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Original article

Methods of oak silviculture in Austria

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Summary — In Austria oak stands occupy an area covering ≈ 150 000 ha or ≈ 4% of the total forest area. Half of the oak stands are managed as coppice or coppice with standards, and half are managed as high forest. During the last 2 decades there has been a remarkable increase in developing young oak stands. The interest in managing suitable forest areas for oak is apparently growing. Therefore regeneration methods, timely and proper management and thinning regimes will be very important in the near future. As a result of different growth performances it is necessary to determine different production targets and rotation cycles. For this reason treatment programmes have been developed dependent on selected sites considering biological, ecological and technical parameters to achieve high economic yield. Investigations into oak stands of different age classes have already shown the importance of timely cleaning, tending and continuous thinning during the first third of the rotation cycles. Various treatment programmes and practical knowledge relating to regeneration, tending, crop selection and thinning have been discussed.

silviculture / oak / high forest system / coppice with standards / coppice

Résumé — Méthodes de sylviculture du chêne en Autriche. *La chênaie occupe en Autriche une superficie d'environ 150 000 ha, soit près de 4% de la surface forestière totale. La moitié des peuplements de chênes est traitée en taillis ou taillis-sous-futaie, l'autre moitié est aménagée en futaie. Au cours des 2 dernières décennies, il y a eu un accroissement remarquable de création de jeunes peuplements de chênes. L'intérêt pour l'aménagement des stations favorables aux chênes est apparemment grandissant. Pour cette raison, les méthodes de régénération, époque, aménagement et régime des éclaircies, seront très importantes dans la prochaine période. En relation avec les différentes performances de croissance, il est nécessaire de définir différents niveaux de productivité et de durée de rotation. C'est pour ces raisons que des programmes d'aménagement ont été développés, en liaison avec les caractéristiques des stations, prenant en compte les paramètres biologiques, écologiques et techniques, cela afin d'aboutir à une production de haute valeur économique. Les recherches menées dans des peuplements de chêne de différentes classes d'âge mettent en évidence l'importance de la période des dégagements et le rôle de la gestion des éclaircies au cours du premier tiers de la rotation. Différents types d'aménagement et les connaissances pratiques concernant la régénération, le régime des éclaircies, la sélection des tiges sont examinés.*

sylviculture / chêne / futaie / taillis-sous-futaie / taillis

INTRODUCTION

In Austria high and production forests of oak stands (*Quercus petraea* and *Quercus robur*) cover 51 000 ha. The most important trees in the oak-rich mixed forests are beech and hornbeam. 70 000 ha belong to the "land-coppice system" and the coppice with the standard system and 25 000 ha are part of coppice in the alluvial plains. In the overwood of these forests oak dominates by 65%.

Oak stands are predominant in both large and small private forests. Due to the economic changes and increasing respect for the ecological interrelations in federal and private forests, over the last 2 decades, the following systems have been applied:

– increased planting of (mixed) oak stands;

– a more intensive tending and fostering of oaks in the oak-rich high forests and coppice with standards;

– an increasing change from coppice systems and/or coppice with a standards system with diffuse standards into overwood-rich coppice with standards system (high forest system).

The aim of these measures is to use the existing capacity of the sites more efficiently and to build up more stable mixed oak stands.

Due to the catastrophic infestation of the coppice with standard forests by the oak-mistletoe *(Loranthus europaeus)* in the eastern parts of Austria (Krapfenbauer, 1982; Mayer *et al,* 1982; Buchleitner, 1983) a more intensive study of these problems began. After heavy damage to the mixed beech forest sites in the lower alpine areas, where spruce and pine are still dominant, the establishment of mixed deciduous woods (oak stands) is becoming more important.

Large private forest enterprises have given the (high-quality) timber production of oak special attention. The above-mentioned damage and a change in the silvicultural and economic potential for high-quality timber has led to a rethinking process.

Numerous examples show that the objective-oriented treatment of oak stands considering the growth potential of the site in the high forests as well as in the coppice with standards forests, presents an opportunity for the owners of small forests to meet a part of the production costs (Anonymous, 1987; Weilharter, 1991).

The coppice system has grown more important as a source of biomass energy.

On the one hand, one finds increasing silvicultural efforts to promote oak forests, and on the other one observes an alarming loss of vitality in oaks, which has been increasing and extending dramatically over the last couple of years.

PRODUCTION OBJECTIVE – THE SILVICULTURAL SYSTEM

Several sites are suitable for high-quality oak timber production: mixed deciduous forest sites in the alluvial plain regions, oak-rich beech forest sites and typical oak–hornbeam forest sites in the submontane regions (annual precipitation ≈ (600) 700–900 mm, mean annual temperature 8–9°C) and dry oak–hornbeam forest sites under Pannonic influence in the eastern part of Austria (annual precipitation of ≈ 450–700 mm, mean annual temperature 8–10°C).

A major objective for the production of high-quality timber is the achievement of a diameter of 50(60) cm with a regular annual ring structure, straight trunk and branch-free bottom logs.

Different site factors cause a different term in growth (fig 1) and due to this different production periods and objectives are possible. With the decreasing quality of a site the possibilities are obviously more limited. When establishing the production objective, very differentiated actions are required. A number of reports have shown that annual rate of growth and length of high-quality logs are not only decisively influenced by the silvicultural treatment of the stand (tree) (Oswald, 1979; Spiecker, 1991) but also by the site factor (Schütz and Badoux, 1976; Polge *et al,* 1979).

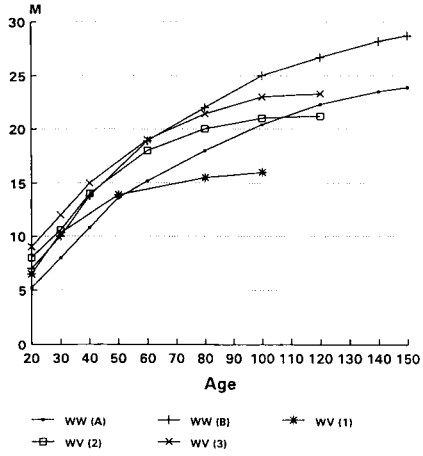

Fig 1. Development of the top-height of oaks in high forest in various regions (A,B = Wienerwald (Hochbichler, 1987); 1,2,3, = Weinviertel/ coppice with standards site (1 = Hochbichler, 1987; Krissl and Müller, 1989)

Investigations of sites in different regions (Jelem *et al,* 1965; Lang and Mayer, 1968; Jelem *et al,* 1974; Anonymous, 1979; Glatzel, 1982) of the growth performances and the structures of stands, partly in combination with economic assessment (Lang and Mayer, 1968; Krapfenbauer, 1983; Pollak, 1983; Hochbichler, 1987; Krissi and Müller, 1989) have constituted the major criteria for the choice of tree species, silvicultural system and type of production objective (table I).

In Austria there are no long-lasting testing areas which could help to set up a silvicultural programme. Due to this, silvicultural programmes have been drawn up taking

Table I. Example of a summary assessment of important biological–ecological features of trees with different site preconditions for growth of high-quality oaks as a basis for optimization of the production objective or production period.

Wienerwald (top height at age 150 yr: 26–29 m)				
Mean annual width of tree rings (mm)	2.7	2.2	1.7	1.2
Mean length of branch-free bottom log (m)	7–8	9–10	12	14–15
Formation of water sprouts (–little/+ high)	–	–	±	+
Quality of stem (+ good/– bad)	+	+	+	±
Weinviertel (Top height at age 120 yr: 21–24 m)				
Mean annual width of tree rings (mm)	2.8	2.2	1.7	1.3
Mean length of branch-tree bottom log (m)	5–7	6–8	10–11	12
Formation of water sprouts (– little/+ high)	–	±	+	+
Quality of stem (+ good/ – bad)	+	+	±	–

into account site-specific growth performance, qualitative–biological timber features and biological–economic considerations regarding cultivation (planting, tending intensity, underplanting, etc) (Hochbichler and Krapfenbauer, 1989: Krissl and Müller, 1989).

The present paper shows that for productive alluvial plain forests a production period of ≈ 100–120 yr and for areas in the submontane regions a production period of (120) 140–160 yr should be determined with a final timber output of 80–100 crop trees per ha and a branch-free bottom bole of 8–12 m. For the most western part of the lower submontane areas, further basic planning on specific sites and silvicultural system has to be carried out.

In the eastern mixed oak forest sites, where coppice with standards system and coppice system dominate, it is above all necessary to find a forest management system, which in relation to the stand site offers the best conditions for achievement of the planned production objective (fig 2).

For vigorous coppice with standards sites (top height 18–24 26-m) a high forest system is suggested with a rotation period of 110–130 yr and a final tree output of 60–70 per ha with a knot-free bole of 5–7 m (Hochbichler and Krapfenbauer, 1987).

On these sites with a suitable stand structure a transformation into stands with "high forest character" seems appropriate (Mayer *et al,* 1982; Pollak, 1983).

For the drier, less vigorous stand sites (top height 12–17 m) which "compel" a coppice system, overwood-rich or overwood-poor silvicultural systems (rotation time 120–150 yr, knot-free bole, 4–6 m) depending on the soil quality of the site are suggested (Krapfenbauer, 1982; Krissl and Müller, 1989).

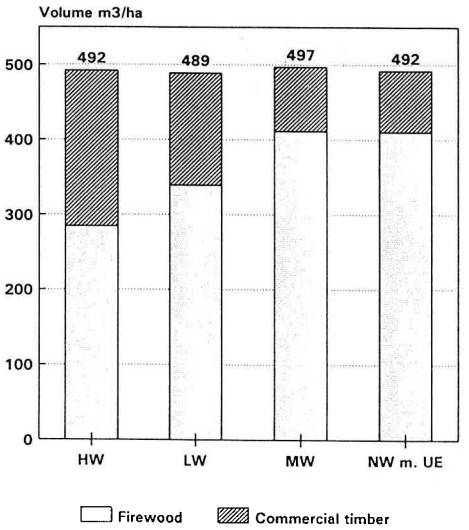

Fig 2. The proportion of firewood and timber for different silvicultural systems on a coppice with standards site and a rotation time of 120 yr (Krissl and Müller, 1989) (HW = high forest system, LW = open stand system; MW = coppice with standards system 30-yr rotation of underwood; NW = coppice system with reservations (60-yr rotation of underwood).

On these rather dry sites coppice regeneration has many advantages for generative propagation, such as the protection of the coppice shoot in the same stump and the absence of unfavourable germ and juvenile phases. Additional yield research incorporating a comparative approach to the silvicultural management system of the middle forest stands will be of particular interest in future.

The following study is mostly concerned with the more vigorous forest sites, namely the Wienerwald and the eastern mixed oak forest sites of the Weinviertel.

SILVICULTURAL TREATMENT

High forest management

Planting and natural regeneration

In the Austrian federal forests regeneration of the stands has been mainly carried out by planting. 4 000–6 000 individual plants per ha (2 000–4 000 oaks; 2 000 hornbeams/limes) have been planted in rows, spaced 2.2 x 0.5–0.7 m apart.

Natural regeneration has not played a major role. Today stands are planted in rows with 3 500 oaks and 3 500 hornbeam/lime, spaced 2.2 x 0.7 m apart (Anonymous, 1990). At the middle forest sites planting is carried out with seedlings spaced 2–4 x 0.3–0.7 m apart, but natural regeneration is also important. Because of the high browsing intensity due to far too large a number of game stock, fencing of juvenile stands in some areas is obligatory.

The growth of these stands gives reason to expect a satisfactory quality, with the exception of stands with a wide row spacing of 3–4 m (Krapfenbauer and Hochbichler, 1984).

The intensive planting of oak stands and the promotion of the oaks in previously untreated oak-rich stands indicates that in the future tending young stands and thinning will become more important (fig 3).

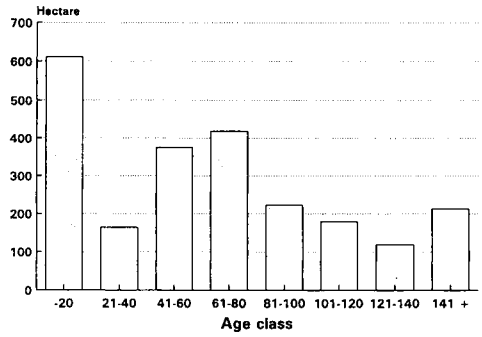

Fig 3. Age classes of oak stands in the Austrian federal forests.

Tending young stands

Numerous surveys on the method of natural artificial regeneration show that thinning from below (negative selection) should end with a thicket. The improvement of the stands with high-quality vital elements in the overstory through positive selection should be encouraged (Leibundgut *et al*, 1976; Röhrig and Schaper, 1983). The mentioned surveys were an important tool when drawing up tending programmes and coincide with the newer surveys by Mosandl *et al* (1991) (table II).

Time and intensity of treatment have to be coordinated with the possibilities of the site, individual dynamics of the stands and the following pole stand period. Early interventions show positive reactions in stand climate and secure a vital and stable secondary stand.

Due to the lack of self-pruning within the juvenile oak stands, only an unsatisfactory development is to be expected; therefore pruning of live branches (combined crown- and stem-tending) to achieve an improvement is suggested (Hochbichler *et al*, 1990). As the future quality–performance of the stand is strongly influenced during this, a far more critical assessment of tending necessities and measures should take place in practice.

Thinning

With the obtention of branch-free bottom logs through pruning a new phase starts, the thinning phase.

The latest findings on the interrelation of age, diameter, crown width (crown length)

Table II. Tending programme for young oak stands established by natural regeneration in the Weinviertel (rotation time 120 yr; mean annual width of tree rings 2.5 mm; crop trees 65 per ha).

Age	*Top height (m)*	*Stem No (overstory)*	*Treatment*
	–2	6 000	Elimination of wolf-tree and badly shaped trees, preferential treatment; sprout pruning
	3–6	1 600	Stem number reduction in the overstory spacing 3 m; beginning of positive selection; possible greenpruning to a length with branch-free bottom log of 3 m (120–150 trees/ha)
	7–12		Favouring of vigorous and well-formed trees spacing 6–7 m by removing 1 or 2 competitors; possible greenpruning to a length with branch–free bottom log of 6(7)-m (60–75 trees/ha)
30	13–15	650	Start of selective thinning: favouring 60–70 trees/ha (spacing 10–14 m)

and the associated control of growth diameter show that quality trees have to be given special support (Oswald, 1979; Schütz and Badoux, 1979; Spiecker, 1991).

Crop selection thinning has been adopted in forest practice. Thinning models, adapted to the production objective and the continuous development of the plus tree, could provide assistance in the decision-making process (fig 4).

The 2 stem number models that are derived from the combined individual tree characteristics (age, diameter, width and length of crowns) by taking into account the planned production objective with the related rotation periods (mean annual width of tree rings from 2.0 and 2.5 mm) largely correspond to the stem number models of other authors with the given growth rate. The models clearly show that depending on the production objective and period, heavy thinning measures are necessary in the early pole stage and should end before the second third of the rotation period.

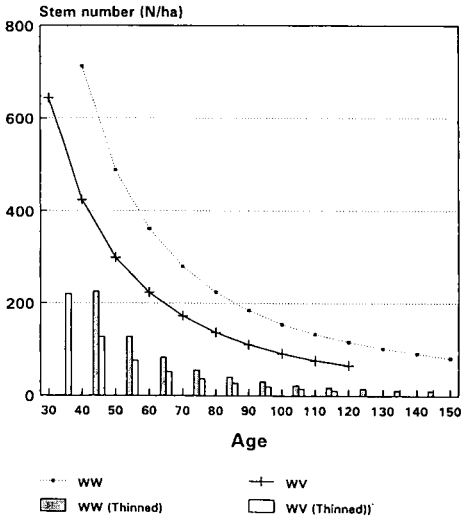

Fig 4. Development of stem number of the remaining and removed stands for thinning models in the Wienerwald (rotation 150 yr; mean annual width of tree rings 2.0 mm; crop trees 80 per ha) and Weinviertel (coppice with standards site; rotation 120 yr; mean annual width of tree rings 2.5 mm; crop trees 65 per ha) (Hochbichler and Krapfenbauer, 1989).

Generally only 1 or 2 competitors should be thinned at the same time; therefore an appropriate thinning cycle is necessary. The keeping of "reserve trees" is not advisable.

Coppice with standards system

Research on different coppice with standards structures clearly shows the need for an objective-oriented, properly planned silvicultural treatment, the most significant consideration being tending of the single tree for sustained cultivation with a balanced distribution of age-classes (diameter size classes) in the overwood with (high-quality) timber proportion and tending in the underwood.

"Ideal coppice with standards structures" which have to be maintained or achieved by forest treatment (for example Krapfenbauer, 1982, 1989; Krissl and Müller, 1989) are recognizable by the following:

– a balanced distribution of age classes and an equal distribution of high-quality trees in the overwood;

– favourable sheltering conditions (50(–70)%), shelter before clear felling;

– sustained upkeep of coppice underwood capability by the appropriate rotation periods (up to a maximum of 30(40)yr),

– sufficient regeneration of the plants with seedlings;

– taking into account of the site-specific potential of soil-nutrients;

– silvicultural treatment to promote natural regeneration.

On the whole, the coppice with standards management in practice offers a broad setting for ecological and economic possibilities.

Regeneration

The removal of stands by natural regeneration is of utmost importance. The underwood rotation in association with the site-specific conditions should not exceed 20–40 yr (maintenance of coppice shoot potential). Apart from the removal of underwood as fuelwood, the regeneration and maintenance of a sufficient amount of oak trees is very important. If natural regeneration by plants of seedling origin is too limited due to an unsatifactory quantity of fruit-producing overwood-oaks, seedlings have to be planted.

Tending

In the regeneration phase the removal of unwanted tree species such as aspen, birch and willow by simultaneous promotion of mixed tree stands (noble broad-leaved tree species) are a main objective. Once again attention should be drawn to the importance of the sheltering circumstances for the regulation of the composition of tree species and growth of the underwood at this age phase (Krissl and Müller, 1989).

From a height of 2–3 m, "thicket-tending" requires differential action. Stool shoots should be reduced to 2–3 saplings per stool. Particular attention should be given to the removal of the far-reaching saplings, because they could hinder the development of the slower-growing plants of seedling origin.

Treatment of the "plus trees"

Selection and crown tending (*eg* green-pruning) are possible at the same time with a sufficient number of well-formed plants of seedling origin for optimal spacing.

With special tending the plus trees can be secured by a balanced development of the crowns and a continuous enlargement of the growing space. With these methods the periodical formation of sprouts after removal of the underwood can be prevented.

Aside from periodical felling in the overwood, the maintenance of high-quality seed trees and the promotion of the future crop trees starting with the younger age-classes with uniform spacing is necessary.

Coppice system

In relation to biomass production as a source of energy (fuelwood), biomass production in the coppice system on sites which are liable to dryness and where coppice regeneration is favoured is increasingly under discussion. Because rotation periods are dependent above all on coppice capability (max 30(40) yr) this type of exploitation remains significantly below its optimal yield performance. Further problems (limiting factors) are the result of a rapid decrease in coppice capability and lowered sprouting vitality and disturbance of nutrient circulations through biomass/nutrient withdrawal (Krapfenbauer, 1989).

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