing season. Stand area is 0.60 ha, Forest Type 1L2.

Fig. 1: Stand 120B 05

252D 04, sample plot no. 27 – Whole-area site preparation by superficial rotary cultivation (logging residues + stumps) in February 2001. Stand area is 1.70 ha, Forest Type 1L2. The vegetative regeneration was divided into rows in the autumn of 2000 and the tufts of root suckers were thinned to the required spacing 4x4 m in the spring of 2002. In March 2002, the plot was enhanced with the white willow. No protection against game damage.

258C 04a, sample plot no. 29 – Whole-area site preparation by superficial rotary cultivation

(logging residues + stumps) in February 2001. Stand area is 1.11 ha, Forest Type 1G4. The vegetative regeneration was divided into rows in the autumn of 2000 and the tufts of root suckers were thinned to the required spacing 4x4 m in the spring of 2001. In March 2002, the plot was enhanced with white willow. No protection against game damages.

212B 01g, sample plot no. 25 – This coppice came to existence in 1993. Root suckers appeared after felling and whole-area dozer site preparation. The stand has already been subjected to two tending measures. Stand area is 0.43 ha, Forest Type 1L4.

233B 01b, sample plot no. 26 – This coppice came to existence in 1997 through the vegetative regeneration of white poplar and trembling aspen. Stand area is 1.08 ha, Forest Type 1L9. The stand has been subjected to one tending measure. The current condition of the stand is illustrated in Fig. 2.

Fig. 2: Stand 233B 01b

CONCLUSIONS

The cultivation of poplar stands is doubtlessly prospective. Their regeneration will be preferably made by using transplanted plants and possible is also the planting of cuttings directly onto forested plots. Regeneration of stands by coppice shoots or by root suckers can be applied only in special-purpose forests such as browsing plots in game preserves or in plantations for dendromass production.

Most frequently planted are clones of so called Euro-American poplars, i.e. hybrids of European and American black poplar (*Populus x euroamericana* Dode/Guinier). These clones are characterized by rapid growth and good quality of wood mass and this is why they gradually forced out our domestic poplar species which do not suit the purpose of cultivation due to markedly worse qualitative and quantitative characteristics.

Although the intensive plantations of artificially bred clones are often considered something unnatural, something that probably even does not belong in our landscape, it should be emphasized that this type of stands whose main function is the function of wood production fulfil a range of other non-wood-producing and social functions. Two main prerequisites for the successful growing of poplar stands can be considered suitable climatic and site conditions and acceptable variety of clones. A matter of course is dilligent care and tending of poplar stands based on the respecting of their ecological requirements.

Important should be considered namely the intensive cooperation of the Forest Enterprise with the research station in Uherské Hradiště. There is no doubt that the research results from numerous sample plots can be applied in practice and are an important condition of success.

Some clones that were commonly planted some 30 or 20 years ago are no longer used and have been replaced by more suitable clones. Concretely, the formerly widely grown clone *1-214* is not even included in the recommended assortment today. Also, the formerly common clone *Robusta* was excluded from cultivation in the Židlochovice Forest Enterprise already several years ago. Other clones eliminated from the assortment of the LZ Židlochovice are *Brabantica* and *Virginiana de Frignicourt*. Clones that are currently used most are *NL-B-132b*, *Blanc de Poitou*, *I-45/51* and *I-476*. In the future, an increased interest can be expected in the growing of intensive plantations also on non-forest lands the primary reason being the surplus of agricultural land. The objective is production of dendromass especially for energy. This type of plantations has not been spread too much in our country so far but on the example of many other European countries we can see their numerous advantages which are not only economic but also social (new jobs) and ecological. Nevertheless, even the foreign experience shows that the establishment of these plantations will call for a government subsidy especially at the beginning.

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REGENERATION OF NOBLE BROADLEAVES ON ALLUVIAL SITES OF THE ŽIDLOCHOVICE FOREST ENTERPRISE

Michal Hrib

Abstract
Most important in the group of other or so called noble broadleaves grown on alluvial sites of the Židlochovice forest management unit (FMU) is the black walnut (*Juglans nigra*). Walnut stands are grown either as monocultures or as mixed 2-storey stands with the lower storey of small-leaved linden (*Tilia cordata*). Interspersed in the southern part of the floodplain forests are wild pear (*Pyrus pyraster*) and crab apple (*Malus sylvestris*). Efforts focused on the increase of the formerly high share of elms (*Ulmus* sp.) have been failing up to now. Underestimated still remains black elder (*Alnus glutinosa*) which can be found on water-logged sites or growing along the streams. Black walnut is regenerated exclusively artificially by seeding. The other valuable broadleaved species are however a very material component for the development and conservation of biological diversity in the floodplain forests.

Key words
black walnut, noble hardwoods, silviculture, ecological stability, production potential, silvicultural measures

INTRODUCTION

Tree species composition of floodplain forests in the forest management unit (FMU) Židlochovice is dominated by pedunculate oak (*Quercus robur*) and by narrow-leaved and/or European ash (*Fraxinus angustifolia, F. excelsior*) at a share of up to 70 %.

General understanding of the group which is referred to as noble hardwoods features several distinctive characteristics which together may be considered to represent a certain definition:

- similar character of dispersed occurrence in European mixed forests,
- high ecological requirements,
- high wood quality.

According to EUFORGEN definition criteria (Vančura 1998) noble hardwood species are as follows: *Acer platanoides* and *A. pseudoplatanus*, *Alnus glutinosa*, *Malus sylvestris*, *Prunus avium*, *Pyrus pyraster*, *Tilia cordata*, *T. platyphyllos*, *Ulmus glabra*, *U. laevis* and *U. minor*. In the Czech Republic the group was added the common ash. However, ash which is together with oak the main commercial tree species will not be discussed in this paper. Although the black walnut (*Juglans nigra*) is not classified in the Czech Republic with these broadleaves, it would be impossible to neglect this introduced species whose representation in the Židlochovice FMU reaches 1.6 % of total stand area.

Other deciduous species that could be referred to as noble hardwoods form approximately 8 % of total area under cover on alluvial sites.

Natural conditions of the Židlochovice FMU

The forest management unit Židlochovice is situated in Natural Forest Region no. 35 - South-Moravian Grabens (Jihomoravské úvaly). According to the regional division of the CR relief, this region with a forest cover percentage of mere 13 %, the area of which is 294,552 ha and the total area of forest stands intended to fulfil forest functions in it is 40,809 ha occupies the Dyjsko-svratecký úval (Dyje-Svratka Graben), the Dolnomoravský úval (Lower Morava Graben) with the alluvial plain of Dyje and Morava rivers, the Valtická pahorkatina Highland and the Dyjsko-moravská pahorkatina Higland. Between the two grabens there is the Mikulovská vrchovina Upland with the Pavlovské vrchy Hills and the Milovická pahorkatina Highland. With its eastern corner it reaches the southern margin of the Ždánický les Forest with the Hustopečská pahorkatina Highland and the Boleradická vrchovina Upland, and further on the southern part of the Kyjovská pahorkatina Highland – the south of the Mutěnická pahorkatina Highland.

Relief of the western part is largely of plain character, at some places passing into highland on the edges of uplands. As to height articulation it has character of a flat highland to lowland with altitudes ranging from 190 - 280 m a.s.l.

South of the Dyje River there is an articulated hilly land of 170 - 460 m a.s.l., the highest summit of the Pavlovské vrchy Hills is Děvín (550 m a.s.l.). The eastern half of the territory is a hilly land and is occupied by terraces of the Morava River with eolian sands. Elevation is 170 -3 60 m a.s.l.

In the natural forest region there are alluvial plains of the Morava River and its tributaries. The lowest point is the Dyje-Morava confluence (148 m a.s.l.); the highest point is the Svitava River alluvium in Brno – 200 m a.s.l.

The natural forest region includes the Pannonian biogeographical province, the Northern-Pannonian biogeographical sub-province with the biogeographical regions: Lechovický, Mikulovský, Hustopečský, Hodonínský and Dyjsko-Moravský.

According to the climatic division developed by Quitt (1992), the natural forest region (NFR) 35 lies in the warm zone T4 which is characterized as a zone with a very long, warm and dry summer and with a very short transitional period. Spring and autumn are warm. Winter is usually short, moderately warm and dry to very dry, with very short snow cover endurance. The zone is the warmest one in the Czech Republic, only its higher situated margins lie in zone T2.

History of black walnut growing in the Židlochovice FMU

Although the black walnut has been grown in South Moravia since the beginning of the 19th century, most of its oldest stands were established by planting some 120 years ago.

The Židlochovice FMU came gradually to existence as a merge of forests that belonged in the Hapsburg estate situated in the Židlochovice district and in the Lichtenstein estate situated in the Břeclav district. This is why the two parts experienced different development. Historically older stands can be found on the former Lichtenstein property near Lednice (the Lednice-Valtice area). In service to the Lichtenstein family a botanist named Joseph van der Schott set out to America to procure seed stock right on the spot, which is later documented by reports from the beginning of the 19th century about the successful planting of North-American tree species in nurseries and plantations and even directly in the stands of the Lichtenstein estate (Nožička 1956).

Table 1: Climatic characteristics of the Natural Forest Region Jihomoravské úvaly Grabens (Regional Forest Development Plan, NFR 35) (1999)

Characteristics of climatic macroregions in the territory	**Southern**	**Central**	**Northern (marginal)**
Mean air temperature in January (ºC)	- 2 až -3	-2 až -3	-2 až -3
Mean air temperature in April (ºC)	9 - 10	9 - 10	8 - 9
Mean air temperature in July (ºC)	19 - 20	19 - 20	18 - 19
Mean air temperature in October (ºC)	9 - 10	9 - 10	8 - 9
Days with $t_{max} \geq 30$ ºC (tropical days)	≥13	10 - 13	8 - 10
Days with $t_{max} \geq 25$ ºC (summer days)	60 - 70	60 - 70	50 - 60
Days with $t_{min} \leq 0{,}1$ºC (frost days)	100 - 110	100 - 110	100 - 110
Days with $t_{max} \leq -0{,}1$ ºC (ice days)	≤ 30	30 - 40	30 - 40
Days with $t_{min} \leq -10$ºC (with bitter frost)	10 - 15	10 - 15	10 - 15
Days with $t_{max} \leq -10{,}1$ ºC (arctic days)	≤ 2	≤ 2	≤ 2
Days with average temperature ≥ 10ºC	170 -180	170 - 180	160 - 170
Days with average temperature ≥ 0º C	270 - 290	270 - 290	260 - 270
Beginning of period with average temperature ≥ 0 ºC	≤ 11.3	≤ 11.3.	11.3 – 16.3.
End of period with average temperature ≥ 0 ºC	1.1.-6.1	26.12.-1.1	26.12.- 1.1.
Temperature sums ≥5 ºC	≥ 2,000	1,800 - 2,000	1,600 - 1,800
Temperature sums ≥10 ºC	≥ 1,000	800 - 1,000	600 - 800
Total precipitation amount in vegetation period (mm)	300 – 350	300 - 350	350 - 400
Total precipitation amount in winter period (mm)	200 – 250	200 - 250	200 - 250
Days with precipitation ≥ 1 mm	80 – 90	80 - 90	90 - 100
Days with precipitation ≥ 10 mm	12 – 15	12 – 15	12 – 15
Days with snow cover 1 to 20 cm	30 - 40	30 – 40	30 - 40
Days with snow cover 21 to 40 cm	≤ 10	≤ 10	10-15
Days with snow cover 41 and more cm	≤ 5	≤ 5	≤ 5
Cloudy days	110 - 120	110 – 120	120 - 140
Clear days	50 - 60	50 - 60	40 – 50

On the former Hapsburg estate of Židlochovice the black walnut began to be grown in the last decennium of the 19th century. The likely origin of seeds is from another Hapsburg estate – from the floodplain forests of Slavonia in the today's Croatia at the confluence of Drava R. and Danube R. near the village of Bilje (Béllye in Hungarian). The report of the Vienna office of Archduke Frederick from 1891 about the forwarding of about 10 hectolitres of walnut seeds from Béllye to Židlochovice was found in archives by Nožička and publicized by Šika (1964).

The extent of growing black walnut before World War II in the Židlochovice district can be documented by the Forest Management Plan for the period 1927 - 1936. FMP presents in tables figures on the date of 1 January 1925 as follows: total area of black walnut stands 3.17 ha (2.39 ha in the high forest and 0.78 ha in the low forest), management class "A" with high production potential and rotation of 80 years. The negligible area occupied mere 0.2 % of the forest area in management class "A".

AREA OF THE BLACK WALNUT FOREST STANDS

At the beginning of the new FMP (1 January 2000), the reduced area of black walnut stands in the Židlochovice FMU was 263.5 ha and 80 % of these stands occurred on sites corresponding according to the classification by Zlatník to Group of Forest Types 1L – Elm floodplain. Forest types most represented in this group of forest types (GFT) are those of *Ulmeto-Fraxineum carpineum*. Nearly a half (47.1 %) of the forest stand area is in special-purpose forests – mostly in pheasantries. The category of commercial forests the principal function of which is production of wood mass included 35.2 % of black walnut stand area.

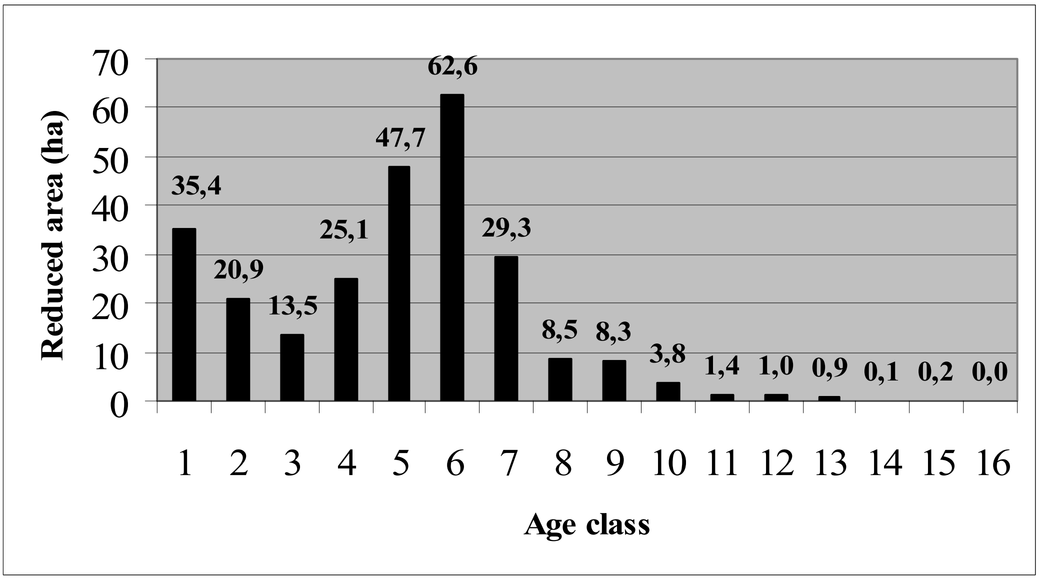

Fig. 1: Reduced area of black walnut stands by age classes in the stands of the FMP Židlochovice

ESTABLISHMENT AND TENDING OF BLACK WALNUT STANDS

Principal decision of forest managers concerning tree species selection with a matter-of-course respect to site conditions and ecology of the species is currently treated by the framework management regulations in which the alternative of growing black walnut has already been specified. Upper limit for exotic tree species is in the Czech forestry a total representation of 7 % of all introduced tree species (Beran, Šindelář 1996). Limiting factor is in this case valid environmental legislation, namely the Act no. 289/1995 Coll. on forests, and the Act no. 114/1992 Coll. on nature conservation and landscape protection. Regarding the prognoses of long-term climate development with possible global warming, the black walnut appears to be one of prospective tree species suitable for cultivation in our conditions.

Framework management regulations

The share of geographically non-autochthonous tree species (GNS) in the primary management group of stands (MGS) is set by the approved Regional Forest Development Plan (RFDP) pursuant to §1 subsection 5 of the Decree no. 83 of the Ministry of Agriculture on the preparation of regional forest development plans (RFDP) and specification of management groups of stands. Pursuant to item h) of the above subsection the RFDP stipulates that the Regional Forest Development Plan includes the "proposal for the use of geographically non-autochthonous tree species".

In line with §23 subsection 1 of the Forest Law a condition is stipulated for the approval of the particular RFDP that a binding statement be issued by the central authority of nature conservation state administration with respect to the introduction of geographically non-autochthonous forest tree species. The binding statement for NFR 35 was issued in 1999, which defined a maximum share of GNS represented in the tree species composition only in MGS 19 for black walnut (BW – in tables ORC) + to 1 % outside the Pálava Protected Landscape Area, further stipulating that pure stands of black walnut are undesirable in all composition elements of territorial systems of ecological stability. Regeneration of forest stands should avoid GNS monocultures and the share of GNS together with the main commercial tree species must not exceed 70 % in the target species composition. The use of geographically non-autochthonous tree species is not recommended in the Pálava PLA territory.

Management group of stands 19 – oak management of alluvial plains is in the NFR Jihomoravské úvaly Grabens represented on 14,037 hectares. Thus, the area share of black walnut stands must not be greater than 140 ha pursuant to the above mentioned regulations.

The largest share of stands with the black walnut in the Židlochovice FMU can be found in MGS 9185 and MGS195 – oak management of alluvial plains (and special-purpose management in detached pheasantries). The relatively high current representation of walnut in MGS 9847 (8.9 %) will not be further increased. Black walnut was used relatively often as a tree species in wind breaks, 5.7 % of its stand area is included in MGS 7247 – special-purpose management of fertile sites in lowlands – protective forest belts, wind breaks, in which the black walnut is not considered a target species even as a recommended one of the permitted geographically non-autochthonous tree species.

THREAT BY ABIOTIC AND BIOTIC AGENTS

With respect to threat by abiotic agents and to stand stability the black walnut appears to be a species which does not differ significantly from other tree species of the hardwood forest of lowland rivers.

Threat by biotic agents is not an obstacle to its growing. The species suffers a relatively low damage due to browsing and nipping, damage by stripping was not recorded. Some individuals of the youngest age class may be wounded by roe deer fraying. It is even pointed out that the resistance of black walnut against nipping and browsing was –apart from favourable parameters of wood mass production- one of material reasons for its planting in the Židlochovice district where wild rabbit was abundant until the 1970s and the protection of plantations was relatively costly.

However, the black walnut is frequently infested by mistletoe (*Viscum album* L.) in the Břeclav and Valtice districts, both solitary trees and whole stands. The presence of mistletoe in the oldest Židlochovice stands was not recorded at all in the past but recently some individual cases of infestation appeared in the stands of age class 5.

Interesting was also the occurrence of wood-decaying honey fungus (*Armillaria gallica* Marxmüller et Romagnesi) detected during the logging of stand 126C 11 in which 11 % of trees (19 pcs) were infested by the honey fungus. Dark rot of heartwood (in the middle part) however never exceeded a height of 1 m; yet some most valuable stem parts up to that height were depreciated – a total of 4.7 m^3 of wood mass. It is assumed that reason may be the fact that the fertile soils might have been in the past used for farming and the infestation of subsequently planted tree species by wood-decaying fungi is relatively common on these soils.

SEED SOURCES

NFR 35 Jihomoravské úvaly Graben has a total of 11 stands of the black walnut of phenotype class "B" at a total reduced area of 13.34 ha. A stand of the phenotype class "A" was planned for felling in 2000 and this is why there is no certified black walnut stand of phenotype class"A" existing either at LZ Židlochovice or in NFR 35.

Table 2: Black walnut stands certified for seed harvest at Židlochovice Forest Enterprise

Registration number	District	Phenotype class	Stand designation	Reduced area (ha)
B-ORC-0013-35-1-BV	Břeclav	B	224D10	0.92
B –ORC- 001-35-1-BO	Brno-venkov	B	121B5	2.24
B –ORC-111-35-1-HO	Hodonín	B	529D8	0.64
B –ORC-111-35-1-HO	Hodonín	B	529A9	2.05
B –ORC-111-35-1-HO	Hodonín	B	529F8	0.67
Total area (ha)	6.52			

Stands of black walnut begin to bear very early and exceptional are not even cases when seeds appear in 8-year old stands. Annual fructification of varying intensity is regular but no problems have been ever recorded with the sufficient amount of seeds for the requirements of forest management. Collection of seeds after their fall in October and November is very easy. Some authors mention the procedure of exocarp removal in water bath by washing in running water or by "trampling" (Pokorný 1952). Procedure well proven in practice is relatively simple and makes use of seeds with no previous treatment directly in seeding.

Annex no. 6 to the Decree no. 82/1996 Coll. stipulates characteristics for the tree species of black walnut as follows: share of seeds in fruits 50 %, purity 95 %, germinative capacity (viability) of purified seeds 55 %, hectolitre weight of undried fruits 30 kg, weight of 1,000 seeds 12.3 kg, number of seeds in 1 kg 80, number of purified germinable seeds in 1 kg 42.

The simpliest method of stratification is to pour the nuts closely in a layer on a bed in the nursery and to cover them with a 10 cm layer of earth, possibly adding leaves on the top. Removal of exocarps is not necessary as the method makes the check of germination possible.

Heeling of seeds can be also made on a heap under the stand but the heeled seeds have to be secured against being taken away by wild boar and there is also a danger of them being stolen by squirrels and rodents. Seeds stored in this way should be sown latest within half a year next spring.

ESTABLISHMENT OF FOREST STANDS

Black walnut stands were established by sowing into furrows after whole-area soil preparation. Since the black walnut is characterized by rapid growth at young age and by the tendency towards forking crowns, it is recommended to underplant the stands with linden (small-leaved or large-leaved) in Year 2 or Year 3 after planting. Stands without underplanting are grown with a higher number of individuals in rows (row spacing 1x1.6 m). At the beginning (up to the third year) it is possible to employ agroforestry which is a method to raise agricultural crops in between the rows established by sowing. In the past, this method of stand establishment was widely spread namely in the Židlochovice district, being conditioned by the interest of small farmers to grow field crops. In this way, the farming was favourable especially due to cheap lease of the forest land. This method of forest land use is today rather exceptional.

Mechanized autumn sowing is made with ca. 450-550 $kg.ha^{-1}$ walnut seeds including pericarps. Some of the seeds however would not emerge in the spring but only in the autumn or would even delay germination until the next year, which has to be taken into account for possible additional seeding which should not be done hastily. Germinative capacity of seeds is high (55-80 %). It is advised that a soil-improving species (most frequently linden) is planted in inter-rows in Year 2 and Year 3 after seeding. The seedlings being usually relatively dense and rapidly growing at young age (height 8 - 10 m in Year 10), the improvement species regulates the stand microclimate rather than affecting the height of fork (crown) setting, which can be seen in Stand 126C 11 in which the linden was underplanted as late as at the stand age of 51 years.

Creation of suitable stand mixtures is a relatively difficult task. In Germany, in the Rhein basin the walnut was planted in the oldest plantations only in groups into hardwood stands of lowland rivers after the felling of oak reserved trees or on clearings after disasters (e.g. Holländerschläg). Individual planting of black walnut as an interspersed species into stands is missing sense because in such a case this light-loving species would create stems with a forking and low-set crown. Inadvisable is also a too large spacing with a low number of individuals per hectare, which can be documented on some stands established by Lichtenstein foresters on elevated sand and gravel floodplain forest sites (so called dunes) in the Soutok forest district.

FOREST TENDING

Forest tending objective is quality and high share of valuable assortments in the case of the alternative with BW in MGS 19. Rotation period is 140 years, regeneration period 30 years, beginning of regeneration at 121 years, management system is clear felling (possibly regeneration by border felling).

The first measure is to be carried out at 5-6 years after completed canopy closure. Tending of young growths is characterized by negative selection in the main level and in the dominant level. Wolf trees, poorly formed individuals and overtopping trees must be removed in the walnut similarly as in the main tree species but the canopy closure must not be disturbed. During the first treatments it is also advisable to reduce the number of individuals only in heavily crowded sowings otherwise the density needs not be regulated (self-reduction). Mixture reduction is not necessary. The second juvenile thinning (cleaning) follows after approx. 5 years. The third juvenile thinning after next five years may already be of the character of positive selection in the main level. Important is the stand division into working fields already for the first cleanings.

Maturing stands aged 30-40 years cannot be at the initial stage subjected to negative selection in the main level; forking individuals are to be preferably removed – qualitative main level thinning. Regarding the walnut growth properties, treatments made in this period are decisive with respect to the qualitative development of the stand. However, the treatment must be adequate and the crown canopy should be kept closed. As a light-demander walnut would use a surplus space resulting from disturbed canopy closure for the production and diameter growth of forks, which may lead to the subsequent impairment of stand stability (fork breakages). During the following thinnings it is recommended to find about 400 promising trees per hectare and to focus the subsequent thinnings in the high forest on increment thinnings with ca. 150-200 target trees.

Table 3: Establishment and felling in the stands of black walnut in FMP periods 1990 - 1999 and 2000 - 2009

FMP 1990 - 1999	Sowing (ha)	Repeated sowing (ha)	Logging (m^3)				
			Advance felling			Main felling	
			Up to 40 years*	Over 40 years**	Incidental	Regeneration	Incidental
	48.82	5.22	1,308.54	568.43	701.91	321.71	53.46
Total	54.04		2,954.05				

* Advance felling – total area in stands up to 40 years of age 75.24 ha

** Advance felling – total area in stands older than 40 years 23.61 ha

FMP 2000 - 2009	Sowing (ha)	Repeated sowing (ha)	Logging (m^3)				
			Advance felling			Main felling	
			Up to 40 years*	Over 40 years**	Incidental	Regeneration	Incidental
Period 2000-06/2007	17.6	5.22	712.66	1,369.14	394.84	1713.1	972.3
Total	22.82		5,162.21				

* Advance felling – total area in stands up to 40 years of age 38.82 ha

** Advance felling – total area in stands older than 40 years 51.56 ha

Results of management pursuant to FMP 1990 - 1999 are summarized in Table 3 with data for the current FMP being added separately to the same table. In the period of the previous FMP, a total amount of timber felled was 2,974.15 m^3 and an area of newly established walnut stands was 48.82 ha. Main felling was however representing only 12.6 % in the total volume of BW timber felled. A relatively high (19 %) share of timber felled was represented by incidental advance fellings. As compared with the previous FMP, the total amount of felling is nearly double in the middle of the eighth year of the current FMP. However, incidental felling represents a share of 26 %, which is much more than during the previous FMP. The area of newly established stands is nearly by half smaller and corresponds to the trend of the decreasing walnut representation.

MENSURATIONAL CHARACTERISTICS OF THE HIGH-QUALITY BLACK WALNUT STAND 126C 11 IN THE ŽIDLOCHOVICE FOREST DISTRICT

At the turn of 2000/2001, a 107-year old stand of black walnut was intended for cutting, which was one of the best at the Židlochovice FMU. The last full callipering of the stand was made in 1996 but data were found from the management records and from literature, on the basis of which it was possible to at least partly assess its production characteristics. It should be added to provide full information that the underplanting of small-leaved linden was carried out in this stand only in 1942.

In 1966, a detailed survey was made in order to establish standing volume in this stand. Results of measurements are presented in the following tables of mensurational characteristics.

Table 4: Basic characteristics of the stand 126C 11 – I

Species	**Black walnut (ORC)**	**Small-leaved linden (LP)**
Trees in the stand (pcs)	172	748
Trees per hectare (pcs)	154	785
Mean-tree volume (m^3 o.b.)	4.9	0.2

Table 5: Basic characteristics of the stand 126C 11 – II

Species	**Black walnut (ORC) $d_{1.3}$ (cm)**	**Black walnut (ORC) - height h (m)**	**Small-leaved linden (LP) $d_{1.3}$ (cm)**	**Small-leaved linden (LP) - height h (m)**
Weighted arithmetic mean	56.3	35.9	16.8	15.8
Max. value of the set	81.0	41.0	34.5	20.0
Min. value of the set	37.5	30.0	7.5	8.0
Size of the set (pcs)	172	49	748	31

Basic mensurational characteristics detected in the black walnut stand 126C 11 unambiguously demonstrated its high production capacity – 718 m^3 per hectare at the age of 103 years. Av. setting height of the first crown branches or fork was 12 m. The share of bark (up to 22 %) in total stem part of the tree is nothing exceptional and was described at a comparable measure also in other species (pine, larch, oak). However, the information is valuable for the consideration of deductions at timber sales.

Table 6: Stand 126C 11 – Growing stock

Species	**Black walnut (ORC)**	**Small-leaved linden (LP)**
Growing stock (m^3 o.b.)	837	141
Growing stock per ha (m^3 o.b.)	718	148
Growing stock (FMP, 1990)	848	not included

Based on the height growth analysis, silvicultural measures expect the greatest plasticity and response to tending measure at a relatively young age, i.e. up to 30-40 years. Results from the analysis of diameter increment demonstrate fluctuating –in some cases increasing- diameter increment at higher age. It can be therefore expected that the effect of increased light increment could be sufficiently substantiated in the system of high forest with reserves. Very interesting is the fact that the volume growth of the walnut did not exhibited an inflexion point within the analyzed tree age (103 years) and a slow-down of the volume increment has not occurred yet, which testified justification of increasing the felling age to above 110 years. It is however only the volume culmination not the culmination of stem value expressed by sales of assortments. Also, the fact of developing fungal diseases at higher age has not been taken into account. From this point of view, the conclusion about volume increment should be understood only as a benchmark. Felling maturity assessment has to be made at a level of whole stands with the use of forest management records and with the grading of timber volumes to be felled both in the main stand and in the secondary (thinning stand). For a comparison it is possible to mention the rotation period recommended for black walnut stands in the framework forest management regulations for the Židlochovice FMU. The regulations stipulate rotation to be made at the age of 140 years with a 30-year regeneration period and with the forest manager being responsible for the decision upon concrete felling age of a stand on the basis of further criteria (e.g. demand and supply, health condition of the stand).

Forest Enterprise Židlochovice makes use of the advantage following out from the existence of own centralized log conversion depots. Black walnut wood is sold from these depots after previous cross-cutting. Data in Table 7 are presented as an example of conversion into money which is on average relatively high (5,153 CZK) and was given by extremely high share of qualitative logs from the concerned stand. The average realization of black walnut timber is in all cases higher than in oak timber. Rather interesting is a fact that the proportion between walnut and oak wood has remained nearly unchanged as compared with the data of 1949 (Pokorný 1952).

Demand is currently much higher than supply. Traditional business partners are foreign customers namely from Austria. Czech manufacturer PETROF, a.s. used the walnut wood to make veneers for the bodies of musical instruments; this wood was also used to manufacture legs of concert grands and pianos in a specialized wood-carving workshop. The wood offers itself for the manufacture of furniture and special construction elements such as ornamental floors, staircases, railings.

OTHER NOBLE HARDWOODS

The representation of elms (*Ulmus* sp.) in the floodplain forests dominated by *Ulmeto-Fraxineta* was initially 10 % but has been steadily decreasing since the mid-20th century due to Dutch elm disease to the current share which is less than 1 %. Most resistant individuals, mainly the white elm (*Ulmus laevis*) are marked and intended for genetic resources. White elm appears also as natural regeneration or advance growth, apparently due to a more favourable hydrological situation (e.g. the Kančí obora Game Preserve). Bred resistant individuals of white elm were experimentally planted in newly established stands in the forest districts of Židlochovice and Velký Dvůr but even these plantations begin to show symptoms of Dutch elm disease at the age of about 15 years.

Table 7: Example of timber realization after cross-cutting on the conversion depot in March 2000 mainly from Stand 126C 11, LZ Židlochovice

Grade (ORC)	**Amount (m^3 u.b.)**	**Share of grades in assortments**	**Average realization (CZK/m^3 u.b.)**
I.	44.5	7.9	25,310
II.	118.8	21.0	9,385
III.	170.8	30.1	3,450
V.	202.9	35.8	400
Fuelwood + own production after logging	29.1	5.2	250
Total ORC	566.5	100.00	5,153
LP - linden from the lower storey	79.8	Grade V.	400
Total – stand 126C11	646.3		4,566

Species interspersed in the stands of hardwoods in the southern section, in forests at the confluence of Dyje R. and Morava R. is wild pear (*Pyrus pyraster*) and crab apple (*Malus sylvestris*). If the species occur in a natural way, they are given silvicultural treatment and are supported during tending measures. Regarding the fact that the forest complexes are also a subject to intensive game management, it is also possible to successfully use possibilities of artificial planting of these species from geographically autochthonous stock and it is also possible to mention the aesthetic function of these tree species.

Wild cherry (*Prunus avium*) is not a typical tree species of alluvial sites yet it was planted into a newly established stand of common ash in the Židlochovice forest district in 1997 as interspersed species. The individually interspersed tree species are to be further supported in tending operations. At the age of 10 years the stand was two times affected by floods (1997 and 2006), the cherry trees are pruned and their growth dynamics is encouraged by releasing the surrounding trees in order to assure enough light for assimilation area development up to now comparable with that of ash.

Black alder (*Alnus glutinosa*) can be encountered on water-logged sites or on the banks of watercourses and forest canals. Average realization of wood mass corresponding to Grade II amounts currently to 2,100 CZK (comparable with linden) and is not without commercial significance. Moreover, alder is an ideal tree species for artificial or natural regeneration of various terrain depressions and water-logged sites. Together with willow and poplar it should constitute an important stabilization element in the regeneration of stands also within the framework of applied whole-area soil preparation methods.

Issues of growing ash (*Fraxinus excelsior* and *F. angustifolia*) relate in forest practice primarily to the establishment of stands with the preferred production function of floodplain sites in tending so that mixed stands of these species can come to existence. Typical tree species of alluvial sites at lower reaches of Dyje R. and Morava R. is field maple (*Acer campestre*) which is of tree habit in these localities. Thus, regular mast years and the copious occurrence of natural self-seeding of this species represent a distinct competition for a possibility of using natural regeneration of pedunculate oak. Other maple species (*Acer platanoides* and *A. pseudoplatanus*) can be supported in silvicultural treatment as interspersed species.

Linden (*Tilia cordata* and *T. platyphylos*) as tree species tolerant to shade at young age represent together with hornbeam (*Carpinus betulus*) a challenge for being used in stands that are to be grown as multi-storeyed stands. In the Židlochovice forest district the linden can be met with as a tree species used in the lower storey of black walnut stands or in older poplar plantations.

CONCLUSION

The comparison of black walnut growth pursuant to growth tables of tree species in the Czech Republic with oak and ash demonstrated that production reached by walnut at a comparable age is higher than that of oak. The comparison of walnut and ash showed that the production cycle of ash can be understood as shorter, its production being at a comparable age higher than that of black walnut. For a possible focus on increased introduction of black walnut on the production sites it should be pointed out however that the species is introduced and its impact on the autochthonous woody, plant and animal communities in our conditions has not been yet fully clarified. Foreign authors described for example a relatively strong allelopathic effect of black walnut on the undergrowth and surrounding trees. The fact of a possible adverse impact of introduced tree species on the original ecosystems led to a "preventive" recommendation that the representation of these species in the Židlochovice FMU be max. 1 % of stand area in the target MGS 19 – oak management of alluvial sites.

Total amount of harvested wood mass in the period of the previous forest management plan for the Židlochovice FMU in 1990 - 1999 was nearly 3,000 m^3 and the planned timber volume of approximately the same level for the current forest management plan (valid in 2000 - 2009) gives the Forest Enterprise Židlochovice opportunity to use the timber for a targeted offer to specialized timber converters. High-quality wood of black walnut is used for example in the manufacture of musical instruments and with its properties can entirely substitute the wood of tropical timber species.

Growing black walnut in the South-Moravian Grabens with a tradition of nearly two hundred years, namely on floodplain sites of the Židlochovice Forest Enterprise, has become a common practice. Many of these qualitative stands of black walnut grown on these sites reach the felling age. Establishment of new black walnut stands on suitable sites in compliance with valid legislation as well as their subsequent felling when the timber from these stands is used as domestic recent raw material contributes to the fulfilment of the principles of sustainable forest management.

Planting or support of other noble hardwoods contributes not only to the maintenance of ecological stability and biological diversity but it also makes it possible – apart from the potentional production function- to use the species as landscape-forming elements with emphasis on their aesthetic function.

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PROBLEMS OF FLOODPLAIN FOREST CLASSIFICATION

Petr Maděra

Abstract
The paper deals with classification and typification of floodplain forests in European context with detailed focus on floodplain forest of nemoral zone of Europe. At the same time it determinates the main problems of classification of floodplain forests, which follow especially from strong human pressure on the water streams and their alluviums across the whole Europe.

Key words
floodplain forests, typology, classification

FLOODPLAIN PHENOMENON

Landscape types with a peculiar structure and dynamics which, thanks to specific abiotic conditions, are characterized by specific features of biodiversity and geodiversity non-reproducible in other landscape types are termed a landscape phenomenon. The floodplain phenomenon is typical by its homeorhesis – the dynamic development of ecosystems in the trajectory of continuous changes in conditions (Míchal 1994). Unlike other European geobiocoenoses where permanent ecological conditions of particular ecotope segments remain preserved also with changes in a biotic component, alluvial plains are characterized by a long-term continual dynamic development of ecotopes conditioning developmental succession processes of biocoenoses. Thanks to fluvial landscape-forming processes the dynamic fluvial seccession series of floodplain biotopes (Buček, Lacina 1994) constantly develops as a scale of aquatic, wetland and terrestrial biocoenoses either natural or conditioned by man in various stages of the succession development creating the typical structure of a natural floodplain geosystem.

The structure of a floodplain landscape is formed by a mosaic of hydrobiocoenoses of watercourses and riverina lakes together with geobiocoenoses of wetlands, grasslands and various types of floodplain forests from the moistest communities of soft-wooded broadleaves to the driest types of hard-wooded broadleaves. The preservation of biodiversity of the floodplain landscape is conditioned by the completeness of a series of floodplain biotopes in various stages of development from initial stages over developmental to successionally mature communities approaching climax conditions. The floodplain phenomenon is characterized by spatial connectivity and time continuity of the development of biocoenoses. Periodical repetition of events of a disaster character such as large floods is a natural component of the homeorhetic dynamics of a floodplain landscape. Thanks to flooding and sedimentation of flood materials in the course of last millennia the alluvial plains have originated. The extent of alluvial plains forms thus a "memory of the landscape" documenting the natural course of fluvial landscape-forming processes.

The completeness of a series of alluvial biotopes forming the floodplain phenomenon is dependent on the permanent effects of fluvial processes. It refers particularly to the shift of a river bed by the lateral erosion of banks, sedimentation and erosion processes in the river bed and sedimentation processes in the river floodplain in the period of floods. Consequences of fluvial processes affect for a long time the nature of hydrological conditions of particular segments of geobiocoenoses (height and fluctuation of the groundwater table, height and duration of floods). The complete dynamics of the fluvial series of floodplain biotopes can be preserved only in such a way that at least in some places of the floodplain landscape we restore natural fluvial processes and thus we ensure spatial connectivity of biocoenoses and continuity of their development.

Hydrobiocoenoses and geobiocoenoses of alluvial plains rank among the most productive and species-richest ecosystems. The decisive factor of their condition and development is a specific hydrological regime dependent particularly on periodical changes in the river water level. A typical scale of floodplain biocoenoses – from riverine lakes, fen wetlands, and periodical pools of flooded floodplain forests with a high groundwater level to un-flooded types of a floodplain forest situated on elevated places is dependent on the duration of floods and height of the groundwater table.

Duration of floods is a decisive factor of the differentiation of floodplain ecosystems. It also decides on the possibility of the origin of floodplain forests because a boundary between permanently and temporarily flooded ecotopes forms a physical limit for the growth of trees termed as "hydric forest limit" (Jeník 1990). Terrestrial and wetland alluvial ecosystems are characterized by a surprising tolerance to differences in the duration and height of floods. As for forest communities, the most tolerant to floods are stands of white willow (*Salix alba*) which can be flooded without any permanent damage as many as 190 days per year and the water level can be higher than 4 m. Stands of pedunculate oak (*Quercus robur*) and other species of a so-called hard-wooded floodplain forest can survive a flood taking as many as three months and tolerate the height of floods amounting to 2.5 m. Some meadow communities tolerate an average period of flooding taking as many as 4 months (Dister 1990). Differentiation of floodplain ecosystems is also conditioned by relatively very small differences in the topography because they affect the duration of floods as well as differences in the dynamics of a groundwater table. Thanks to the deposition of flood materials alluvial soils are characterized by the extremely high content of nutrients ensuring the high production of biomass. A notable feature of alluvial plains is the "microstepped character" of soils manifesting in the regular sequence of differences in moisture conditions dependent particularly on the groundwater table and its fluctuation during the year.

European alluvial plains are situated mostly in densely populated and long-term used agricultural regions. Effects of human activities show there virtually in the course of the whole Holocene. Through timber harvesting and livestock grazing in floodplain forests and their conversion to meadows and pastures, a mosaic has originated of man-made natural ecosystems (van der Maarel 1975). By many features (high species diversity, highly organized structure and long life cycle) these communities approach developed natural communities. In the agricultural landscape with the absolute predominance of agrocoenoses of small ecological stability, near-natural floodplain forests appear to be an important refuge of biotic diversity showing a basic importance for the landscape ecological stability.

In the period of Holocene, the development of the alluvial plain landscape was very complicated. Natural landscape-forming processes related to the activity of rivers and their hydrological regime was modified by effects of human activities. Intensity of the effects gradually increased since the beginning of the agricultural use of landscape in Neolithic. Marked changes in the floodplain abiotic environment were caused by increased erosion and changes in the hydrological regime of rivers due to deforestation of head water areas in the period of the medieval colonization. The number and extent of floods increased, flood materials which deposited as flood loams levelled previously more broken surface of the alluvial plain formed originally mainly by gravel sand. Regular floods enriched annually alluvial soils by mineral nutrients and made impossible to convert natural floodplain biocoenoses to arable land. Thus, the characteristic structure of species-rich and biologically highly productive biocoenoses of alluvial plains gradually developed. This natural condition of geobiocoenoses with exceedingly high species diversity is, thus, a result of the effect of man on the landscape processes lasting for thousand years.

FLOODPLAIN FOREST COMMUNITIES AND THEIR CLASSIFICATION

Floodplain forests in the European context

According to phytogeographic aspects, the European continent belongs to the Holoarctic region (Melchior 1964 in Hendrych 1984) including the outside-tropical part of the northern hemisphere. The florogenetic basis of vegetation is created there by the Tertiary Turgai flora considerably destructed by the Pleistocene fluctuations of climate. According to Meusel & Jägr (1992), the European part of the Holoarctic region belongs particularly to the Boreal and Temperate zones. The northern margin of Europe is, however, situated in the Arctic zone whereas the southern part of the continent belongs to the Submediterranean and Mediterranean zones with markedly different Aral-Caspian province partly wedging into Europe from south-east. According to Walter (1984), the following vegetation belts affect Europe: etesian vegetation, deciduous broadleaved forests, steppes, deserts, boreal coniferous forests, tundra and high mountains.

Formations of floodplain forests are distributed throughout Europe from the south-arctic region to the Mediterranean region and deserts near the Caspian Sea at various altitudes. Although floodplain forests belong to the azonal vegetation based on the enumeration of phytogeographical units affecting the European continent it is evident that these forests will be of different properties in various parts of Europe. Of importance will be particularly physiognomic and floristic differences between northern, western, central, southern and Eastern Europe.

In the map of natural vegetation of Europe, Bohn et al. (2000/2003) classify European floodplain forests to five main formations:

- South-arctic floodplain shrubland particularly with shrubby willows – e.g. *Salix phylicifolia, S. hastata, S. lanata, S. glauca* and alders (*Alnus fruticosa)*, from other species e.g. *Ribes nigrum*, *Lonicera pallasii*. Arctic climate excludes the growth of arborescent species.

- Boreal floodplain forests where conifers play an important role in final succession stages (*Picea abies, P. obovata, Abies sibirica*) with the shrubby undergrowth of *Sorbus sibirica, Padus avium, Frangula alnus, Alnus fruticosa, Lonicera pallassi*, *Ribes rubrum, Rosa acicularis, R. cinnamomea* etc. and rather in younger developmental stages of succession, also cold-loving broadleaves (*Alnus incana, Betula pubescens,* shrubby willows, e.g. *Salix phylicipholia, S. nigricans, S. cinerea, S. glauca, S. viminalis, S. triandra, S. acutifolia)*. On the southern limit, also *Quercus robur, Alnus glutinosa, Tilia cordata* and *Ulmus laevis* are admixed in boreal floodplain forests.

- Nemoral floodplain forests which are quite without conifers. Natural floodplain forests of the nemoral zone of Europe are often compared with tropical rain forests due to their structure and fast growth. They show the common multi-stratum vertical structure of a tree layer with the numerous amounts of species, in warm regions abundant occurrence of lianas and fast-growing regeneration stages. Floodplain forests of lowland wide alluvial plains are divided on the basis of differences in the groundwater table on the particular site, by frequency, duration and height of the flood table to: "soft-wooded" floodplain (lower situated often flooded parts of alluvia with poplars, willows and alders) and "hard-wooded" floodplain (higher situated parts of alluvia flooded rarely and for a shorter time with predominating oaks, ashes and elms). Communities of the hard-wooded species are very young from phylogenetic aspects and, thus, they are species-unsuturated, with considerable regional differences being virtually without any peculiar species. The species spectrum of a tree layer consists mostly of floodplain ecotype trees of contact communities of adjacent uplands. In the nemoral zone, floodplain forests of stream alluvia of upland up to submontane locations are considerably widespread.

- Mediterranean and submediterranean floodplain forests and shrublands already with an admixture of evergreen elements. In southern Europe, primarily arborescent poplars (*Populus alba, P. nigra*) predominate in the "soft-wooded" floodplain, secondly willows (in the Balkan peninsula *Salix alba,* in the Pyrenean peninsula *S. atrocinerea*, *S. x rubens, Salix eleagnos* subsp. *angustifolia, S. cantabrica,* shrubby willows *S. viminalis* and *S. triandra* being more abundant). In the Canary Islands, riverine gallery forests are created by endemic *Salix canariensis.* In the "hard-wooded" floodplain, ash trees predominate (*Fraxinus angustifolia s.l.,* in the Balkan peninsula also *F. pallisae)*, elm (*Ulmus minor*), oak (with the exception of *Q. robur* according to regions *Q. pyrenaica, Q. canariensis, Q. pedunculiflora, Q. pubescens, Q. hartwissiana*), *Alnus glutinosa* is always frequent, in the region of Balkan also *Acer campestre, Ulmus laevis* and *Carpinus betulus.* The proportion of liana species is also considerable (*Clematis vitalba, Hedera helix, Vitis vinifera* subsp. *sylvestris, Lonicera peryclimenum* subsp. *hispanica* etc.). In the southern and eastern parts of the Mediterranean region, *Platanus orientalis* predominates in floodplains. *Juglans regia* and in the shrub layer *Nerium oleander, Pyracantha coccinea* and *Ficus carica* are other species. From the aspect of physiognomy, floodplains in Crete are quite different. Tree layer consists of *Phoenix theophrasii*, shrub layer of *Pistacia lentiscus*. In the Mediterranean region along temporarily drying up rivers and streams, floodplain shrublands occur formed particularly by tamarisk species (*Tamarix parviflora, T. tetrandra, T. hampeana, T. africana, T. canariensis)* and oleanders (*Nerium oleander*) *Vitex agnus-castus* being also admixed, and in Sicily, it is *Salix pedicellata* and *S. gussonei*.

- Continental "soft-wooded" floodplain and tamarisk floodplain shrublands**.** In the eastern and south-eastern continental part of Europe, large-area stands of "soft-wooded" species consisting of *Salix alba* and poplars (*Populus nigra, P. alba*) occur along large rivers. The presence of shrubs *Eleagnus angustifolia, Salix acutifolia, S. viminalis, S. triandra* or *Calligonum aphyllum* is also typical. Floodplain shrublands in the region of the Danube-Pontic and Caspian steppes and deserts are mainly created by halophilous species *Tamarix ramosissima, Eleagnus angustifolia* and *Hippophae rhamnoides*, in the herb layer species of the genus *Artemisia*.

The position of natural communities of floodplain forests and shrublands in the phytocenological system

The only primary classification system of plant communities including the whole area of Europe is a phytocenological (Braun-Blanquet) system. All other existing all-European classifications are derived from it. Natural communities of floodplain forests and shrublands can be found there in five syntaxa:

Alnion incanae Pawlowski in Pawlowski, Sokolowski & Wallisch 1928 – floodplain forests of the nemoral zone ("hard-wooded" floodplains) and ash-alder forests of small watercourses, partly south-boreal Nordic floodplain forests.

Populetalia albae Br.-Bl. 1931 poplar/willow floodplains of the (sub)mediterranean region with *Platanus orientalis* and *Fraxinus angustifolia* s.l.

Salicetalia purpureae Moor 1958 temperate up to continental (Pontic-Caspian) "soft-wooded floodplains" and willow shrublands on frequently flooded sites with little-developed soils.

Nerio-Tamaricetea Br.-Bl. et O. de Bolós 1958 Mediterranean tamarisk and oleander shrublands along temporarily drying up rivers and streams in the Mediterranean region (*Tamarix gallica, T. africana, Nerium oleander, Vitex agnus-castus*).

Vaccinio-Piceetea Br.-Bl. in Br.-Bl., Sissingh et Vlieger 1939 floodplain forests with conifers and other boreal shrubs and herbs in the European zone of taiga.

Naturally, in particular countries of Europe, there are manifold specific national classification systems, mostly forestry ones, which are of course territorially limited being based on various standardization principles.

Principles of the classification of nemoral floodplain forests

These azonal forest communities are determined by the predominance of deciduous broadleaved species. They occur from the western coast of Europe (particularly France) with Atlantic climate (including British islands) and over Central Europe reaching to eastern markedly continental Europe up to the Urals. The northern limit of occurrence runs roughly to the 57°N from Denmark again to the Urals approximately to the Kama and Belaja rivers confluence, southern limits being the Pyrenees, the Alps with the Pad river lowland, the Danube with its tributaries. Between the Black Sea and the Caspian Sea, a boundary is formed by the Kura river floodplain between the Large and Small Caucasus.

Classification of floodplain forests arises from biogeographical principles mentioned above based above all on main differences in climate properties and chorological conditions. At a regional or topical scale, particular types are differentiated of floodplain forests on the basis of differences in the effect of leading ecological factors in floodplains.

These factors are as follows:

- The position of a floodplain within the longitudinal profile of a river (altitude, stream velocity and resulting sediment transport capacity or properties of floodplain sediments). Here, it is most important if it refers to a wide alluvial plain of the lower part of large watercourses or a narrow river or stream floodplain of central or upper parts of watercourses.
- The position of a site within the cross section of a floodplain (distance from the watercourse, superelevation, ie a position above the mean water level in the river), resulting hydrological regime of the site, ie particularly depth of the groundwater table and its fluctuation and further frequency, duration and height of the flood level. The rate of flow during floods and thus sediment properties are dependent on the distance from the watercourse.

On the basis of these criteria, the majority of classification systems distinguish "soft-wooded floodplain", "hard-wooded" floodplain and stream ash-alder forests.

The term "soft-wooded floodplain" is used for willow, poplar and willow-poplar floodplain communities often with an admixture of alder. The stands occur in depressions, near a river or right on young fluvial deposits being often and for a long time flooded. As compared with a "hard-wooded" floodplain, the tree layer is species-poorer (*Salix alba, Salix rubens,* *Populus nigra, P. alba, P.* x *canescens,* rarely *Alnus glutinosa, Salix fragilis* and *S. excelsa*) because it has to tolerate frequent, high and long-term floods. Their survival is made possible, e.g. by the formation of adventitious roots. The herb layer of short-age stands is composed mostly of non-forest species of moist up to marsh sites. Spring geophytes are little represented or are missing completely because in the period of their vegetation, the communities are mostly below the water level. The "soft-wooded floodplain" communities are initial stages of the primary succession on new ecotopes originated by fluvial processes. Woody species are very well adapted for these conditions and as r-strategists, they excel particularly in growth rate in the first years of their life. This property of poplars and willows is used in growing energy forests with a short-term rotation.

The term "hard-wooded" floodplain is used for communities occupying upper and central locations of wide alluvia in central and lower parts of large rivers which are periodically or episodically flooded. They are rich in long-lived species (particularly oak, ash and elm). The undergrowth synusia resembles that of mesophillous deciduous broadleaved forests. Shade-tolerating forest species of hygric up to wetland sites predominate. Therophytes are suppressed as compared with a "soft-wooded floodplain", however, there is a large number of geophytes particularly of vernal aspect. In the summer aspect, nitrophilous species show an important role. They occupy clay, loamy and sandy alluvial soils of various depth. The average groundwater table is more than 1-1.5 m below the soil surface. Nutrient-rich soils predominate. Many regions are used for a long time as gardens, to grow sugar beet, vegetable and other agricultural crops because the soils provide high yields.

Ash-alder communities of small river valleys including communities of *Alnus incana* and maple-ash communities are distinguished from floodplains of large rivers by the dominance of *Alnus glutinosa* and *Fraxinus excelsior* (in south with *Fraxinus angustifolia* s.l.) in the tree layer, in mountain regions an important role is played by *Acer pseudoplatanus, Ulmus glabra* and *Alnus incana.* Alpine-Central European submontane and montane communities of *Alnus incana* and maple-ash communities are rich in high montane herbs in places. A partial admixture of spruce (*Picea abies*) may be natural. Broadly distributed indicators of moisture are common – *Angelica sylvestris, Caltha palustris, Crepis paludosa, Deschampsia caespitosa, Filipendula ulmaria, Phalaris arundinacea, Carex brizoides*.

The following description of floodplain communities is based on the Czech school of geobiocoenological typology established by Zlatník (1956, 1960, 1976). The typology is based on the classification of potential forest and shrubland communities. The geobiocoenological classification system is built on superstructural units – vegetation zones, trophic and hydric series (Buček, Lacina 1999) the group of geobiocene types being a basic unit. It is based on the geobiocene type theory (Zlatník 1973, 1975). According to the theory, the geobiocene type is the set of a natural geobiocenosis and all other geobiocenoses and geobiocenoids derived from it and variously changed including developmental stages which can be replaced in the segment of certain permanent ecological conditions.

The description of geobiocoene types of forest communities is based on characteristics of Central European floodplain forests. Deviations are stressed resulting from biogeographical differences of various parts of the temperate zone of Europe the description being completed by corresponding syntaxa of the geobotanical classification system of plant communities.

Forest communities of flood and stream plains and their classification

Oberdorfer (1953) founded modern classification of floodplain forest communities of Europe in the geobotanical conception of Zurich-Montpellier school. The survey of European floodplain forests given by Oberdorfer (1953) informed well on their phytocoenological composition throughout the ecological and geographical extent from lowland floodplains up to foothill and mountain floodplains. Similarly Ellenberg (1988) dealt with the description of vegetation in the scale of Central Europe. He classifies forests and shrublands according to altitude to floodplains of alpine valleys, alpine foothills, lowlands and uplands and estuaries to the North Sea. Ellenberg's survey of floodplain forest communities is rather schematic but deals also in detail with their ecology. It is unambiguously based on the classification of vegetation in geobotanical conception. He extends it by detailed characteristics of ecological properties and the community development dynamics. Moravec et al. (1995) or recently Husová et al. (2000) and Neuhäuslová (2003) describe climax and developmental succession stages of floodplain woody communities of the Czech Republic in 3 classes, 4 orders, 6 alliances, 2 sub-alliances and 20 associations (including wetlands, which can occur also outside floodplains).

From the point of view of forest typological schools, Zlatník (1948) indicates the typification of floodplain forests first. Mezera (1956) gives in detail the analysis of vegetation of Bohemian and Moravian-Silesian floodplain forests in his monography. He starts from needs of forest practice creating his own classification system based on "degrees" of woody species distinguished especially in view of the creation of soil surface and properties. Within the "degrees of woody species" he distinguishes particular communities according to growth and the proportion of species and according to the composition of the undergrowth synusia. At present, the Institute of Forest Management Planning registers 66,902 ha forests in floodplains, which can be termed as floodplain forests (Macků 2003). From the point of view of typology it refers to the following forest type groups on edaphic categories enriched by water (L, U) or waterlogged (G, T):

1L *Ulmi - Quercetum alluviale*: 29,142 ha – flat alluvial plains and elevations

2L *Fraxini - Quercetum alluviale*: 4,311 ha – terraces of watercourses

1U *Querceto - Populetum vallidosum*: 1,298 ha – flooded alluvia along watercourses

3U *Acereto - Fraxinetum vallidosum*: 9,014 ha

1G *Saliceto – Alnetum*: 3,873 ha – boggy depressions and swamp pools

1T *Betuleto - Alnetum (paludosum)*: 1,180 ha – lowered flats on low bogs and aeolian sands

3L *Fraxineto - Alnetum alluviale*: 13,825 ha – waterlogged alluvia

5L *(Fraxineto) - Alnetum montanum*: 4,053 ha

6L *Alnetum incanae*: 206 ha

In the CR, alluvial plains, ie floodplains in lower parts of large watercourses occur particularly in three areas, namely in Bohemia, a region along the Labe and Ohře rivers (Polabí and Poohří), in Moravia, a region along the upper Morava and Odra rivers (Pomoraví and Poodří) and a region along the central and lower Morava and Dyje rivers (Pomoraví and Podyjí). Forest types of 1L, 1U and 1G, marginally also 2L, 3L and 1T groups occur there mostly.

Principles of the geobiocoenological typification of floodplain forests founded Zlatník (1959, 1976), who defined a geobiocoene type (Zlatník 1973, 1975) as the group of natural geobiocoenosis and all other geobiocoenoses derived from it and to a various extent changed geobiocoenoses (geobiocoenoids) including developmental stages. Before 1976, Zlatník

(1956 a+b, 1959) did not distinguish hydric series but within trophic series A-D, he specified two forest type groups affected by water, viz. "a" and "c". Thus, according to this conception, floodplain communities belonged to the group "c" and it referred to forest type groups, which were processed by Hančinský (1972) up to forest types. Horák (1961) developed in detail the typology of forest communities of a south-Moravian floodplain.

Buček and Lacina (1999) carried out the general revision of the system of Zlatník with the detailed description of units including floodplain geobiocoenes. They simplified the originally complicated system of units of series 4, 5a and 5b and made it more logical. They deleted units occurring only in Slovakia, cancelled some hypothetical unexemplified units or merged them with other units and, on the contrary, they defined some new units. The authors introduced also altitudinal zonation to lowland floodplains or moved the range of the wide floodplain geobiocoenes up to the 3rd vegetation zone. They revised hydric series and modified the extent of trophic series in some groups of geobiocoene types as well as characterized in detail all units of the system. Thus, they made the geobiocoenological system well utilizable in practice (e.g. Buček, Lacina 1998; Buček, Štykar 2001, 2002), particularly at the biogeographical differentiation of the landscape in the geobiocoenological conception (Buček, Lacina 1979, 1984). Zlatník's tabular survey of the geobiocoene type groups of originally forest and shrub communities in the CSSR was, virtually, considerably deductive being unexemplified by analytic material in a number of units, particularly as for floodplain forests.

A geobotanical classification system ranks among the most used systems during the survey of vegetation. Its advantage consists in geographical versatility, ie it is used and developed in a number of countries of the world. However, it is also associated with its important disadvantage, viz. it is very exacting for a user. Thanks to the vast number of authors of various syntaxa in various time intervals the system became rather confused. There is a large number of synonyms, modifications and invalid names. Units of the system have developed gradually and thus, the nomenclature of this classification system is even more complicated than botanical nomenclature. In various local or regional phytocoenological studies, authors use or create their own units and thus, their comparison is very difficult, particularly if primary data are not sufficiently published. There is considerable unbalance between two most used levels of the system, viz. "alliance" and "association". Alliance is mostly a very broadly defined unit whereas association is a unit often related to a local subject. Typification of communities based only on qualitative and quantitative properties of actual vegetation without reference to the ecotope character results (in case of forests) in the origin of very wide units going across several forest types, which are often termed as stand stages or stand types.

The typological systems of ÚHÚL (Institute for Forest Management Planning) as well as the geobiocoenological classification were originally developed for needs of forest management although the latter system extended its utilization in connection with the ÚSES (Territorial System of Landscape Ecological Stability) practice to the whole landscape in recent decades. It concerns systems with important related practical applications. The basis of both systems is a terrestrial forest ecosystem as a potential community at the given site. Thus, it differs from a geobotanical system where the basis of typification consists of the actual condition of vegetation and not only that of terrestrial forest communities. Both forest classification systems consider forest trees as edificators of ecosystems attaching great importance to them at typification taking into account not only abundance and dominance but also the storey pattern or growth parameters. On the other hand, the geobotanical system regards forest tree species as one of the community plant taxa.

All systems are connected by the phytocoenological method of the community description and data collection. Thus, on the basis of this procedure, it is possible to compare particular units of the systems. However, as for the geobotanical system, only units representing potential climax vegetation, vegetation of natural succession stages or vegetation of blocked succession stages are comparable. All other units describing substitute vegetation, vegetation to a certain extent conditioned by man or non-forest vegetation (e.g. aquatic) are incommensurable with the ÚHÚL system and with the geobiocoenological system.

Nevertheless, these facts do not decrease the importance of the typology of floodplain communities. The geobotanic classification (Moravec et al. 1994) serves as an important tool to record the variety of communities including actual communities making possible to get an idea on developmental series under various conditions in a floodplain. The geobiocoenological classification (Zlatník 1976, Buček, Lacina 1999) describes best potential forest communities enabling thus, on the landscape level, to evaluate anthropic effects on floodplain communities by the method of the biogeographic differentiation of the landscape (Buček, Lacina 1979). Forest typology of ÚHÚL (Anonymus) is a suitable tool for the differentiated planning and implementation of management measures depending on site properties.

All systems dealing with the classification of forest communities of floodplains are consistent on the level of the category of hard-wooded and soft-wooded floodplain forest (Mezera 1956). However, they diverge more or less at classification to smaller units.

Problems of the typology of floodplain forest communities

Typology of floodplain forest communities faces several basic problems.

A) The typological classification of floodplain forest communities is considerably complicated or made impossible by the absence of virgin forest stands. From the point of view of history, floodplains were under anthropic stress since the Neolithic (Nožička 1956; Opravil 1982; Wenger et al. 1990; Klimo, Hager 2000). Thus, in the Central European areas, natural segments of forests have not been preserved. Moreover, hard-wooded floodplain forest (in the present form of high forest) is the typical example of a man-made natural ecosystem (Maarel 1975), which originated by clear-felled regeneration in combination with alternate forest and farm crops. Even the present most preserved virgin forest reserves, such as Ranšpurk and Cahnov-Soutok, are not real virgin forests but originally grazing forests left several decades without any silvicultural measures. Forest typological units (Zlatník 1948, 1976; Mezera 1956; Horák 1961; Hančinský 1972; Buček, Lacina 1999; ÚHÚL – Macků 2003) or potential units in geobotanical conception (Oberdorfer 1953; Jurko 1958; Ellenberg 1988; Moravec et al. 1995, 2000; Husová et al. 2000, Neuhäuslová 2003, Chytrý et al. 2001, Neuhäuselová in Bohn et al. 2000/2003) cannot be sufficiently seriously supported by conclusive materials and more or less differ.

B) In addition, other problems occur. The expansion of invasive neophytic plant species is one of major problems, namely not only herbs (*Aster lanceolatus*, *Solidago gigantea*, *Solidago canadensis*, *Helianthus tuberosus*, *Impatiens glandulosa*, *Impatiens parviflora*, *Echynocystis lobata* etc.), which often predominate in the undergrowth synusia being able to suppress indigenous species, but also tree species. In floodplain forests of the CR, *Acer negundo* is nearly omnipresent, *Reynoutria* spp. are frequently dominant and also other species, such as *Juglans nigra*, *Fraxinus pensylvannica*, *Quercus rubra*, *Ailanthus glandulosa*, *Aesculus hippocastanum*, *Parthenocissus quinquefolia* etc. run wild at present.

C) The change in the hydrological regime of watercourses caused by their channelization is one of the most marked anthropic effects. The fall of the groundwater level and prevention of regular floods show a fundamental effect on the floodplain forest development. Indicative hydrochorous and hygrophilous plant species disappear from the undergrowth synusia and, on the contrary, wood species become dominant. Tree species of woods regenerate and, on the other hand, floodplain forest edificators, particularly pedunculate oak, are nearly excluded from natural regeneration. Area changes in the floodplain forest diversity occur; wet type floodplain communities gradually change to dry type communities. In Horní les near Lednice, we even found abundantly distributed species of thermophilic oak and oak-hornbeam forests (e.g. *Viola mirabilis*, *Vincetoxicum hirundinaria*, *Bromus benekenii*, *Melampyrum nemorosum*, *Galium odoratum*, *Melica nutans* etc.).

D) Thanks to the channelization of watercourses initial stages of floodplain forests, which are an important biotope for pioneer species such as willows and poplars, disappear. At present, black poplar (*Populus nigra*) occurs already in the list of endangered species of plants.

E) Because of Dutch elm disease, *Ulmus minor* disappeared nearly from the community of floodplain forests. The species was formerly one of the most frequent trees and also the abundance of *Ulmus laevis* markedly decreased.

F) Typological mapping can be problematic even in a close-to-nature floodplain because thanks to a meandering river and floods conditions of an ecotope can rapidly change in the floodplain. For example, in Croatia in the Danube floodplain, 103 ha new biotopes originated at the only meander in the course of 40 years. On the other hand, 34 ha territory has been carried away. In total, 14.5 million m^3 soil was eroded, ie 360,000 m^3 per year (Vukelić, Pernar & Vratarić 2005).

The floodplain forest typology cannot be considered to be a static matter. Thanks to the watercourse kinetic energy the floodplain forest ecosystem is very dynamic. The theory of dynamic fluvial succession series of floodplain biotopes describes very well processes in the floodplain landscape. Particular types of a floodplain forest concur within fluvial succession thus mowing towards the driest type, viz. hornbeam/elm ash forest. Fluvial processes - frequent floods, moving watercourses and the permanent alluvia guarantee (in natural floodplain unaffected by man) permanent occurrence of the initial succession stages of moist types of communities. In a floodplain affected by man, with straight and dyked streams and with lowered water level the diversity of floodplain communities decreases because the communities gradually occur on the most of area in the final driest stage of fluvial succession. This fact was partly predicted by Mezera (1956) and Horák (1964) described in detail a hypothesis dealing with the gradual change of geobiocoene type groups depending on the anthropicly affected main ecological factors of floodplain communities, ie groundwater depth and floods. In recent decades, more than 20 years after the completion of the Morava and Dyje rivers channelization, a number of authors support this hypothesis (Štykar 1994; Vrška 1997, 1998; Bagár, Klimánek 1999; Viewegh 2002, Maděra 2001) and evidence is brought also from other areas (Pišút et al. 1996). Thus, a theory of the dynamic fluvial succession series of floodplain biotopes appears to be a very suitable framework to study the dynamics of natural and anthropic effects on the development of floodplain forests.

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MOISTURE CONDITIONS AND HYDROLOGICAL REGIME OF FLOODPLAIN FORESTS IN THE TERRITORY OF SOUTHERN MORAVIA

Pavel Hadaš, Tomáš Litschmann

Abstract

The ecosystem of floodplain forests in the alluvial plain of lower reaches of the Morava and Dyje rivers belongs to the most singular natural creations of the riverine landscape. Its significance is supraregional to such an extent that the locality “Floodplain of the lower Dyje River” was incorporated in the newly conceived trilateral Czech-Slovak-Austrian Ramsar site “Floodplains of Morava-Dyje-Danube Confluence”. Starting with 2003, the territory comprising the floodplain forests in the alluvial plain of the Morava and Dyje rivers has been part of the Lower Morava Biosphere Reserve. In the past century, the riverine landscape of the alluvial forests underwent extensive hydrological measures. In this period, local measures and forest ameliorations were replaced by a complex hydrological regulation which was reflected in the ecological stability of the floodplain forests, water regime of the alluvial plain and thus in the moisture regime of the soils. The last decade is contrarily marked with an effort aimed at regenerating natural dynamics of the water regime in the alluvial plain within the framework of revitalization measures. The paper documents which hydrological and climatic factors affect the general moisture regime of the floodplain ecosystem soils on the basis of performed measurements.

Key words

groundwater table, soil moisture, water regime, moisture conditions, floodplain forest ecosystem of the Morava and Dyje rivers

INTRODUCTION

Water regime represents a natural and vital ecological factor of the alluvial forests ecosystem in the lower reaches of the Dyje and Morava rivers. Another ecological factor – soil moisture regime – depends on the water regime. In the 1980s, the water regime in the floodplain of the Dyje R. changed substantially following the accomplishment of hydrotechnical regulations by the completion of the third reservoir Nové Mlýny (Mráz 1979; Prax 1991, 1991a). The water regime in these parts of the floodplain is dependent on the regulated discharge flow and inundation in the reservoirs of the hydroengineering work Nové Mlýny. Channelization of the stream in the Morava R. floodplain caused the acceleration of the water runoff. Technocrats maintain a positive opinion with respect to these measures because they claim that they provide space for valuable fluvial and alluvial ecosystems as well as for the people who live in the river floodplain. Flood protection has partially increased and natural inundations were liquidated on the one hand, but on the other hand the groundwater table was decreased, the dynamics of regular groundwater table fluctuation in the course of the year was reduced and the river system became isolated from its meander branches. As far as the ecological stability of the alluvial forests ecosystem is concerned, the implemented measures are perceived negatively. Between 1995 and 2000, a vast programme of river network revitalization was undertaken in the floodplains of the lower reaches of Dyje and Morava rivers to prevent future negative influencing of the floodplain forest moisture regime tied with the drying of the forest stands.

Present soil moisture regime in the alluvial plains of the Dyje and Morava rivers is further affected by local revitalization of the water regime. Revitalization measures accomplished in 2000 were based on the water regime condition resulting from hydrotechnical regulations carried out in the past and in fact contributed to the improvement and helped stabilize the condition of the water regime in the Dyje R. floodplain downstream from Nové Mlýny and the floodplain upstream from the confluence of the Dyje and Morava rivers. The revitalization measures consisted in the regeneration of the lengthwise and transverse connections of the original channels and old branches of the Dyje and Morava rivers and in the adjustment of the sluice gate structures of the backbone streams of the Dyje and Morava rivers (Vašíček 2000). The accepted solutions to the water regime focused chiefly on the determination of the course of the surface discharge levels and completely neglected their essential dynamics. Present local revitalization measures are to a great degree tied to the static and artificially heightened groundwater level and to some extent curb the possibilities of renewing the dynamics of the discharge regime. System of measuring selected abiotic parameters directly or indirectly representing the water regime and alluvial forest humidity conditions was set up to monitor effects of the revitalization measures on the water regime and floodplain forests moisture conditions.

MONITORING OF PARAMETERS OF THE WATER REGIME AND MOISTURE CONDITIONS

Moisture regime in the floodplain forests of southern Moravia has been monitored by the workplace of the Department of Forest Ecology at the Faculty of Forestry and Wood Technology (LDF) of Mendel University of Agriculture and Forestry in Brno (MZLU) since 1969. Towards the end of 1994, a network of five automatic stations was constructed in selected localities of floodplain forests of the Dyje and Morava rivers alluvial plain thanks to the collaboration of the Pálava PLA Administration, Forests of the Czech Republic, s.e. (LČR, s.p.), Židlochovice Forest enterprise and the Department of Forest Ecology at the LDF of MZLU in Brno. On January 1st, 1995, regular measurements of groundwater table (hereinafter “HPV”), soil moisture at the level of 30 and 60 cm (hereinafter “OVP”), soil temperatures at the level of 5 cm (hereinafter “TP”) and total precipitation (hereinafter “SRA”) were commenced in the Křivé jezero Lake, Herdy, Prameniště, Ranšpurk and Soutok localities. In mid 1998, the measurements were expanded to involve further parameters – temperature and relative humidity (hereinafter “T” and “RH”) and soil surface temperature. In mid 2002, the measuring network was extended by measurements of soil moisture at 10 and 60 cm, temperatures and relative air humidity, soil surface temperatures, atmospheric precipitation in a specifically extreme site of a floodplain forest – in a forest clearing in the Pohansko and Herdy localities. The location of the stations is shown on Fig. 1.

HPV measurements are executed in a drill hole fitted with a steel casing tube by a manometric sensor (it measures the pressure elicited by the weight of a water column above the sensor positioned in the lowest part of the drill hole). Maintenance of the station, data collection and control of the groundwater table by manual measurement by means of a Rang's pipe are performed every four weeks. OVP is measured in hourly intervals by VIRRIB volumetric moisture sensors positioned horizontally. Monitoring of the water regime and soil moisture conditions follows after the stand microclimate monitoring of T and RH (sensors are 150 cm above the soil surface), TP and SRA in the same time intervals. Meteorological sensors are connected to the HOBO recorder (produced by Onset Computer, USA). Other measurements of discharges taken from stream gauge stations Dyje-Ladná, Morava-Strážnice (Czech Hydrometeorological Institute – ČHMÚ) and Morava-Moravský Ján (Slovak Hydrometeorological Institute – SHMÚ) can be also used to evaluate the water regime.

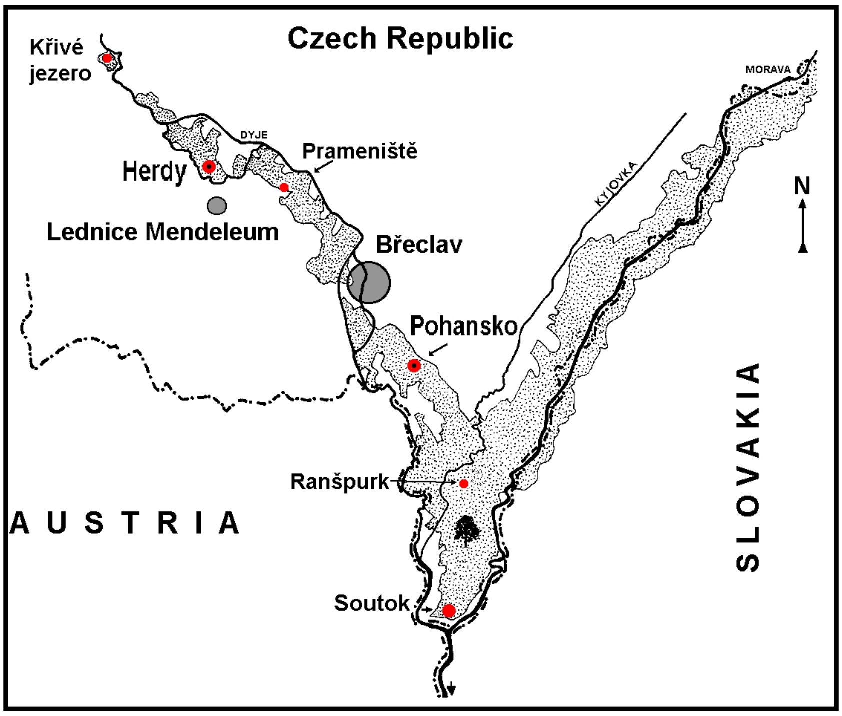

Fig. 1: Distribution of stations measuring parameters of the water regime and moisture conditions in the floodplain forests ecosystem in the lower reaches of the Morava and Dyje rivers

WATER REGIME

Earlier surveys (Hadaš, Prax 1999) arrived at a conclusion that the water regime of the floodplain forests of the Morava and Dyje rivers, represented by the HPV dynamics, is significantly affected by the discharge regime of the backbone streams of Morava and Dyje in the spring periods. The analysis of the dependence between the discharge regime and the HPV level in the Soutok locality determined that the HPV dynamics in the spring period is affected by the upswell of surface water in the Morava R. watercourse from 78-82 %. In the course of such an upswell, hydraulic continuity between the surface water level in the recipient and the HPV is established. It was statistically verified that when discharge flows in the streams reach higher values, the riparian infiltration surface through which the groundwater becomes replenished increases. With the onset of low discharge periods however the hydraulic continuity becomes interrupted due to colmatage of the recipient's bottom and thus also the replenishment of groundwater becomes considerably reduced (Hadaš, Prax 1999). The analysis of the dependence between the Morava R. discharge and the HPV also specifies that when discharge flows ranging between 300-350 m^3s^{-1} are reached (this discharge is equivalent to the second degree of flood alert), groundwater starts flooding the terrain in depressions.

Due to a relatively flat character of the floodplains of the Morava and Dyje rivers evaluation of the moisture regime of a specific location must take into account influence of the elevation gradients of the microrelief (fluctuating in decimetres) and the level of the upper layer of subsoil gravels lying under layers of flood loam of heavier texture (Hadaš, Prax 2001). If the HPV decreases below the bottom level of the layer of flood loams of heavier texture, the capillary water mobility towards the upper soil horizons becomes reduced. This means that in the summer period the OVP decreases in the heavier flood loam layers due to intense evapotranspiration of the floodplain forest ecosystem and also because of the interruption of replenishment of water by means of capillarity from the water-bearing layer of subsoil gravels. Vertical level of the upper layer of subsoil gravels is considered as the co called HPV "critical level" and can serve as a factor for assessing the water regime and its impact on moisture conditions of the soils. The level of the upper subsoil gravels layer in the Soutok locality starts in the depth of 120 cm, in the Ranšpurk locality in the depth of 160 cm, in the Herdy locality it starts at 110 cm below the surface of the local terrain (Prax 1991), in the locality Prameniště the upper subsoil gravel layers lie in the depth of approximately 130 cm. We can therefore apply the level of HPV, one of the measured parameters of the moisture regime, as a decisive factor of the water regime and thus also the ecological stability of the floodplain forests ecosystem. The determined data regarding the HPV can be used for the evaluation of ecological stability in a floodplain forest or for the assessment of the soil moisture regime, soil water balance and soil water supply.

DEVELOPMENT OF THE GROUNDWATER TABLE

Detailed measurement of the HPV level has been under way in the alluvial plain of the Morava and Dyje rivers for already 12 years. In the course of this period extreme conditions elicited by flood discharges in the backbone watercourses of the Morava and Dyje rivers as well as by the occurrence of a prolonged period of dry hot climate have been registered in the HPV development. During the summer floods of 1997, the stations Křivé jezero Lake and Soutok were damaged. The spring flood of 2006 exceeded all hitherto experiences and assumptions concerning the possible water level height and the measuring systems in the localities Křivé jezero Lake, Herdy and Soutok were inundated and damaged. Solely the stations Prameniště and Ranšpurk "resisted" the floods and the acquired time series of the average daily and monthly values of HPV levels can be applied for characterizing the water regime development in the floodplain of the Dyje and Morava rivers.

FLOODPLAIN OF THE DYJE R.

Fig. 2 shows the course of average daily HPV values below the terrain surface in the Prameniště station typical for the water regime in the territory of Dolní les Forest of the Dyje R. floodplain. The influence of a regulated discharge regime in the Dyje R. and performed controlled floodings (since 1999) are reflected in the HPV dynamics. It follows from the correlation analysis of the discharge flows and HPV development shown in Fig. 3 and the HPV that the HPV height can be explained according to the determinant value (D=0.1459) by the development of discharges in approximately 14.6 % of the cases. In the years 1995-1997 and in 2005, the course of the annual HPV dynamics was almost regular; i.e. at the beginning of the growing season it went up to the maximum and towards the end of it and in the autumn it reached the minimum levels. Between 1998 and 1999, impact of the collecting works of the Lednice water conduit which are situated approximately 500 m from the locality probably also reflects in the HPV dynamics.

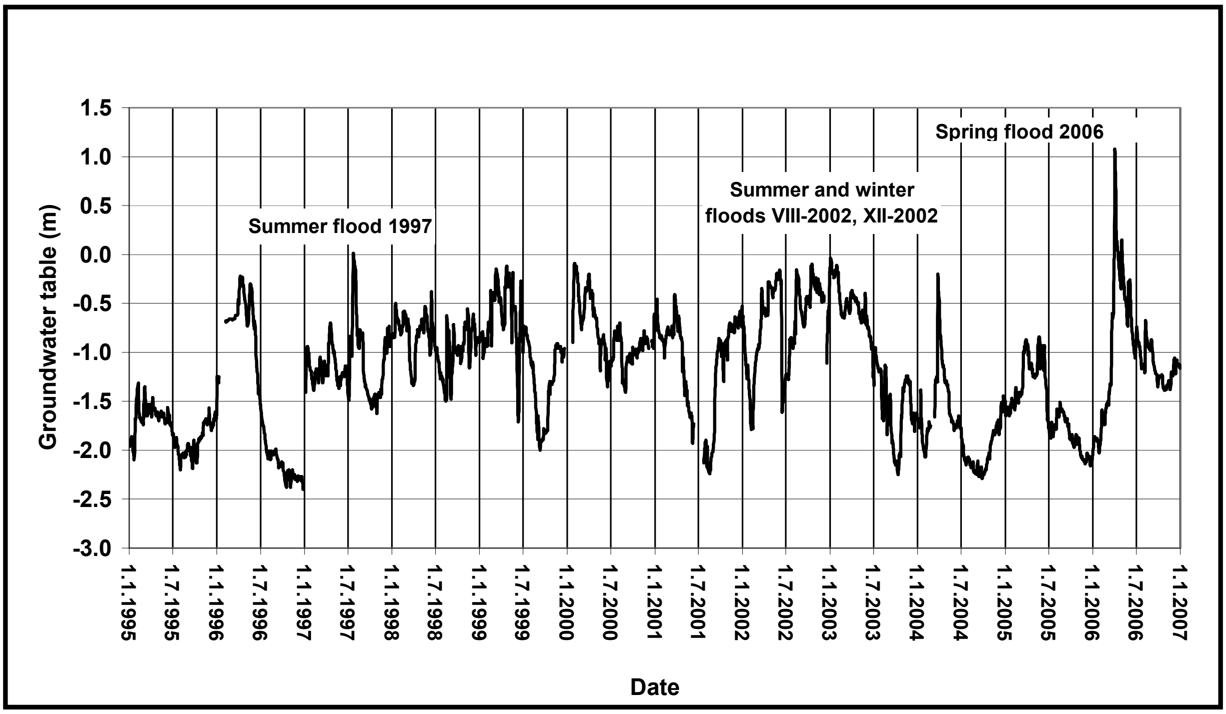

Fig 2: Development of daily averages of the groundwater table level between 1995 and 2006 in the monitoring site of the locality Dolní les Forest in the Dyje R. floodplain. The groundwater table level is expressed by the depth of the water surface below the terrain.

The lowest values of HPV, reaching the depth of up to 2.4 m below the surface, were determined in the drier period of the year (from the end of summer until the start of winter). Maximum levels of the HPV (apart from overflowings) of 20 to 40 cm below the surface occur at the beginning of the growing season. In the period of flood water overflowing into the inundations the level of HPV can stay at 1.0 m above the surface for a number of days (spring flood of 2006). At the time of the first measurement (1995), the HPV level showed the lowest values at the onset of the growing season (–1.65 m and lower). The upper layer of subsoil gravels becomes gradually saturated due to higher discharges which are the result of the growth of precipitation amounts in the upper reach of the Dyje R. catchment area and artificial flooding (within the framework of revitalization). This process was taking place between 1996 and 1999. In the years from 2000 to 2004, the optimum HPV level dynamics could be maintained only by means of artificial flooding. Due to the arrivals of dry hot summers, e.g. in 2003 and 2004, along with fall of precipitation in a part of the Dyje R. catchment area, the HPV level rapidly decreased to the depth of –2.0 m below the surface. The exception is the year 2002 in which the April to May HPV level was first affected by artificial flooding and subsequently by the August flood situation in the Dyje R. catchment. At the turn of the years 2002/2003, there was another flood in the Dyje catchment area causing significant increase in the HPV level which then almost reached the surface (even less than 10 cm). In 2003, the HPV dynamics was characterized by a falling trend of HPV level caused by extreme draught which started in the winter period, continued through the summer and ended with the onset of winter. It follows out from the statistical evaluation of the HPV dynamics that more than 36 % of the HPV values are below the so called critical level of HPV of –1.30 m.

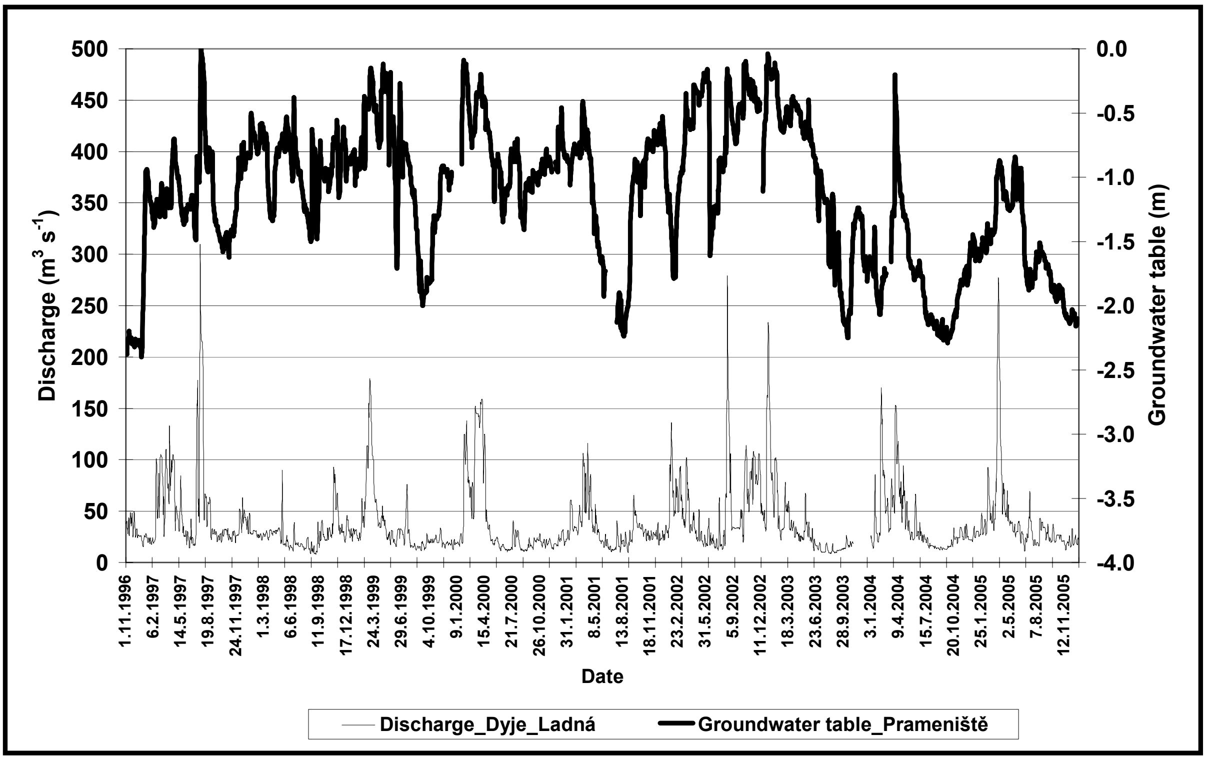

Fig. 3: Development of daily discharges in the hydrological profile Dyje_Ladná and the groundwater table (HPV) levels in the locality Prameniště in the period of November 1, 1996 – November 30, 2005. The data were taken from the Hydrological yearbooks published by the ČHMÚ Prague between 1997 and 2006

ALLUVIAL PLAIN OF THE MORAVA R. BEFORE THE CONFLUENCE WITH THE DYJE R.

Fig. 4 shows the development of average daily HPV values below the terrain level at the Ranšpurk station standing for the water regime in the region of the Soutok forest district. Development of HPV in this locality significantly differs from the development in the Dyje R. floodplain. A different method of hydrotechnical regulations performed in the Morava R. (discharge regime is closer to the natural state) and reciprocal mixing of the discharge regimes of the Morava and Dyje rivers entering the confluence floodplain is reflected in the HPV development in the Ranšpurk locality. The water regime is also affected by artificial flooding which has been taking place in this locality since 1996. The correlation analysis of HPV and discharge development which is shown in Fig. 5 document that the HPV level can be explained according to the determinant value (D=0,139) by discharge development only in about 14 % of cases. The lowest HPV level values, reaching the depth of 2.7 m below the surface (2003), occur in the drier period of the year (from the start of summer until the onset of winter). Maximum HPV level values (apart from the overflowings) at the level of 20 to 60 cm below the surface occur at the beginning of the growing season.

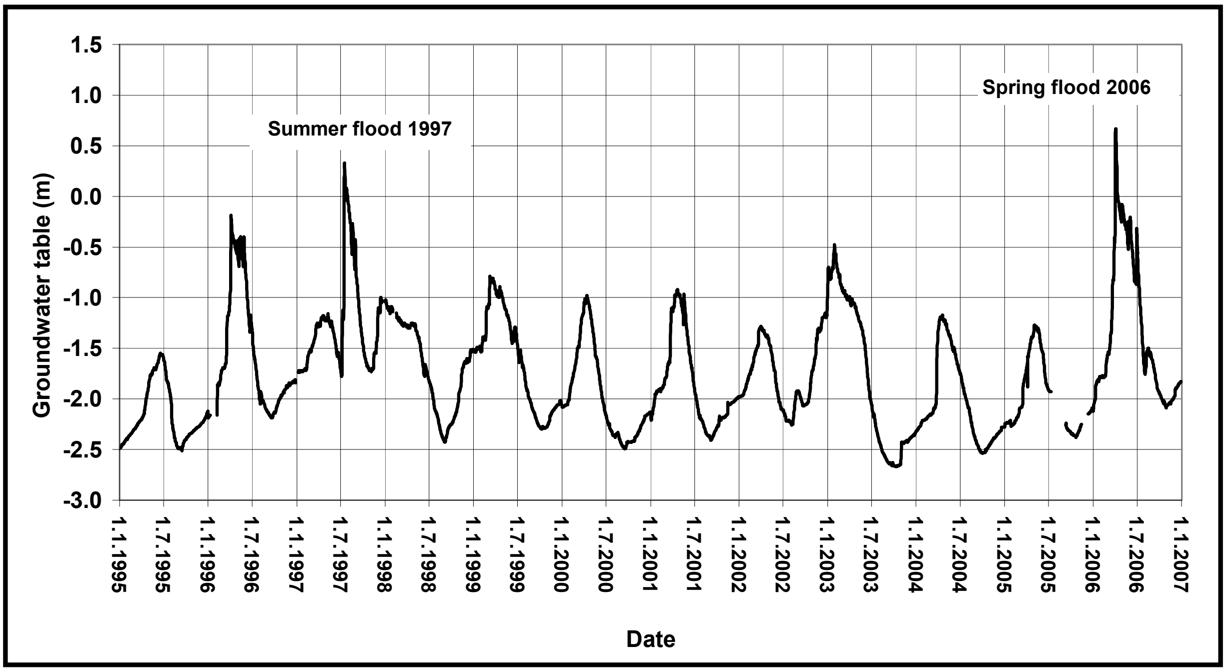

Fig 4: Development of daily averages of the groundwater table level between 1995-2006 in the monitoring site Ranšpurk in the locality of the forest district Soutok in the confluence floodplain of the Morava and Dyje rivers. The groundwater table level is expressed by the depth of the water level below the terrain

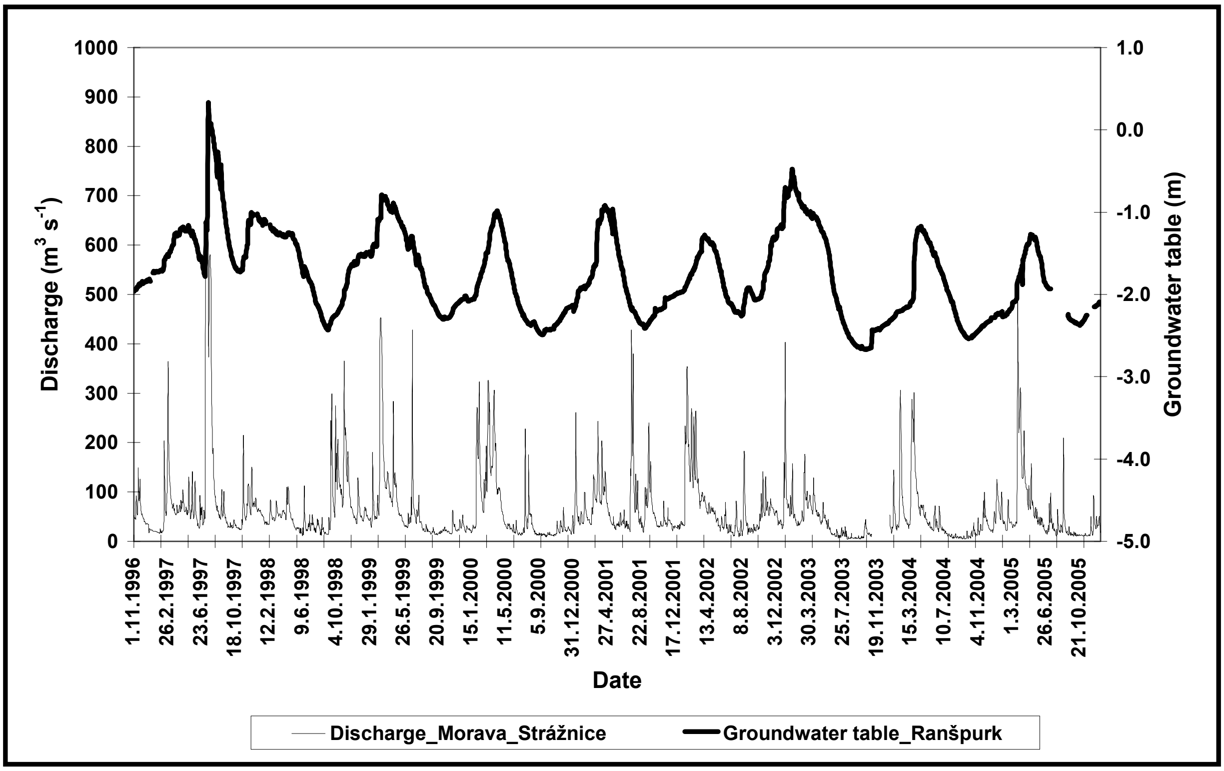

Fig. 5: Development of daily discharges in the hydrological profile Morava-Strážnice and groundwater table levels (HPV) in the locality Ranšpurk in the period between November 1, 1996 – November 30, 2005. The data were taken from the Hydrological yearbooks of the CR published by the ČHMÚ Prague between years 1997 and 2006

It is obvious that the HPV dynamics reflects the time variance between the discharge regimes of the Morava and Dyje rivers. The representativeness of the Morava-Strážnice hydrological profile's discharge regime must be assessed with certain cautiousness due to its location approx. 30 km upstream the Morava R. It was further determined that in the course of flood situations in the section of hydrological profiles Morava-Strážnice and Morava-Moravský Ján, variations in the direction of the water flow occur accompanied by remarkable water losses. These runoffs are caused by subsoil infiltration into water-bearing gravel layers as well as by the phenomenon of partial runoff of water at the confluence of the Morava and Dyje rivers upstream the Dyje R. watercourse which occurs during higher discharge in the Morava R. This happened for example during the disastrous flood in July 1997 (from July 6 to July 20) when the town of Břeclav was threatened by flood water from the Morava R. the discharge of which culminated at 1,000 m^3s^{-1}. The discharge in the outlet object of the lower reservoir of the hydraulic structure Nové Mlýny had to be increased to 280 m^3s^-1 in order to avert the flood threat to Břeclav which lies upstream the Dyje R. In Fig. 6 the water losses are expressed by negative values of the average daily discharge within the framework of a discharge balance which can reach the amount of up to 378 m^3s^{-1}. After the decrease of discharges in the Morava R., the water in the Dyje R. is coming back and the discharge balance reaches positive values of 166 m^3s^{-1}. The discharge balance was elaborated on the basis of the variance between average daily discharges in the Morava – Moravský Ján, Dyje – Ladná and Morava – Strážnice hydrological profiles for the period of November 1, 1996 – October 1, 1999.

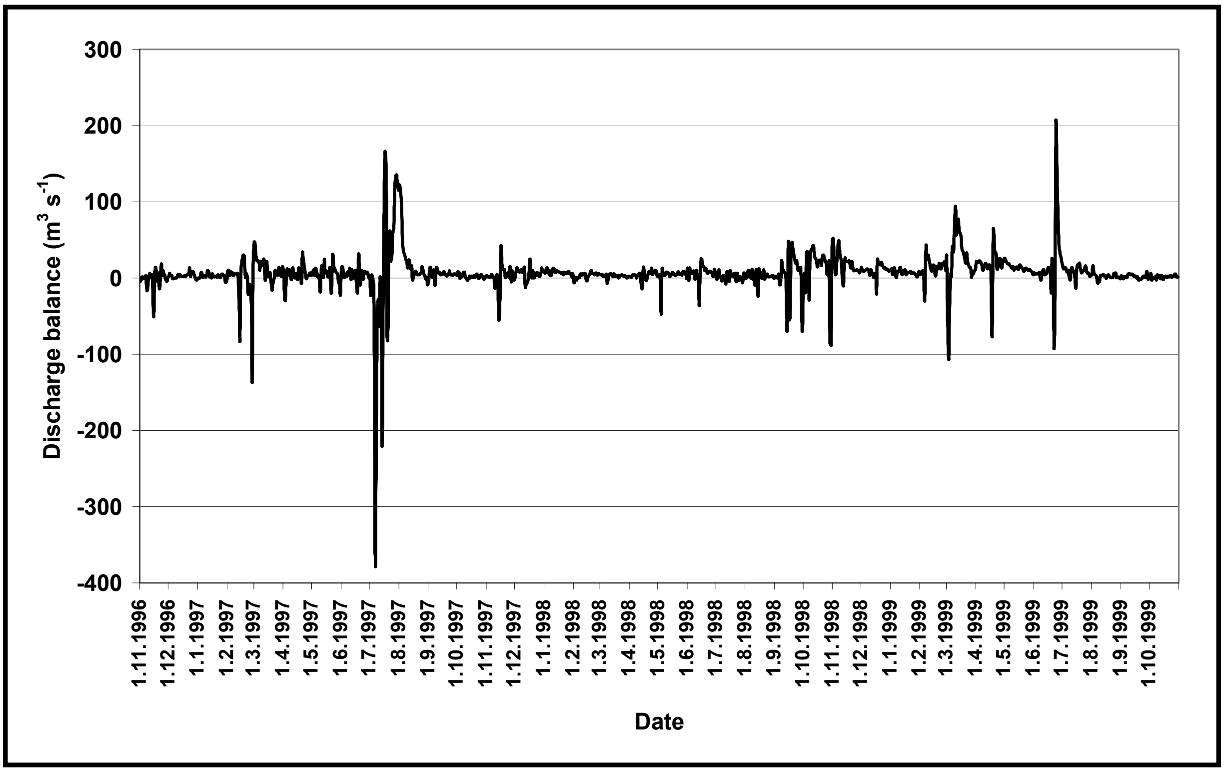

Fig. 6: Balance of average daily discharges (m^3s^{-1}) of a section of the Morava R. passing through a floodplain forest in the forest district Soutok for the period of November 1, 1996 – October 11, 1999 (the stretch between the hydrological profile Morava-Strážnice and Morava-Moravský Ján). The data were taken from the SHMÚ Bratislava and from Hydrological yearbooks of the CR (ČHMÚ Prague)

A characteristic feature of HPV of the confluence floodplain locality is the preservation of typical HPV dynamics. This means that the maximum level of HPV is time dependent on the beginning of the growing season and that the minimum level occurs in the autumn. This feature of the HPV dynamics was being attained also at the beginning of the measurements in 1995. However, conditions of moisture stress (for the longer part of the growing season, the HPV level is below the level of –1.60 m) form in the alluvial plain ecosystem due to HPV "critical level." Owing to increased discharges as a result of gradual increase in precipitation amounts in the upper reach of the Morava R. basin and partly also due to managed artificial flooding the HPV level is progressively rising to the lower horizons of flood loams of heavier texture. HPV level between the years 1996 and 1997 was quickly rising not only in the spring period but the the growing tendency could be observed also in the course of the whole year. The reason for this was the predominantly increasing total precipitation in the upper reach of the Morava R. basin which first provoked local floods in the Bruntál Region and then, in July 1997, disastrous floods in the entire Morava R. catchment area. The July 1997 flood in the locality Ranšpurk culminated in the overflowing of water at the height of 33 cm above the terrain. Between 1998-2002, the HPV level dynamics in the spring period became stabilized around the levels of –0.50 to –1.00 m; in the summer, the HPV level dropped to the level of –2.20 to –2.50 m below the terrain. The year 2003 presents a certain exception because the Morava R. first showed a more distinct discharge growth from the melting snow in the upper reach of the river's catchment area. In a dry and extremely hot climate during the summer, the favourable HPV level (over –1.60 m) could be maintained by means of artificial flooding only until June. In August and September, the HPV level rapidly fell down to the absolute minimum levels of –2.70 m. In 2004 and 2005, the HPV level dynamics started improving slightly thanks to the growing spring discharges from the thawing snow pack. This process culminated in the second largest flood registered in the period of 1995-2006 in the Morava R. basin. The spring flood of 2006 reached its peak in the locality Ranšpurk at the turn of March and April by flood water overflowing with the highest level of water above the terrain of 67 cm. The statistical analysis of the HPV dynamics shows that 59 % of the HPV values are below the HPV critical level of –1.60 m. Substantial part of these low HPV values nevertheless falls into the autumn period.

MOISTURE REGIME

OVP dynamics at the level of 60 cm in the Prameniště and Ranšpurk localities for the period of 1995-2006 is shown in Fig. 7. The Figure documents that the OVP development in each of the two surveyed localities varies. The Ranšpurk locality shows substantially lower values of OVP at the level of 60 cm than the Prameniště locality. In the majority of cases the difference amounts to 5 to 10 volumetric % and in some period it even exceeds 20 volumetric %. Only in a small number of cases is the OVP value higher in the locality Ranšpurk than in Prameniště. It is apparent that with respect to moisture conditions the locality Ranšpurk ranks among drier sites. The reason for lower OVP values is the fact that locality Ranšpurk is situated on a slightly elevated Holý hrúd site at altitudes ranging from 152.5 to 153.5 m a.s.l. The Holý hrúd microrelief is constituted by an approximately 0.5 m thicker layer of flood loams of heavier texture which cover the upper water-bearing layer of subsoil gravels.

Fig. 7 shows that the highest OVP values (absolute maximums of 50 volumetric %) occur at the beginning of spring and in the first months of the growing season. With the advance of summer, the OVP values are marked with a gradual fall to the absolute minimums of about 25-24 volumetric % (Ranšpurk) or 32-35 volumetric % (Prameniště). The values are highest in the autumn. In the winter period, moisture regime "regenerates." We can see that in the

Ranšpurk locality the absolute maximums of 50 volumetric % occur only in the period of flood water overflowings into the forest, e.g. in July 1997 or in April 2006.

The acquired data regarding the stand microclimate and the level of groundwater table serve the evaluation of moisture conditions and soil water supply in the floodplain forests ecosystem. Floodplain forest vegetation covers a big majority of its water consumption from groundwater sources. It is clear that local conditions for evaporation and specific site differences in humidity balance become reflected in the moisture regime. Localities with a logged-over stand can be classified as one of the specific site conditions. The process of replacing the logged-over stand by a new generation is accompanied by specific ecological and site conditions of the stand environment. Subsequent stand grows up in a free space (clear-cut area) without any ecological protection of the parent stand at full light treat and the maintenance of the tree species is limited and threatened by extremes of the stand microclimate which affect chiefly the moisture conditions.

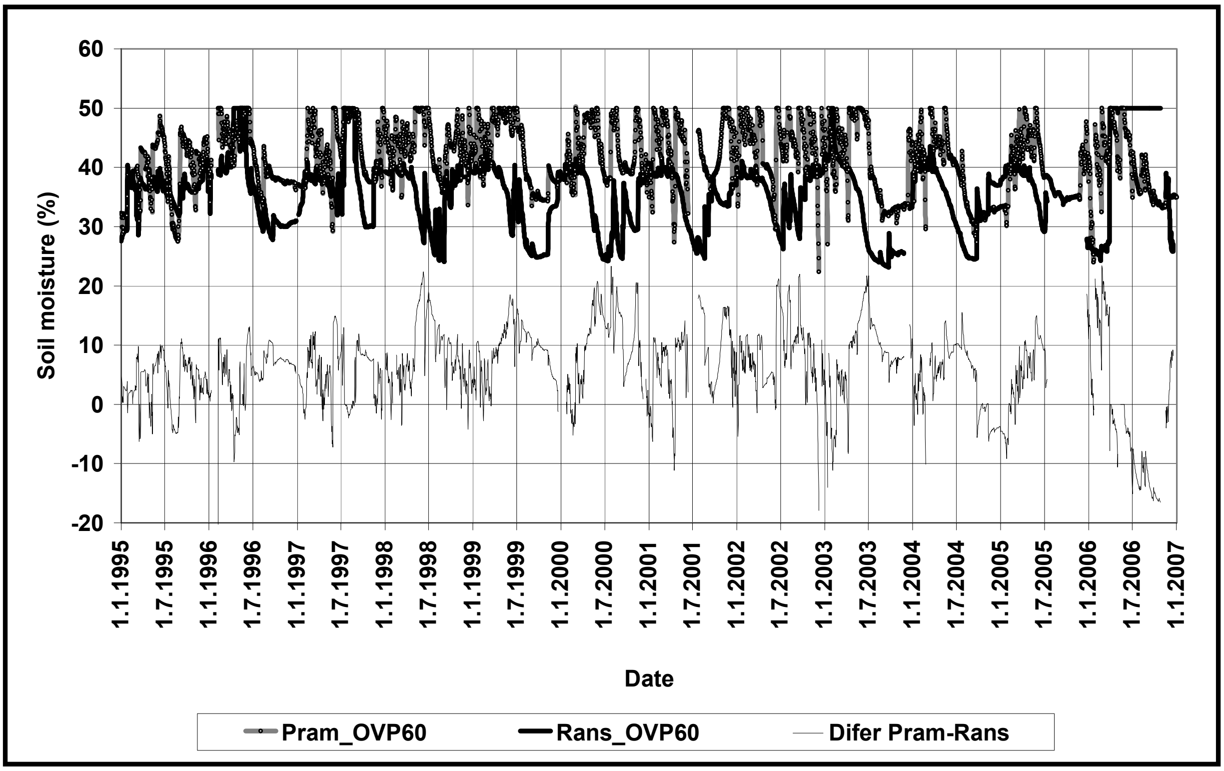

Fig. 7: Dynamics of soil moisture at the level of 60 cm in the localities Prameniště and Ranšpurk for the period of 1995-2006 in the territory of alluvial forests of southern Moravia. The graph illustrates the difference in OVP values between the surveyed localities

Fig. 8 shows the development of soil moisture measured in a forest clearing 10 cm deep (hereinafter as OVP10) and the development of moisture balance in the locality of Herdy. It well follows out from the figure that daily OVP10 average very well responds to the development of moisture balance of the soil surface. OVP10 responds to negative or positive balances by a decrease or increase. During the transition of moisture balance into the most severe precipitation deficit (-76.2 mm as of September 22, 2004), the OVP in the depth of 10 cm responds by the lowest soil moisture of 22 volumetric %. The development of soil moisture in the forest clearing in the depth of 10 cm demonstrates that the soil moisture in this situation came close to the point of wilting. We considered the point of wilting to have the value of 21.12 volumetric % (Hadaš, Litschmann, Hybler 2006). If the soil moisture falls below the point of wilting, we can presume that vegetation the root system of which draws the moisture mainly from the depth of 10 cm (e.g. during the initial period of stand regeneration) can be weakened or irreversibly damaged due to draught.

The proportion of abiotic factors influencing the moisture conditions at 10 and 60 cm can be determined on the basis of a regression and correlation analysis (Hadaš 2004). Results of the analysis are specified in Tab. 1. The table shows that moisture conditions in the forest clearing represented by soil moisture in the depth of 10 cm in the Herdy locality are affected by the level of groundwater table from nearly 32 %, almost 21 % is attributed to relative humidity, 17.5 % to precipitation amounts and more than 28 % to potential evapotranspiration (according to Turc). Moisture conditions of the forest clearing represented by soil moisture at 60 cm are affected by the groundwater table level from nearly 81 %, more than 4 % is attributed to relative humidity, 0.5 % to precipitation amounts and more than 13 % to potential evapotranspiration.

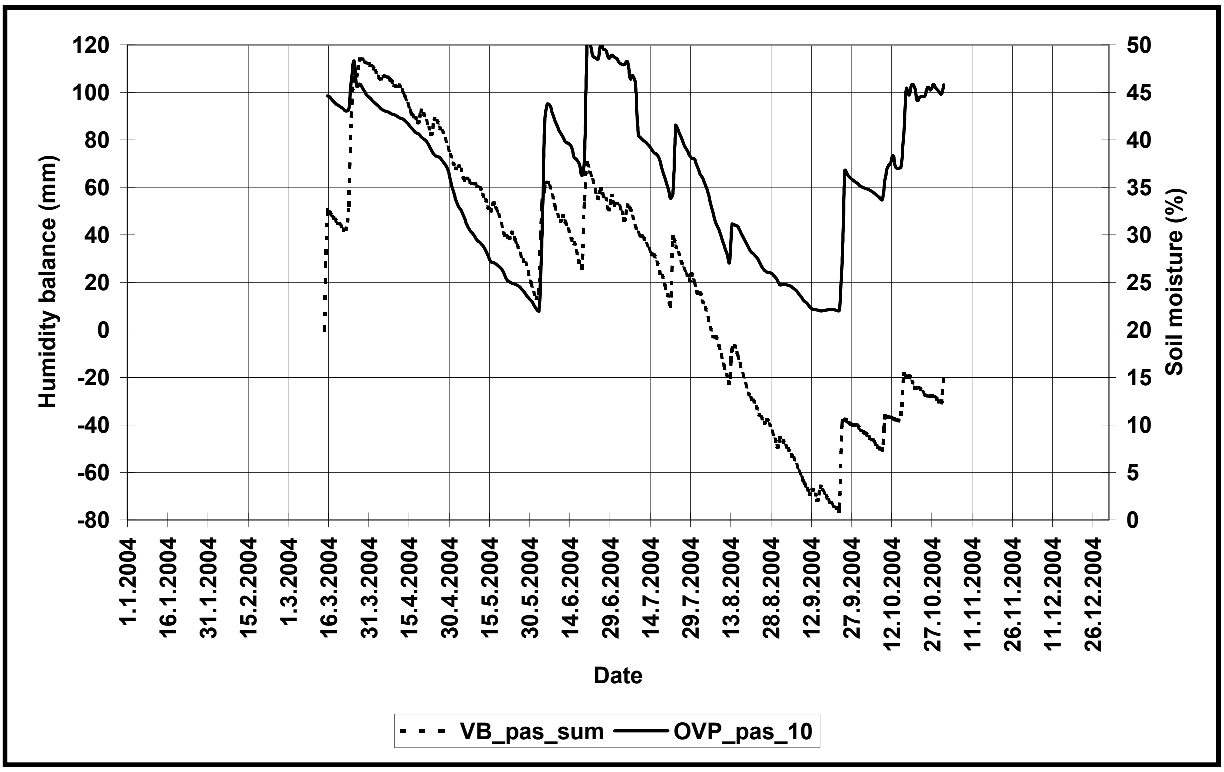

Fig. 8: Development of soil moisture measured in the forest clearing at 10 cm (OVP_pas_10) and the development of humidity balance (VB_pas_sum) in the locality of Herdy in the period between March 15 – October 31, 2004. Humidity balance is expressed as a continually summed up daily value of humidity balance

These results are consistent with an earlier finding that moisture regime of floodplain soils in forest stand site characterized by soil moisture at 30 cm is on average affected by the development of groundwater table level from 53 % in the growing season, 6 % is attributed to the temperature regime of the atmosphere and 0.9 % to local daily total precipitation amounts. Floodplain soils moisture regime of a forest stand site characterized by soil moisture at 60 cm is on average affected by the groundwater table level from 45 % in the growing season, 6.3 % is attributed to the temperature regime of the atmosphere and 1.3 % to local daily precipitation amounts (Hadaš, Prax 2001). The monitored moisture levels still involve a proportion of roughly 40-47 % which can be attributed to the influence of transpiration from the vegetation stand (of tree species and herbs) and of evaporation from the soil surface. We presume that the root system of the stands draws on water from the layer 30 to 60 cm deep. In situations when the groundwater table is deep enough, the capillary afflux can no longer cover the needs of trees and moisture of the soil decreases also in deeper situated layers.

Table 1: Proportion of selected parameters of abiotic environment affecting moisture conditions of the forest clearing represented by OVP at 10 and 60 cm in the Herdy locality in 2003.

Environmental parameters	OVP10 %	OVP60 %
HPV	31.92	80.78
RH	20.78	4.18
SRA	17.54	0.58
PET (according to Turc)	28.31	13.09
Other	1.45	1.36

CONCLUSION

When evaluating the water regime development and moisture conditions of floodplain forests in southern Moravia, it is necessary to take into account the discharge regime which brings water from the surrounding more elevated areas of the backbone stream basins into the system apart from the groundwater table level and soil moisture. Their regime and quantity of water are affected by a series of natural (climatic, hydrogeological) factors as well as by manipulation at the hydraulic structure Nové Mlýny or local hydrotechnical equipment installed directly in the forest.

It was determined that if the HPV level decreases below the bottom level of the layer of flood loam of heavier texture, the mobility of capillary water towards the upper soil horizons becomes reduced as well. This means that OVP diminishes in the layers of heavier flood loams in the summer period due to intense vegetation transpiration and evaporation from the soil surface as well as due to the interruption of water replenishment by means of capillarity from the water-bearing layer of subsoil gravels. The depth level of the upper layer of subsoil gravels can be considered as the “critical level” of HPV and it can be used as a factor for assessing the water regime and its impact on the situation of soil moisture conditions. For example, 36 % of HPV values reach the critical level in the Prameniště locality and 59 % of values in the Ranšpurk locality. Large majority of the HPV values at the critical level occur in the winter period.

It was further discovered that the attainment of HPV critical level is manifested in deteriorated moisture conditions in elevated microreliefs. Soil moisture decreases in such sites by up to 20 volumetric % and can draw near the point of wilting.

Moisture regime of floodplain soils in a forest stand site characterized by soil moisture at 30 cm is on average affected by the development of groundwater table from 53 % in the growing season. Moisture regime of floodplain soils in a forest stand site characterized by soil moisture at 60 cm is on average affected by the development of groundwater table from 45 % in the growing season. Moisture conditions of a forest clearing represented by soil moisture at 10 cm are influenced by the groundwater table level from almost 32 %. Moisture conditions of a forest clearing represented by soil moisture at 60 cm are affected by groundwater table level from nearly 81 %.

The main objective of a long-run research of the water regime and moisture conditions of floodplain forests in southern Moravia is to provide data for the optimization of water quantity which the forest ecosystem needs for sustaining natural dynamics of the groundwater table and moisture regime with respect to the presumed climate changes.

ACKNOWLEDGEMENTS

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VERTEBRATE AS PESTS IN FOREST PLANTATIONS AND FLOODPLAIN FOREST STANDS

Josef Suchomel

Abstract

The impact of selected groups of vertebrate on forest plantations and floodplain forest stands was analyzed. The analysis draws on both published and unpublished data of the author and literary sources. The most significant damage to floodplain forests is caused predominantly by small rodents (Rodentia), *Castor fiber* (Linnaeus) and by ungulate animals, such as *Cervus elaphus* (Linnaeus) and *Capreolus capreolus* (Linnaeus). Small mammals include predominantly *Apodemus flavicollis* (Melchior), which causes damage, by consumption of tree seeds (mainly of oak) and *Myodes glareolus* (Schreber), whose impact on acorn yield is enhanced by browsing. Owing to dominant representation of oak in production floodplain forests, damage through seed consumption is more significant than browsing of bark, whose high content of essential oils is not overtly attractive for rodents. At present, *Castor fiber* causes most damage to trees and this species has become problematic especially in the Soutok Game Preserve (South Moravia). The worst affected tree species in the area include *Salix* spp., *Fraxinus* spp. and *Populus* spp. Roe deer and red deer damage trees by browsing, mainly on oak, and by peeling bark of ash trees.

Key words

floodplain forest, impact on forest stands, European beaver, small rodents, Cervidae

INTRODUCTION

Vertebrate are an indispensable part of the floodplain forest ecosystem, where they represent both significant consumers of primary production and a significant source of secondary production. Floodplain forests' high productivity and the consequent high production of plant and animal biomass attest to a considerable trophy of this ecosystem, which enables certain vertebrate species to reach high population densities in its environment. Under certain conditions these species can cause significant damage to the forest stands by consuming large quantities of biomass. However, owing to the specific natural conditions of floodplain forests (low snow cover, long vegetation period, etc.), which allow high primary production and fast regeneration of phytomass (Penka et al. 1985), the impact on vegetation is low. Yet, under certain conditions some groups of animals can cause damage to selected types of vegetation. From the perspective of forest management, these types of vegetation include mostly forest stands of significant tree species (predominantly oak) and their various growth stages.

Out of the many vertebrate species which occur in floodplain forests, virtually only two mammals (Mammalia) groups produce significant tree pests. They include representatives of the orders of rodents (Rodentia) and ungulates (Artiodactyla). Rodents encompass predominantly forest species from the Muridae family, as well as Arvicolidae (Suchomel 2006, 2007; Suchomel, Heroldová 2004, 2006) and recently also Castoridae (Kostkan, 2000; Úřadníček, 2004). Ungulates include predominantly representatives from the family of Cervidae (e.g. Barančeková 2004; Čermák and Mrkva 2006; Prokešová et al. 2006).

MATERIAL AND METHODS

In order to assess the impact of small mammals on floodplain forest regeneration through the consumption of tree seeds, the author drew on his own data from the research of small mammal ecology in forest ecosystems of South Moravia (floodplain forests in the vicinity of the town Lednice na Moravě) in 2002 – 2006. These data were related to the population dynamics fluctuation of significant rodent species, such as *Apodemus* spp. and bank vole (*Myodes glareolus* Schreber). These data were supplemented with partial published data on the monitored communities of small mammals and the relevant food supply of acorns in the monitored period (Suchomel, Heroldová 2004, 2006, 2008; Suchomel 2006, 2007).

In order to present the impact of small mammals on forest regeneration through browsing of tree bark, information was acquired from a still unpublished assessment of 30 one-off research plots in plantations of selected tree species managed by the Židlochovice Forest Enterprise. 20 research plots covered pedunculate oak plantations (*Quercus robur* L.), 5 research plots were in plantations of Scots pine (*Pinus silvestris* L.), there were two plots of ash (*Fraxinus excelsior* L.) and three plots of white poplar (*Populus alba* L.).

The presentation of the European beaver impact on floodplain forest tree species was based on the results of tree species preference monitoring carried out in the area of Soutok (according to Kostkan 2000) as part of a research project of the Faculty of Forestry and Wood Technology (hereafter FFWT) at MZLU in Brno and on the data collected by students of FFWT as part of their bachelor and diploma works.

The information on deer impact on plantations and floodplain forest stands were considered only complementary, as neither author's own data nor experience can be drawn on. Information from published works by Barančeková (2004), Čermák, Mrkva (2006), Prokešová et al. (2006) and others was used as well (see References).

RESULTS AND DISCUSSION

1. Impact of small rodents on forest regeneration through seed and diaspora consumption

One of the most significant impacts on both artificial and natural forest tree species regeneration in floodplain forests is the consumption of tree seeds by small rodents. This consumption significantly affects commercially valuable tree species, such as oaks. In pedunculate oak (*Quercus robur* L.) it affects mostly sowing (Mauer pers.com.), in sessile oak (*Q. petraea* Liebl) consumption of acorns occurs predominantly following a natural seed crop (Suchomel, Heroldová 2004). The most significant consumer of oak seed in floodplain forests is the yellow-necked mouse (*Apodemus flavicollis* Mell.). In certain cases (especially in years of excessive acorn crops), a number of other small mammal species feed on oak diasporas as well. Wood mouse (*A. sylvaticus*) and bank vole (*Myodes glareolus* Schreb.) rank among the most common in floodplain forests.

Out of all our small mammals, the yellow-necked mouse is best fit to consume large seeds of tree species. These constitute its main food source and in years of excessive crops, mice make winter supplies as well (Obrtel, Holišová 1974; Zejda et al. 2002). This species is highly adaptable and best adapted to forest habitats, where in optimal conditions it reaches significant dominance in relation to other small mammal species. For instance, in the monitored period 2002 – 2006, dominance of the yellow-necked mouse in South Moravian floodplain forests reached approximately 59 %, which accounted for more than half of all the captured small mammals (Table1)!

The numbers of acorns as available food supply affect the abundance of yellow-necked mouse populations as well. In periods of strong seed crops mice enjoy excessive food supply, which in the following year results in a steep rise in their abundance (Flowerdew J. R. 1985; Pucek et al. 1993; Suchomel, Heroldová 2004, 2008; Fig. 1). Wood mouse and bank vole have different trophic requirements and as such manifest significantly lower dominance in case of sympatric occurrence in oak stands (Zejda 1976, 1991; Suchomel, Heroldová 2004; Fig. 1). This concerns mainly the wood mouse, which does not find optimal living conditions in floodplain forests with their high percentage of oak (dominance of approx. 6 %, Table 1). This is explained by the lack of small-seed tree species, whose seeds constitute main food source for wood mouse, as well as by better adaptability of the more aggressive yellow-necked mouse (Zejda et al. 2002). The situation of bank vole, whose 32 % dominance makes it the second most abundant small mammal, is rather different. This rodent preferably feeds on the green mass of the herb layer, and thus avoids food competition of mice, and its supplementary food sources are seeds and fungi (Obrtel, Holišová 1974).

In case of excessive acorn crops, when food is abundant for virtually all rodents feeding on seeds, the competition pressure of the yellow-necked mouse on this food source is not sufficient. As a result, both wood mouse and bank vole react to excessive seed crops by increasing the abundance of their populations and they can become significant oak seed pests as well (Flowerdew J. R. 1985**;** Pucek et al. 1993; Suchomel 2007), even though their abundance does not usually reach the abundance of the yellow-necked mouse (Fig. 1). Despite their lower population densities, a close relation to excessive seed crops has been noted. Increase in body size of caught specimens in the year following a high acorn crop was proved statistically in both mouse species as well as in the bank vole. This attests to a close link to this food source, when available, as well as to the rodents' effort to maximize its use (Suchomel, Heroldová 2008).

Table 1: Species composition of small mammal community in the floodplain forest in "Horní les" (Lednice na Moravě) site, as studied in 2002-2006

rA – relative abundance (%), D – species dominance

Species	***Apodemus flavicollis***	***Apodemus sylvaticus***	***Myodes glareolus***	***Microtus arvalis***	***Mus musculus***	***Sorex araneus***	**Σ**	**Traps/Nights**
n	330	37	179	8	1	4	559	6,900
rA	4.78	0.54	2.60	0.12	0.01	0.06	8.10	
D (%)	59.03	6.62	32.02	1.43	0.18	0.72		

Mice are quick to react to abundance of food in the form of acorn crops by increasing the abundance of their populations and thus they pose a significant threat to both natural and artificial supplies of oak seeds (sowings). Yet, regular cyclical outbreaks do not occur in these species, unlike in voles, e.g. in the bank vole (Pucek et al. 1993). Owing to mice's adaptability and their relatively wide trophic valency, they are capable of maintaining strong populations even in times of poor oak seed crops, as they can feed on other types of plant and animal food (Zejda et al. 2002).

Owing to the fact that no regular monitoring of damage caused by rodents to tree seeds has been carried out, virtually no data are available on the extent of such damage. However, results of the research of small mammals food ecology and their relation to seed crops and seed consumption reveal the following: the extent of their detraction of seed production is considerable and can have a significant impact on forest management methods of oak regeneration based on acorn sowing in floodplain forests, especially in times of high abundance of rodents.

2. Impact of small rodents on forest regeneration through browsing

Small terrestrial mammals cause significant damage to forest plantations by browsing bark, predominantly in winter when food is scarce. Browsing of small mammals is characteristic by small teeth grooves. This type of damage is caused mainly by representatives of the *Arvicolidae* family. In forest stands it is the bank vole (*Myodes glareolus*) and voles of the *Microtus* order, which in floodplain forests means only the common pine vole (*M. subterraneus* de Sélys-Longchamps) and the common vole (*M. arvalis* Pall.) (Zejda 1976, 1991; Suchomel, Heroldová 2004). The latter, being an open habitat species, penetrates floodplain forests along roads and open clear-cut areas, which present a suitable steppe-type environment for this species (Zejda et al. 2002). However, the most significant pest among voles, the field vole (*M. agrestis*), which causes significant damage to trees in mountain and upland forests (Bryja et al. 2001; Heroldová et. al. 2007), does not occur in floodplain forests (Zejda 1976; Suchomel, Heroldová 2004). Thus, the only potentially dangerous pest in floodplain forests is the bank vole, as the common vole can cause only local damage to more open habitats with relatively low grass undergrowth (Zejda et al. 2002). Voles manifest different character of browsing. Bank voles, which are good climbers, damage plantations at relatively big heights of up to several meters above the ground. Consequently, any browsing of this type can be ascribed to them. Common voles, which do not climb, browse saplings only close to the ground along their stem bases (Heroldová et. al. 2007). If a sapling is stripped of bark along its entire circumference, it dies. Winters with high snow cover present an exception, as they enable voles to browse above the ground. However, most bark is consumed under the snow cover. Saplings of up to 10 cm in diameter are attacked most frequently, occasionally saplings of 25-50 cm in diameter are browsed as well. Species of the *Microtus* order are capable of moving under the snow cover even upwards along the stem and consequently can strip a sapling' s entire bark up to the height of 1 m and more (Baxter, Hansson 2001).

Damage in floodplain forests caused by browsing is far less significant than damage caused by seed consumption, which can lead to complete destruction of sowed oak plantations (Mauer pers. com.). This attests to the fact that most plantations in the area consist of oak, whose bark contains a high percentage of essential oils (approx. 20 %) which rodents do not deem very tasty. They prefer other tree species, such as blackthorn (*Prunus spinosa* L.) or European elder (*Sambucus nigra* L.). Owing to the low impact, no damage through browsing has been recorded in floodplain forests. In order to gain information on the extent of the aforementioned type of damage in South Moravian forests we carried out monitoring of 30 plantation sites, out of which 20 were oak plantations, 5 sites covered pine plantations, 2 sites ash and 3 sites of poplar. Out of the total of 1,500 inspected saplings, only 144, which are 9.6 %, were damaged. Out of 1000 oak saplings, 12.3 % (n = 123) were damaged, 0 % of the 250 pines were damaged, 4 % (n = 4) of 100 ash saplings were damaged, as well as 11.3 % of 150 poplar saplings (n = 17). All the affected saplings continued to develop healthily and their mortality upon browsing was zero. The monitored damage was thus insignificant in comparison with that caused by voles in upland and mountain forest stands (Bryja et al. 2001; Heroldová et al. 2007 etc.).

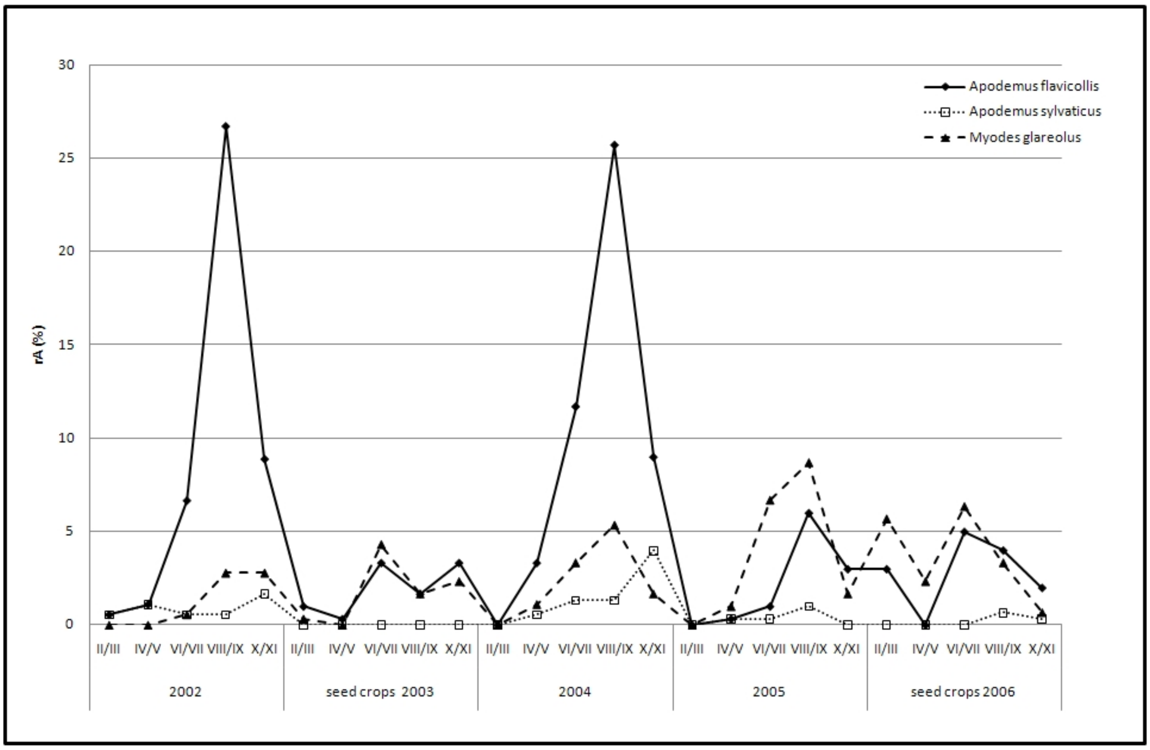

Fig. 1: Fluctuation of relative abundance of small mammals in a floodplain forest (Lednice – Horní les)

3. The impact of the European beaver on floodplain forest composition and regeneration

European beaver (*Castor fiber* L.) is a relatively new element of floodplain forest fauna in the Czech Republic. It initially appeared in Moravia in the mid-1980s, in the area of Soutok at the confluence of the Morava and Dyje rivers, from where it migrated to neighboring Austria. However, isolated sightings were recorded already in the late 1970s. In the early 1990s, a second beaver population began to form in the Litovelské Pomoraví Protected Landscape Area (hereinafter PLA), where several specimens were reintroduced into the wild in 1991 and 1992 (Kostkan 2000). At present beavers have spread along suitable water streams in large parts of Central and South Moravia and their range continues to widen (Šafář 2002). Today (as of 2005) more than 1,000 beavers live in the whole of the Czech Republic. Approximately 300 animals can be found in the floodplain forests of the Litovelské Pomoraví PLA, about 500 beavers in the South Moravian floodplain forests ranging from the Lednice-Valtice Cultural Landscape to the Soutok Game Preserve and their numbers continue to grow (John 2004; Kostkan pers.com.).

However, as the population of beavers grows and their natural range widens, damage caused to forest stands increases as well. The activity of beavers affects the landscape character significantly and both their food and building preferences, which focus almost exclusively on trees, are in disagreement with forest management. Unlike the aforementioned rodent species, damage caused by beavers can be highly significant (Úradníček 2004).

Viewed from this perspective, the most problematic area in our country is probably the Soutok Game Preserve in South Moravia. Beavers tend to fell trees approximately 50 m from river banks, only exceptionally further (Kostkan 2000). However, the network of water channels in the area is so thick that it allows beavers to operate along streams within the entire area. This results in a substantially larger area of forest stands being affected than for example in the Litovelské Pomoraví PLA (Kostkan, Lehký 1997). Moreover, a number of oak stands line the channel banks and as such are under the direct threat of beavers. Beavers also favour the oak or ash hardwood as building material for their dams and in order to get it they are capable of covering substantial distances from the bank directly to the fenced oak plantations. They also fell mature oaks growing on river banks in order to open up the habitat and to support growth of softwood, fast-growing tree species such as willows (*Salix* spp.) or poplars (*Populus* spp.), which constitute the key component of beavers' diet (Heidecke 1989; Kostkan 2000). Apart from browsing, beavers damage forest stands through local inundations. They create lakes which enable them to get to trees safely underwater, even in places outside the regular riverbed. Permanently flooded trees consequently dry up and gradually die.

As part of our monitoring of the population in the area of Soutok, we focus on the beavers' temporary-spatial activity through monitoring tree browsing. For instance, in 2006 the total of 3,536 trees browsed by beavers were monitored on the area of 50.5 ha (Table 1), which attests to an intensive impact on the surrounding stands. Willows (*Salix* spp.), as the most preferred tree species, constituted 36.3 % of all the felled trees. Ashes (*Fraxinus* spp.) and maples (*Acer* spp.) also showed significant representation of 20.5 % and 18 % respectively. The remaining approx. 25 % includes other tree species, predominantly elms (*Ulmus* spp.), poplars (*Populus* spp.), oaks (*Quercus* spp.) and hawthorn (*Crataegus* spp.) (see Fig. 2 – Forest soils).

Tree species preference is conditioned not only by the existing offer but also by their stems' diameter. The most frequent diameter was up to 2.5 cm (Table 2), which for example in willows constituted 66.7 % of all the felled specimens. The same diameter was intensively preferred also in ash (46.8 % of all the felled specimens). Literary sources quote rather larger dimensions of 5 – 20 cm but the felled trees can have even over 1 m in diameter (Kostkan 2000). Table 2 shows preferences of monitored tree species and varying stem diameters.

From the perspective of damage to commercial tree species, the most widely affected species in South Moravia include ash and possibly poplar. Oak, on the other hand, is preferred significantly less (only up to 3.5 %), despite the fact that within exclusion fences and forest stands along streams notable local damage can be caused (Fig. 2). Trees constitute a significant part of beavers' diet at the end of the vegetation period, i.e. from October to December, when winter supplies are prepared intensively. The numbers of felled trees in this period vary. For instance, the numbers in the Litovelské Pomoraví PLA fluctuate between 0.027 and 13.7 m^3 in non-vegetation periods (Kostkan 2000). One specimen's average consumption is 0.4 m^3 and a family's consumption is approx. 1 - 2 m^3 per non-vegetation season (Janýšková 1997). During the vegetation period, when beavers feed mostly on various herb species, the impact on tree species is significantly lower (Heidecke 1989; Prokešová et al. 2007). Felling of coniferous trees is an interesting example of uncharacteristic food source (Syrovátková 1998; Hoření 2005). The reason for this can be the effort to eliminate the intake of harmful substances from a specific tree species or a shortage of vitamins in autumn and spring months (Kostkan 2000).

Beavers' trophic pressure on forest stands is conditioned by population density. Notably the trophic base seems to act as a key factor influencing beavers' existence. Feeding activity can decrease local supply of consumed plants to such an extent that the drop in preferred tree species is faster than their regeneration (Fryxell 2001). In the long term, this effect results in the populations' fluctuation. In most sites which have been inhabited for prolonged periods of time, the danger of a fast decrease in the area's potential trophy is imminent and can thwart the population's successful development. Consequently, either the pressure to increase the given territory grows or the site is deserted (Kostkan 2000; Fryxell 2001). In South Moravia, this problem is pressing at present.

Table 2: Preferences of stem diameters and tree species monitored in 2006 in European beaver (*Castor fiber*) in the area of the Soutok Game Preserve (data in the table refer to the numbers of individual browsed trees)

DO – completed browsing, NO – incomplete browsing

Tree species / Diameter DO (cm)	***Acer* sp.**	***Alnus* sp.**	***Carpinus* sp.**	***Crataegus* sp.**	***Fraxinus* sp.**	***Helianthus tub.***	***Juglans* sp.**	***Populus* sp.**	***Prunus* sp.**	***Quercus* sp.**	***Salix* sp.**	***Tilia* sp.**	***Ulmus* sp.**	**Total**
0-2,5	168	5	0	31	340	31	0	58	38	40	857	0	54	1,622
2,5-6	200	4	0	44	247	4	1	18	100	30	222	43	148	1,061
6-12	219	4	0	5	126	0	0	10	8	51	95	40	64	622
12-20	37	0	3	6	12	0	0	4	1	0	43	0	4	110
20-30	8	0	0	0	0	0	0	6	0	0	16	0	1	31
30-40	3	0	0	0	1	0	0	6	1	1	17	0	2	31
40-50	0	0	1	1	0	0	0	0	1	0	12	0	7	22
50+	1	0	0	0	0	0	0	10	0	0	22	0	4	37
Total	636	13	4	87	726	35	1	112	149	122	1,284	83	284	3,536
NO	12	2	0	1	48	0	0	32	0	11	82	1	10	199

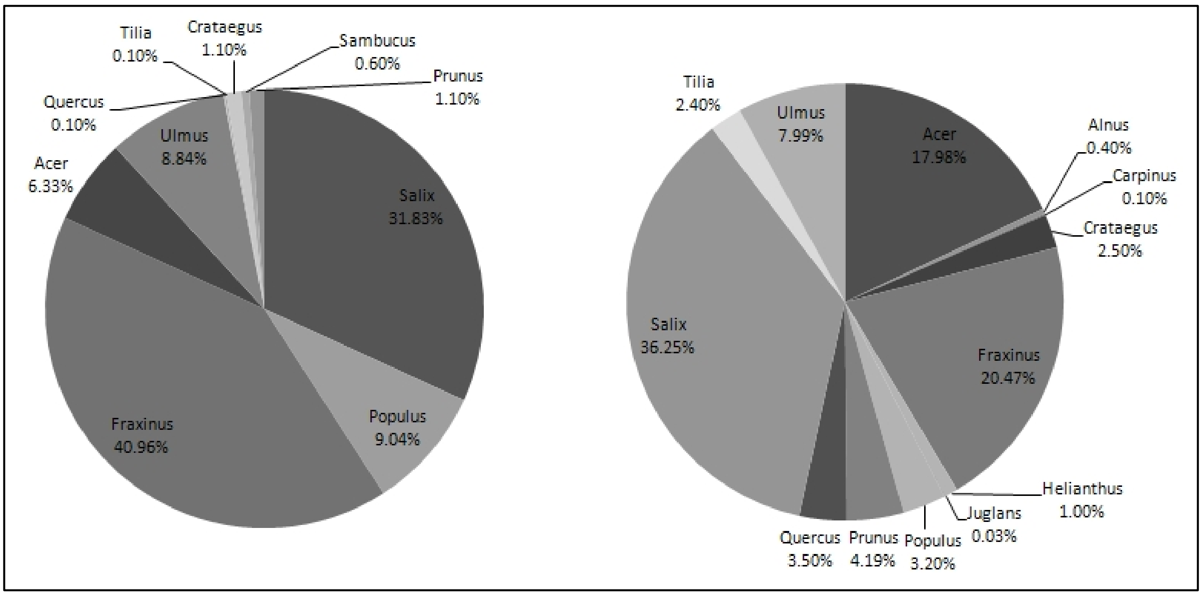

Fig. 2: Preferences of tree species on non-forest land (left) and forest soils (right) as monitored in European beaver in the Soutok Game Preserve (South Moravia) in 2006

As damage caused by beavers mounts, the question of their regulation arises. It is necessary to bear in mind that limiting damage through regulation of beaver populations is still problematic, due to the fact that beaver is a protected species both on the national and international level. The species is protected under the Regulation No. 395/1992 of the Ministry of the Environment of the Czech Republic, which lists it as "Severely Endangered" and it is also listed in Amendments II and IV of the Council Directive 92/43/EEC (Natura 2000). Gamekeeping Act No. 449/2001 defines beaver as game which cannot be hunted. The only legal option, which might solve the issue of damage caused by beavers, is the Act No. 115/2000, on providing reimbursements for damage caused by selected specially protected animals. This document establishes European beaver as a species upon which reimbursements can be claimed in case it causes damage to forest or field stands.

Damage to commercial tree species at present can thus be best limited through a change in forest management. This would involve, for instance, planting softwood non-target tree species preferred by beaver in the vicinity of water streams within the perimeter of 50 m from the banks. Commercial tree species should then be planted beyond this zone, further protection could possibly include protection of individual free-growing trees. However, it is highly probable that regulation of beaver populations through hunting will be necessary in the future.

4. Impact of ungulates on floodplain forest regeneration and plantations

Ungulates are one of the key factors influencing the development of forest vegetation, mainly trees and shrubs. Red deer (*Cervus elaphus* L.) and roe deer (*Capreolus capreolus* L.) are the most significant species in floodplain forests. They cause damage to trees through browsing branches and peeling bark. Particularly in winter, young shoots of trees constitute an important part of their diet (Gill, Beardall 2001). The impact of ungulates on floodplain forest vegetation in the Czech Republic has not been studied until recently. Among the first to study it were Barančeková (2004) and Prokešová (2006) in the area of the confluence of the Morava and Dyje rivers, and Čermák, Mrkva (2006) in the area of Litovelské Pomoraví.

Within floodplain forests, virtually only ten-year-old and older stands are available for ungulates, as the widely employed clear-felling system of floodplain forest management is characteristic by deer fencing of forested cleared areas. After approximately ten years of stands' development the fences are removed. The impact of game on tree species was studied mainly in oak (*Quercus* spp.), ash (*Fraxinus* spp.) and hedge maple (*Acer campestre*) forest stands, notably in clear-cut areas and the shrub layer in South Moravian forests. In terms of browsing, studies revealed a significantly higher impact in the winter than in the autumn. Oak was browsed the most, ash the least. Bark peeling, which was monitored in oaks and ashes, constituted a significant damage as well. For instance, out of 100 % of monitored ashes, 88 % were damaged in 2003! Oak is subject to browsing relatively less. For instance, out of the 420 monitored oaks only 11 % were damaged (Barančeková et al. 2004). The aforementioned studies reveal that oak, notably oak plantations, is the most frequently browsed tree species in floodplain forests. In case of a more intensive impact, the attacked saplings can become deformed and have the characteristic dwarfish appearance of bonsais. (Prokešová et al. 2004).

Tree species preference in the diet of ungulates is conditioned by a given habitat's food supply. Studies of diet prove that broadleaf tree species constitute a large part of both the deer species' diets throughout the year. For red deer it is 50 – 85 %, for roe deer 45 – 84 %. The highest percentage of tree species in red deer diet falls to the period between April and May (over 80 %), the lowest percentage was monitored in late summer and autumn, when red deer feed more on corn and grass. Roe deer also prefers tree species throughout the year. Most tree species are consumed in December and January (84 %), least in the period between April and May (52 %). In the latter period, almost half of the diet is constituted by bramble (*Rubus* sp.), which ranks highest among tree species in the roe deer diet. Red deer, on the other hand, feeds on bramble very rarely, mainly in the autumn and in late winter (Barančeková 2004; Prokešová et al. 2004). Tree species constitute a significant part of the diet of both red and roe deer throughout the year and their potential impact on both natural and artificial regeneration can be substantial. Ungulates thus can cause major damage in floodplain forests and their impact is conditioned mostly by their population densities.

CONCLUSIONS

The impact of selected vertebrate groups was analyzed in forest plantations and floodplain forests in South Moravia. The analysis focused on the impact of small mammals on seed crops of tree species and on the browsing of artificial regeneration. It also analyzed the impact of European beaver on both browsing and felling of trees as a recent phenomenon in South Moravian floodplain landscape. The additional focus was on the impact of ungulates on forest regeneration in relation to excessive game populations. Results of this work draw both on author's own published and unpublished data from the monitoring of the given area in recent years, and on literary sources. The presented analyses reveal the following conclusions:

- Rodents of the *Apodemus* and *Myodes* genera have a significant impact on both natural and artificial regeneration of oak in floodplain forests through their consumption of diasporas. When their population densities are high, these rodents restrict the natural regeneration of sessile oak and make pedunculate oak's artificial regeneration by sowing virtually impossible. Reduction of this kind of damage involves a monitoring of the rodents' population dynamics, as well as a monitoring of years with excessive acorn crops, as they result in the increase in the rodents' populations and consequently in increased damage. Collected data can be used to make forecasts on the rodents' abundance and to estimate the right time for using chemical pest control.

- Small rodents, namely the bank vole (*Myodes glareolus*) and potentially the common vole (*Microtus arvalis*), cause less significant damage to floodplain forests by browsing tree bark within plantations in winter. During a one-off inspection of the small rodent impact on tree plantations on 30 sites in South Moravia we detected minimum damage to oak (12.3 % of damage), as its bark contains a high percentage of essential oils and as such it is not attractive for rodents. Other cultivated tree species, such as ash, pine and poplar, were also affected to a minimum extent. Damage which small mammals cause by bark browsing is largely negligible and it is not necessary, unlike in upland and mountain forests, to fight it with rodenticides.
- The European beaver (*Castor fiber*) significantly affects the tree composition of floodplain forests, mainly in the area of the Morava and Dyje rivers confluence, where its activity stimulates softwood tree species regeneration (mostly of willows and poplars). Beaver causes damage both to softwood and hardwood tree species, predominantly ashes. In places where oak plantations reach water stream banks, the damage caused by beaver encompasses the youngest plantations and trees of 1 m in diameter. Owing to the fact that the area of Soutok is part of the Natura 2000 network and beaver is a protected species, its populations in the area cannot be reduced through hunting. Damage to commercial tree species can be limited by changes in forest management, for instance by planting softwood tree species, which are preferred by beaver, within 50 m of river banks and by cultivating oak outside this zone. However, regulation of beaver populations through hunting will probably be necessary in the future.
- Among ungulates, the red deer (*Cervus* elaphus) and the roe deer (*Capreolus capreolus*) exert the most significant impact on floodplain forests. Their browsing damages mostly oak and bark peeling damages mostly ash. At present, their populations are considerably smaller than in the past. On the other hand, roe deer and red deer can help foresters control the spread of undesirable and insignificant tree species, such as hedge maple.

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POSSIBILITIES TO ASSURE RESOURCES AND REPRODUCTION MATERIAL FOR THE REGENERATION OF FLOODPLAIN FORESTS IN THE CZECH REPUBLIC

Miloš Pařízek

Abstract

The paper is focused on actual situation in certified sources of the reproductive material of the autochthonous tree species of the floodplain forests. The data are related to the date of 15 December 2006 and 31 August 2007. Certified sources are classified according to source category and source type. The contribution also includes a retrospect on the amounts of collected seeds of individual tree species on the basis of issued origin certificates. The data were acquired from the ERMa information system operated and administered by "authorized person" – Forest Management Institute Brandýs nad Labem.

Key words

certified source, seed amount, information system ERMa, Forest Management Institute

INTRODUCTION

Floodplain forests are communities very interesting with respect to their natural value and specific forestry focus. In order to provide for the preservation and regeneration of these forest stands, it is - among other things - also necessary to search, acknowledge and register possible sources of the reproduction material of tree species autochthonous in the floodplain forests. The current legislation stipulates in the Act. no. 149/2003 Coll. as amended the obligation of an "authorized person" to keep records in the "Register of certified sources of the reproduction material of all forest tree species", hence also the recognized sources of the reproduction stock of floodplain forest tree species. The authorized person is to date the Forest Management Institute in Brandýs nad Labem, which operates a central database of certified sources of the forest tree species reproduction stock referred to as a Register of Reproduction Material (ERMa). Outputs from the database make it possible to analyze the current condition of resources of the forest tree species reproduction material, i.e. numbers of parent trees, clones, seed orchards, and stands certified for seed collection. The sources can be classified by individual categories, forest altitudinal vegetation zones, natural forest regions.

Certified sources of the reproduction material are entered into the database following the decision of a competent public administration authority on the acknowledgement of the reproduction material source. Data on amounts of the obtained seed and other reproduction materials (e.g. cuttings, lifting from natural regeneration, etc.) are taken over from a database of issued certificates of origin the central register of which is included in ERMa, too. Amounts of produced planting stock which are held in the possession of suppliers or which have been introduced into circulation by them are entered into the database as estimates based on the reporting of suppliers who are obliged to deliver the report with figures as of 30 November to the authorized person before 15 December of calendar year.

Main tree species of the floodplain forest contained in the ERMa database, which are the subject of this contribution are as follows: soft broadleaves – a group of willows *Salix* spp. (including all willow species with an exception of goat willow - *Salix caprea* L.), *Populus* *alba*, *Populus nigra*; hard broadleaves – *Ulmus laevis*, *Ulmus glabra*, *Fraxinus excelsior*, *Quercus robur*, and *Fraxinus angustifolia* autochthonous in the South-Moravian grabens.

REPRODUCTION MATERIAL SOURCES BY INDIVIDUAL TREE SPECIES

The below presented tables contain data on:

1. amounts, categories and types of sources, and are divided by the main tree species represented in the Czech floodplain forests
2. the production of seed stock or other reproduction materials as well as the reproduction material in growing, which are with the suppliers in individual years (only for years 2004, 2005 - functioning is the reporting of suppliers, data estimates for 2006 have not been entered into the database); figures for the planting material in growing being summarized with no regard to age and method of growing.

Tables presented for the respective tree species originate from September 2007 and they were obtained from the ERMa database of certified sources.

LVS = forest vegetation belt
PLO = natural forest region

Pedunculate oak (*Qercus robur*)

Table 1: Sources of reproduction material (DS_ERMa, IX, 2007)

Source category	Source type	Number of individuals/Area	
		PLO 34 LVS 1 a 2	PLO 35 LVS 1 a 2
Identified	Seed source	1 pcs	0
	Stand of phenotype class „A“	0	0
	Stand of phenotype class „B“	0	0
	Stand of phenotype class „C“	191.71 ha	86.84 ha
Selected	Stand of phenotype class „A“	23.97 ha	72.32 ha
	Stand of phenotype class „B“	287.48 ha	366.72 ha
Qualified	Seed orchard	0	0
	Parent tree	0	0
	Clone	0	5 pcs
	Clone mixture	0	0
Tested		0	0

Table 2: Seed production on the basis of issued certificates of origin in 2004-2006 and planting stock from PLO 34 a 35, LVS 1 a 2, in years 2004 – 2006

Year	Seed amount	Planting stock in growing
2004	0 kg	2,375,012 pcs
2005	11,030 kg	1,771,007 pcs
2006	31,768 kg	not available

Table 3: Required planting stock according to regeneration area from FMPR data for MGS 19

Annual regeneration area requirement NFR 34 and 35	Minimum number of transplants per ha pursuant to Decree 139/20004 Coll	Total anual requirement
92.46 ha	10,000 pcs of transplants	924,460 pcs of transplants

European ash (*Fraxinus exscelsior*)

Table 4: Sources of reproduction material (IX, 2007), PLO 35

Source category	Source type	Number of individuals/Area
		PLO 30-41, LVS 1 a 2
Identified	Seed source	3 pcs
	Stand of phenotype class „A“	0
	Stand of phenotype class „B“	0.04 ha
	Stand of phenotype class „C“	423.38 ha
Selected	Stand of phenotype class „A“	24.27 ha
	Stand of phenotype class „B“	250.77 ha
Qualified	Seed orchard	1.00 ha
	Parent tree	0
	Clone	72 pcs
	Clone mixture	0
Tested		0

Table 5: Seed production on the basis of issued certificates of origin in 2004-2006 and planting stock from PLO 30-41, LVS 1 a 2, in years 2004 – 2006

Year	Seed amount	Planting stock in growing
2004	62 kg	42,500 pcs
2005	456 kg	398,684 pcs
2006	1,024 kg	not available

Table 6: Required planting stock according to regeneration area from FMPR data for MGS 19

Annual regeneration area requirement NFR 34 and 35	Minimum number of transplants per ha pursuant to Decree 139/20004 Coll	Total anual requirement
26.94 ha	6,000 pcs of transplants	161,640 pcs of transplants

Narow-leaved ash (*Fraxinus angustifolia*)

Table 7: Sources of reproduction material (IX, 2007), PLO 35

Source category	Source type	Number of individuals/Area
		PLO 30-41, LVS 1 a 2
Identified	Seed source	0
	Stand of phenotype class „A“	0
	Stand of phenotype class „B“	0
	Stand of phenotype class „C“	0
Selected	Stand of phenotype class „A“	112.65 ha
	Stand of phenotype class „B“	97.49 ha
Qualified	Seed orchard	0
	Parent tree	0
	Clone	0
	Clone mixture	0
Tested		0

Table 8: Seed production on the basis of issued certificates of origin in 2004-2006 and planting stock from PLO 30-41, LVS 1 a 2, in years 2004 – 2006

Year	Seed amount	Planting stock in growing
2004	0	0
2005	378 kg	250,000 pcs
2006	198 kg	not available

Table 9: Required planting stock according to regeneration area from FMPR data for MGS 19

Annual regeneration area requirement NFR 34 and 35	Minimum number of transplants per ha pursuant to Decree 139/20004 Coll	Total anual requirement
7.67 ha	6,000 pcs of transplants	46,020 pcs of transplants

White poplar *(Populus alba*)

Table 10: Sources of reproduction material (IX, 2007), PLO 35

Source category	Source type	Number of individuals/Area
		PLO 30-41, LVS 1 a 2
Identified	Seed source	0
	Stand of phenotype class „A“	0
	Stand of phenotype class „B“	0
	Stand of phenotype class „C“	7.76 ha
Selected	Stand of phenotype class „A“	0
	Stand of phenotype class „B“	0
Qualified	Seed orchard	0
	Parent tree	0
	Clone	0
	Clone mixture	0
Tested		0

Table 11: Seed production on the basis of issued certificates of origin in 2004-2006 and planting stock from PLO 30-41, LVS 1 a 2, in years 2004 – 2006

Year	Seed amount	Planting stock in growing
2004	0	0
2005	0	0
2006	0	not available

Table 12: Required planting stock according to regeneration area from FMPR data for MGS 19

Annual regeneration area requirement NFR 34 and 35	Minimum number of transplants per ha pursuant to Decree 139/20004 Coll	Total anual requirement
9.83 ha	-	-

Black poplar (*Populus nigra*)

Table 13: Sources of reproduction material (IX, 2007), PLO 35

Source category	Source type	Number of individuals/Area
		PLO 30-41, LVS 1 a 2
Identified	Seed source	1 pcs
	Stand of phenotype class „A“	0
	Stand of phenotype class „B“	0
	Stand of phenotype class „C“	26.94 ha
Selected	Stand of phenotype class „A“	0
	Stand of phenotype class „B“	0
Qualified	Seed orchard	0
	Parent tree	0
	Clone	88 pcs
	Clone mixture	1.50 ha
	Parent plant	0.05 ha
Tested		0

Table 14: Seed production on the basis of issued certificates of origin in 2004-2006 and planting stock from PLO 30-41, LVS 1 a 2, in years 2004 – 2006

Year	Seed amount	Planting stock in growing
2004	7,900 pcs of cuttings	0
2005	11,700 pcs of cuttings	5,600 pcs of cuttings
2006	15,600 pcs of cuttings	not available

Table 15: Required planting stock according to regeneration area from FMPR data for MGS 19

Annual regeneration area requirement NFR 34 and 35	Minimum number of transplants per ha pursuant to Decree 139/20004 Coll	Total anual requirement
8.11 ha	500 pcs of saplings	4,055 pcs of transplants

Willows (*Salix* spp.)

Table 16: Sources of reproduction material (IX, 2007), PLO 35

Source category	Source type	Number of individuals/Area
		PLO 30-41, LVS 1 a 2
Identified	Seed source	0
	Stand of phenotype class „A“	0
	Stand of phenotype class „B“	0
	Stand of phenotype class „C“	0.04 ha
Selected	Stand of phenotype class „A“	0
	Stand of phenotype class „B“	0
Qualified	Seed orchard	0
	Parent tree	0
	Clone	0
	Clone mixture	3.00 ha
	Parent plant	0,05 ha
Tested		0

Table 17: Seed production on the basis of issued certificates of origin in 2004-2006 and planting stock from PLO 30-41, LVS 1 a 2, in years 2004 – 2006

Year	Seed amount	Planting stock in growing
2004	14,000 pcs of cuttings	0
2005	8,350 pcs of cuttings	9,403 pcs of cuttings
2006	21,200 pcs of cuttings + 1,750 pcs	not available

Table 18: Required planting stock according to regeneration area from FMPR data for MGS 19

Annual regeneration area requirement NFR 34 and 35	Minimum number of transplants per ha pursuant to Decree 139/20004 Coll	Total anual requirement
2.10 ha	1,100 pcs of transplants	2,310 pcs of transplants

European white elm (*Ulmus laevis*)

Table 19: Sources of reproduction material (IX, 2007), PLO 35

Source category	Source type	Number of individuals/Area
		PLO 30-41, LVS 1 a 2
Identified	Seed source	3 pcs
	Stand of phenotype class „A“	0
	Stand of phenotype class „B“	0
	Stand of phenotype class „C“	1.38 ha
Selected	Stand of phenotype class „A“	0
	Stand of phenotype class „B“	0
Qualified	Seed orchard	3.30 ha
	Parent tree	20 pcs
	Clone	146 pcs
	Clone mixture	0
Tested		0

Table 20: Seed production on the basis of issued certificates of origin in 2004-2006 and planting stock from PLO 30-41, LVS 1 a 2, in years 2004 – 2006

Year	Seed amount	Planting stock in growing
2004	2.3 kg	11,651 pcs
2005	3.7 kg	8,717 pcs
2006	57.5 kg	not available

Table 21: Required planting stock according to regeneration area from FMPR data for MGS 19

Annual regeneration area requirement NFR 34 and 35	Minimum number of transplants per ha pursuant to Decree 139/20004 Coll	Total anual requirement
0.14 ha	6,000 pcs of transplants	840 pcs of transplants

Smooth elm (*Ulmus carpinifolia*)

Table 22: Sources of reproduction material (IX, 2007), PLO 35

Source category	Source type	Number of individuals/Area
		PLO 30-41, LVS 1 a 2
Identified	Seed source	0
	Stand of phenotype class „A“	0
	Stand of phenotype class „B“	0
	Stand of phenotype class „C“	3.14 ha
Selected	Stand of phenotype class „A“	0
	Stand of phenotype class „B“	0.94 ha
Qualified	Seed orchard	1.69 ha
	Parent tree	0
	Clone	59 pcs
	Clone mixture	0
Tested		0

Table 23: Seed production on the basis of issued certificates of origin in 2004-2006 and planting stock from PLO 30-41, LVS 1 a 2, in years 2004 – 2006

Year	Seed amount	Planting stock in growing
2004	0	0
2005	3.0 kg	4,300 pcs
2006	41.0 kg	not available

Table 24: Required planting stock according to regeneration area from FMPR data for MGS 19

Annual regeneration area requirement NFR 34 and 35	Minimum number of transplants per ha pursuant to Decree 139/20004 Coll	Total anual requirement
4.18 ha	6,000 pcs of transplants	25,080 pcs of transplants

Table 25: List of approved hybrid poplar clones for the establishment of short-rotation stands (Věstník MZe ČR, April 2000)

Variety **a) botanical name, sex** **b) commercial name**	**Basic silvicultural characteristics**
Basic assortment	
a) *Populus x euroamericana* (Dode) Guinier cv. *Blanc du Poitou* m b) poplar ´Blanc du Poitou´	Versatile clone, suitable for altitudes 100-400 m a.s.l., produces spreading crown, tolerant to dense canopy at young age.
a) *Populus x euroamericana* (Dode) Guinier cv. *I 45/51* m b) poplar ´I 45/51´	Versatile clone, suitable for altitudes 100-300 m a.s.l.
a) *Populus x euroamericana* (Dode) Guinier cv. *I 476* m b) poplar ´I 476´	Versatile clone, suitable for altitudes 100-300 m a.s.l.
a) *Populus x euroamericana* (Dode) Guinier cv. *NL-B 132b* m b) poplar ´NL-B 132b´	Versatile clone, suitable for altitudes 100-300 m a.s.l., produces narrower crown, convenient for line planting.
Complementary assortment	
a) *Populus x euroamericana* (Dode) Guinier cv. *Brabantica* m b) poplar ´Brabantica´	Fitted only for the best poplar sites at altitudes 100-300 m a.s.l. Suitable for polyclonal mixtures as a complementary clone.
a) *Populus x euroamericana* (Dode) Guinier cv.*Dolomiten* f b) poplar ´Dolomiten´	Good for sites with lower groundwater table at altitudes 100-300 m a.s.l.
a) *Populus x euroamericana* (Dode) Guinier cv. *Eckhof* f b) poplar ´Eckhof´	Suitable as a complementary clone for polyclonal mixtures at altitudes 100-300 m a.s.l.
a) *Populus x euroamericana* (Dode) Guinier cv. *Flachslanden* f b) poplar ´Flachslanden´	Fitted only for the best poplar sites, tolerant to lower groundwater table at altitudes 100-300 m a.s.l.
a) *Populus x euroamericana* (Dode) Guinier cv. *Gelrica* m b) poplar ´Gelrica´	Suitable for poplar sites with lower groundwater table at altitudes 100-400 m a.s.l.
a) *Populus x euroamericana* (Dode) Guinier cv. *Heidemij* m b) poplar ´Heidemij´	Unfitted for stand planting, suitable for line planting at altitudes 100-400 m a.s.l.
a) *Populus x euroamericana* (Dode) Guinier cv. *I 500/53* f b) poplar ´I 500/53´	Suitable for polyclonal mixtures at altitudes 100-300 m a.s.l.
a) *Populus x euroamericana* (Dode) Guinier cv. *Löns* m b) poplar ´Löns´	Suitable for polyclonal mixtures at altitudes 100-400 m a.s.l.

Table 25: Continuing

a) *Populus x euroamericana* (Dode) Guinier cv. *Marilandica* f b) poplar ´Marilandica´	Slowly growing, suitable for mixtures as lower storey. Superb health condition, fitted also for line planting at altitudes 100-600 m a.s.l.
a) *Populus x euroamericana* (Dode) Guinier cv. *Neupotz* f b) poplar ´Neupotz´	Suitable for polyclonal mixtures at altitudes 100-400 m a.s.l.
a) *Populus x euroamericana* (Dode) Guinier cv. *NL-B 132m* b) poplar NL-B 132m	Suitable for polyclonal mixtures at altitudes 100-300 m a.s.l.
a) *Populus x euroamericana* (Dode) Guinier cv. *NL-B 132k* b) poplar ´NL-B 132k´	Suitable for the best poplar sites with higher groundwater table at 100-300 m a.s.l.
a) *Populus x euroamericana* (Dode) Guinier cv. *Robusta* m b) poplar ´Robusta´	Unsuitable for stand planting, in line planting up to 600 m a.s.l.
a) *Populus x euroamericana* (Dode) Guinier cv. *Spreewald* f b) poplar ´Spreewald´	Suitable for polyclonal mixtures at altitudes 100-300 m a.s.l.
a) *Populus x euroamericana* (Dode) Guinier cv. *Virginiana de Frignicour* t f b) topol ´Virginiana de Frignicourt´	Suitable for good poplar sites but even there often crooked, suitable also for line planting at 100-600 m a.s.l.
a) *Populus maximowiczii x berolinensis* (Stout et Schreiner) cv. *Oxford* f b) poplar ´Oxford´	Suitable for stand planting up to 600 m a.s.l. on sites with a good water supply.
a) *Populus maximowiczii x trichocarpa* (Stout et Schreiner) cv. *Androscoggin* m b) poplar ´Androscoggin´	Suitable for stand planting at altitudes 200-700 m a.s.l. Tolerant to poor skeletal soils with a good water supply.
a) *Populus maximowiczii x trichocarpa* (Stout et Schreiner) cv. *NE 42* m b) poplar ´NE 42´	Similarly as in the clone Androscoggin
a) *Populus trichocarpa* Torr. et Gray cv. *Fritzi Pauley* f b) poplar ´Fritzi Pauley´	Similarly as in the clone Androscoggin

SOURCES OF REPRODUCTIVE MATERIAL AND USE OF THE PLANTING STOCK IN FOREST REGENERATION AND FORESTATION IN NATURAL FOREST REGIONS 34 A 35

Act No.149/2003 Coll. introduced a general obligation to obtain reproductive material exclusively from certified sources. Until than the seed was prevailingly collected (in deciduous tree species) from uncertified stands (phenotype class C).

The obligation of seed collection from certified sources is fulfilled by acknowledging sources of the category identified – by this way the former possibilities of seed collection from uncertified sources of phenotype class C have been replaced. According to the presented data there is an increase in certified stands of this category namely in pedunculate oak and European ash.

The issue of assuring pedunculate oak seed and planting stock for NFR 34 a 35 may be problem in the case of poor crop. In the past (1980s and earlier), failures in the fertility of oak stands in these natural forest regions were often remedied by the transfer of acorns from southern Bohemia (NFR 15) or by imports (Slavonic oak). The possibility ended with the Forest Law 289/1996 Coll. and with the Decree no. 82/1996 Coll. and the situation continues until today (Decree no. 139/2004 Coll.) – transfer of pedunculate oak to NFR 34 and 35 from other NFRs is impossible. According to data from supplier reports (Table 2), there is a relatively sufficient amount of available reproductive material at present.

In elms (white elm, small-leaved elm) and black poplar a range of clones (parent trees) was found in connexion with activities concerning the maintenance of genetic resources of these tree species. In case of the two elm species, seed orchards were subsequently established as sources of qualified RM. This demonstrates that prerequisites have been created in these tree species for the assurance of reproductive material resources.

THE ISSUE OF POPLARS

As to the use of poplars (hybrid clones), the Czech forestry recorded a marked down-sizing in the last decade as compared with other European countries. This particularly concerns the growing of short-rotation (20-30 years) poplars where the fundamental usable assortment of clones was issued last in 2000 in the Bulletin of the Ministry of Agriculture (Věstník MZe) (Table 25).

It can be generally stated that with the aid being extended to energy plantations on farmland (energy plantations with a very short rotation period), when the rules for establishment of both reproduction stands and proper plantations are stipulated by agricultural Act no. 219/2003 Coll. as amended (on varieties and planting), the situation with the reproductive material of hybrid poplars in the Czech Republic does not provide an easy survey:

- "Classical" forest clones of hybrid poplars are grown for forestry purposes in the regime of Act no. 149/2003 Coll. as a reproductive material of forest tree species.
- There are also clones of hybrid poplars grown in a different regime (and in a different assortment) of Act no. 219/2003 Coll. as a reproductive material for the purposes of establishment of energy plantations on agricultural land.

CONCLUSIONS

The scope of this contribution was to inform about the situation concerning certified sources of tree species autochthonous in floodplain forests of Czech Republic in September 2007 and to present against a restrospective seed production and amount of grown planting stock for individual tree species on the basis of issued certificates of origin in 2004-2006.

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III. BLOCK: COOPERATION IN DECISION-MAKING WITH PUBLIC ADMINISTRATION AUTHORITIES

FLOODPLAIN FOREST MANAGEMENT FROM THE POINT OF STATE FORESTRY ADMINISTRATION

Martin Vlasák

Abstract
The paper summarizes the valid legislation in the forest management sector and refers to management in the floodplain forests in conformity with the existing regulations, completed by possible exceptions from the mandatory regulations with respect to specific floodplain forest features.

Key words
afforestation, establishment, regeneration, tending, clearcut area, main intentional felling, forest management plan, simplified forest management plan, regional forest management plan, management group of stands

While executing its activities, the State Forestry Administration in the Czech Republic is governed by the issued and valid legal regulations. The Act No. 289 Coll., on forests and on change and amendments of certain acts (Forest Law), as amended, and its Executing Notice No. 83/1995 Sb., on the elaboration of regional forest development plans and on the determination of management groups of stands concern in particular the sector of management in floodplain forests. The publication „Economic Recommendations by Management Groups and Subgroups of Stands: Elaboration of Appendices No. 2, 3 and 4 of the Regulation No. 83/1996 Sb., on the Preparation of Regional Forest Development Plans and Determination of Management Groups of Stands - Praha: Silva Regina, [1997]. - 48 p. + 1 App.“ is included among other norms, though not binding legally, in the practice of the State Forestry Administration bodies.

The Forest Law does not contain any special provision concerning the floodplain forests. The sole explicit reference to the floodplain forest management can be found in provisions of § 31, resolving regeneration and tending of the forest stands. By item 2 of this paragraph the Law enables exception from the determined size or width of the clearcut area up to 2 ha without width limitation in the management group of natural floodplain forest stands permitted by the State Forestry Administration body. The exception is approved by the State Forestry Administration body at the owner's request or during the approval procedure of the forest management plan and/or processing of the simplified forest management plan. From the State Forestry Administration practice it follows that it is desirable to approve the exception directly during the procedure of plan approval or simplified plan elaboration. The reason is that we are speaking about the method of management affecting further silvicultural, tending and felling procedures, which the plan or simplified plan works with. Let us remind that in case of the main intentional felling the Law does not permit size of the clearcut area greater than 1 ha in the majority of other forests and that the clearcut area width may not exceed twice the average height of the logged stand. Importance of this provision for floodplain forest regeneration is out of scope of this paper and will certainly be clarified adequately in other specialized papers of this seminar.

Paragraph 36 of the Forest Law, resolving the issues of management in protective forests and in special purpose forests, is another provision concerning management in the floodplain forests. This provision comprises the phrase that the measures differing from the provisions of the Forest Law, in particular the measures regarding size or coordination of the clearcut areas, can be adopted in favour of special-purpose management in the protective and special purpose forests. Such measures can be designed in the plan or in the simplified plan or are determined by decision of the State Forestry Administration body at its own discretion or upon proposal of the forest owner. This provision creates a relatively large opportunity to regulate management in the floodplain forests and to determine the measures supporting special management procedures in the floodplain forests lawfully, mainly thanks to the word "in particular", contained in the preceding phrase, which quotes item 1 of § 36 if the Forest Law.

Incorporation of the forests in question in the floodplain regions among the special purpose forests is the necessary prerequisite for adoption of the measures according to the preceding paragraph. This incorporation is not automatic due to the very existence of the floodplain forests. Incorporation is requested by the forest owner or can also be done at discretion of the administrative body. Definition of the special purpose forests can be found in the Forest Law, § 8, which reads that only the forests, where the public interest in environmental protection and improvement or another justified interest in fulfillment of non-wood producing functions of the forest is given precedence to the wood-producing function of the forest, can be included into the category of the special purpose forests. The process of forest allocation to individual categories is subject to the administrative proceeding pursuant to the Act No. 00/2004 Coll., Rules of Administrative Procedure.

Legislative determination of the term floodplain forests can be found in the Appendix no. 4 to the Regulation of the Ministry of Agriculture No. 84/2005 Coll., on the preparation of regional forest management plans and on the determination of management groups of stands. This determination is based on the generally applied forest typology and in the Appendix above it is designated as the target management group of stands 19 named "Management of Floodplain Sites". The typological structure of this management group of stands includes basic groups of forest types 1 L, 2 L, 1 U, 3 U and/or the groups 3 L and 5 L.

Another problem, which the State Forestry Administration is concerned with in the sector of floodplain forest management, is the requirement of granting the exception from the statutory term of reforestation and establishment of forest stands. This issue is regulated by § 31, item 6 of the Forest Law which reads that the clear-felled area must be reforested within two years and the forest stands on it established within seven years after its occurrence. These exceptions are granted in the floodplain forest practice as early as during the procedure of forest management plan approval or simplified forest management plan processing. It can also be granted at the owner's request. The general procedures concerning administrative proceedings do not cover permission of longer terms and therefore granting of the exception is not very complex from the administrative point of view.

Author of the paper has tried to reflect the most important cases, where the State Forestry Administration faces differences in the floodplain forest management, compared with the valid legislation in the forest management sector.

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