Silvicultural principles, goals and measures in growing valuable broadleaved tree species

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Waldbauregeln, Ziele und Maßnahmen zur Pflege von Edellaubbaumarten

1 Introduction

In all European countries, valuable broadleaved tree species (Fraxinus, Acer, Prunus, Sorbus, Juglans, Tilia, Alnus, and Betula genera) are important producers of high-quality wood, used especially in the veneer and furniture industries. They play an important economic role in forest management. In order to improve the economic return their costs have to be reduced while the quality and therefore the price of timber has to increase. In addition, forest stability has to be enhanced and ecological services have to be maintained.

There is a big price difference between low quality veneer ("D"), which amounts to a price of less than 10 Euro per cu.m, and high quality veneer ("A, TF and F"), which price varies between 200 and over 1,000 Euro per cu.m. Even though the price of high quality timber from valuable broadleaves fluctuates over time, it has always been significantly higher than that of medium or low quality timber during the recent decades.

The main objective of this article is to produce a framework for describing the silvicultural measures necessary to achieve the goals of improving valuable broadleaved tree species. It is a general scheme that can be used at the level of individual trees in pure or mixed stands, either planted or naturally regenerated. This report is an output of a consortium of researchers from 25 European countries cooperating under the umbrella of COST (COST E42 "VALBRO" further information: http://www.valbro.uni-freiburg.de/)

Zusammenfassung

Europaweit sind die Edellaubbäume eine wichtige Quelle von qualitativ hochwertigem Holz, das besonders in der Furnier- und Möbelindustrie Verwendung findet. Der vorliegende Beitrag zielt in diesem Zusammenhang darauf, einen Rahmen an empfehlenswerten Verbesserungsmaßnahmen für den Waldbau mit „wertvollen Laubholzarten" (VALBRO) zu beschreiben. Dieses Rahmenwerk basiert auf zwei entscheidenden Hauptprinzipien: (1) Reduktion oder Verhindern von Astigkeit und (2) Produktion stark dimensionierter Wertholzbloche.
Der vorliegende Beitrag konzentriert sich auf zwei bedeutende Arten des waldbaulichen Pflegeeingriffes, die künstliche Astung sowie die Durchforstung, als die wesentlichen Komponenten des „Einzelbaum-Waldbaues", der im Falle der Edellaubbäume empfohlen wird.

Schlagworte: Edellaubholz, Wertholz, Entwicklungsphase, Einzelbaum-Waldbau, Durchforstung, Astung.

Summary

In all European countries, valuable broadleaved tree species are important sources of high-quality wood, used especially in the veneer and furniture industries. In this context, the paper aims at producing a framework to describe the measures that should be taken in order to improve the silviculture of valuable broadleaved trees species (VALBRO). This framework is based on two important general principles: (1) Restriction or elimination of branchiness and (2) Production of large diameter butt logs.
The paper focuses on two important silvicultural interventions, artificial pruning and thinning, as the main components of *single-tree silviculture*, recommended in case of VALBRO.

Key words: Valuable broadleaved tree species, valuable wood, phases of development, single-tree silviculture, thinning, artificial pruning.

2 Silvicultural principles

For producing high-quality timber valuable broadleaved trees need to have certain phenotypical characteristics. They should grow straight, the crown should develop monopodially, and forks as well as branches with acute angles should be avoided. Trees should be well-adapted to the site and resistant to biological and environmental threats. To produce high-value timber site fertility should be high.

As in the case of other important broadleaved tree species such as oaks or European beech, the silviculture of valuable broadleaved tree species aims at producing as much high-quality and knot-free timber as possible. To achieve this objective two important general principles are targeted in the case of all valuable broadleaved tree species:

1. *Restrict branchiness*: less branches mean better wood quality and higher market value;
2. *Produce large diameter* ("the larger the better") *butt logs* (Figure 1).

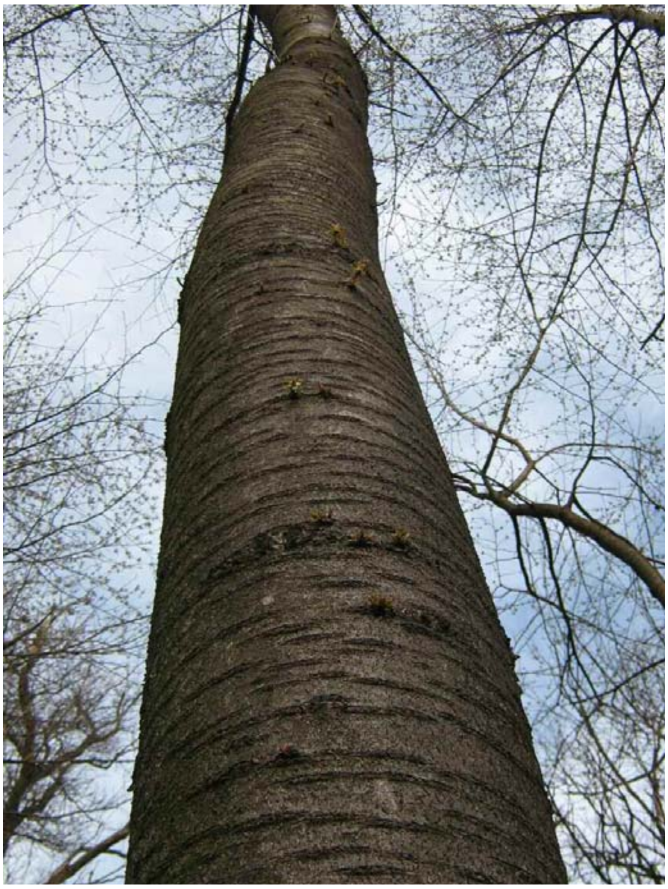

Figure 1: Large diameter wild cherry tree (photo: V.N. NICOLESCU)
Abbildung 1: Stark dimensionierte Wildkirsche (Foto: V.N. NICOLESCU)

Both branchiness and dimensions (diameter and length) can be manipulated by silvicultural measures (stocking, weeding, cleaning-respacing, and thinning) controlling the stand density and available free space around tree crowns. Pruning (formative and high) can have the same effect on branchiness.

High quality timber can be achieved by the application of adequate measures. Economic activities must be linked to the value-producing trees only. When dealing with valuable broadleaved tree species the number of final crop trees per ha is relatively small. This is due to the fact that valuable trees need to have large diameters and crowns. At the rotation age, only a low number (for most species 40–80 per hectare) of large diameter trees is expected. The stand management has to focus on these value-producing trees and their choice and marking facilitates efficient management. Valuable broadleaves generally grow in naturally mixed stands and *single-tree management* may facilitate growing them under such conditions.

Regeneration methods have an important influence in securing the quality of timber production by regulating intensive silvicultural techniques from the young stand phase. Tree quality and stand density are the key parameters for natural regeneration. The number of plants and their spacing design are vital. These are the criteria that influence the future stand development, the need of silvicultural interventions and their costs. The economic success of the production programme depends not only on the value of the wood produced but also on the total costs of the regeneration process, tending operations (including pre-commercial thinning) and the time-lag until the revenues repay the investment. Therefore, well-defined silvicultural goals are needed to fulfil the requirements of target diameter, species composition and especially the process of natural or artificial pruning during the thicket phase.

In order to reduce costs the number of trees to be planted should be much lower than in the past. In some countries a definitive number of target trees (40–80 per hectare) are planted mixed with other nursery species. Sometimes a limited number of tree groups are planted of which the best trees are selected. The proposed silviculture is more *tree-oriented* as opposed to the traditional *stand-oriented*. The contrast between these two silvicultural approaches becomes important in cases where the number of final crop trees is low. A basic question is whether in future we should grow less crop trees with larger crowns or more crop trees with smaller crowns and diameters but reaching a higher crown base? The decision has an impact on the rigour of the selection criteria and on the volume of clean bole timber per ha. Less crop trees with larger crowns may produce better wood quality and larger dimensions; harvesting costs per volume unit may be reduced and stability may be enhanced. The decision may have less effect on diversity and aesthetic values. The total volume production of all wood may slightly decrease when the spacing between trees increases and the stand density decreases considerably. The percentage of the volume of clean bole decreases while the percentage of the crown wood increases when the relative crown length increases. Therefore, the volume of clean bole timber per ha will be smaller (Figure 2). The optimum depends on the economic conditions, especially on the impact of tree diameter on price. The higher the impact of diameter on price the larger should be the diameter and the lower should the crown base be. The price sensitivity to diameter may vary with species and timber use. On more productive sites the bole length can be longer while the same diameter can be reached in a shorter time. The optimum bole length depends on the use of valuable timber. Veneer producers generally require a minimum 2.5 m length or a multiple of 2.5 m. For some species such as *Sorbus spp.* or *Juglans spp.* the bole length can be even shorter.

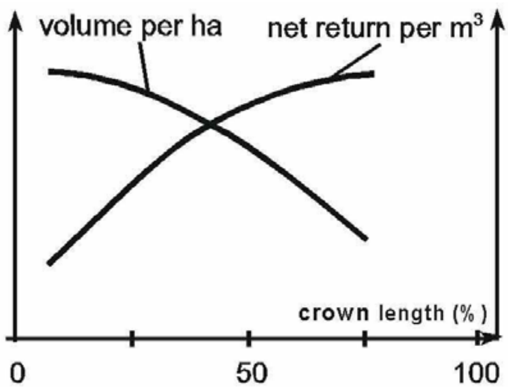

Figure 2: Correlation between crown length (base), volume per ha and timber price (net return) in valuable broadleaved tree species (after SPIECKER, 2006b)

Abbildung 2: Beziehung zwischen Kronenlänge (Basis), Volumen per ha und Holzpreis (Nettoertrag) bei Edellaubhölzern (nach SPIECKER, 2006b)

To decide the timing and manner of practicing such interventions extra information is needed on different issues such as:

- Growth pattern;
- Forest owners' needs and behaviour;
- Wood buyers' requirements;
- Market behaviour;
- Possible defects arising at certain ages as well as derived rotation age taking into account the influence of such defects;
- Economics of silviculture (including the grant system for silvicultural operations as existing in many European countries).

At present many factors influencing the general principles such as growth pattern, owners' needs, buyers' requirements, etc. are not known enough so there is a certain need for these to be better defined. Such a task will require efforts in modelling and simulating the growth and development of valuable broadleaved tree species in relation to all other influencing factors.

Regardless the need for deeper knowledge it is necessary to acknowledge that the management of valuable broadleaved tree species is costly and requires high-intensity silvicultural interventions starting in the early stages of development. Without such inputs the objective of producing high-quality timber with important end-uses will be impossible to fulfil.

3 Development stages, natural processes and silvicultural measures

3.1 Development stages and natural processes

The evolution of forests can be divided in terms of development stages as follows (Oliver and Larson, 1996):

a. *Seedling (establishment) stage:* new or renewed tree cover by establishing young trees naturally or artificially until they reach 1.30 m mean height. At this stage the young trees begin to compete for light, water and nutrients. When the canopy space is fully occupied with crowns, the lowest leaves and branches begin to die.

b. *Young stage:* period between the moment when the trees are 1.30 m mean height and the first thinning (mean dbh about 10 cm). During this stage a great part of height growth takes place and there is a high/severe competition between the young trees. Natural thinning occurs when stand density is high. The lowest branches of the surviving trees die and fall off to a certain extent, depending on the tree species. Stem diameter increases rather slowly because of the competition between the trees.

c. *Thinning stage:* period between the first thinning (mean dbh about 10 cm) and the time when the regeneration felling(s) takes place. During this stage trees are given more space and competition is reduced by thinning. Consequently diameter increases more rapidly. The canopy opens and there will be enough space for the next generation.
d. *Regeneration stage:* regeneration felling(s) are carried out and large-size trees are harvested; measures are taken in order to get a satisfactory regeneration (natural or/and artificial).

3.2 Translation to measures

During these different stages of development various silvicultural goals, connected to each other, play a part. Forest managers have to look for the goals first and then have to select the measures to achieve them. In Table 1 the main silvicultural goals within each stage have been outlined. The next column shows possible silvicultural measures which can be used to reach these goals.

This table can be used to describe the silviculture of valuable broadleaved tree species by filling in the silvicultural goals for a tree species of a region and/or site type. Filling in means that the following questions should be answered:

- What is „good potential quality and growth" (e.g. timber quality, annual height growth/volume growth, etc.)?
- What is the desired stocking (number of trees per ha) or spacing?
- What branch-free length (m, % of reachable height) of tree bole is achievable?
- Which serious diseases or attacks (type, species) have to be controlled?
- What is the optimal diameter growth (ring width)?
- Which diameters (min-max) are usable?

The answers to these questions provide a guide to the measures that are necessary.

In order to control the most important silvicultural characteristics of valuable broadleaved tree species (branchiness and dimensions), two measures described in chapter 4 are vitally important: pruning (natural or artificial) and thinning. Basic conditions can be controlled in

Table 1: The main silvicultural goals and measures in each development stage
Tabelle 1: Waldbauliche Hauptziele und Maßnahmen in den einzelnen Entwicklungsphasen

Development stage	Silvicultural goals	Silvicultural measures
Seedling (establishment) stage	Sufficient number of homogenously-spaced young trees with good shape and growth	Choice of provenance
		Site preparation
		Stocking (number of plants per ha)
		Mixture of species
		Game protection
		Fertilization
		Weed control
		Pest control
		Drainage
Young stage	Branch-free bole of (potential) final crop trees	Artificial pruning
		Removal of "wolf" trees
		Pre-commercial thinning
	Healthy stand/vigorous trees	Pest control
	Final crop trees	Selection of final crop trees
Thinning stage	Optimum diameter growth of final crop trees	Thinning
	No dieback of lower branches (at the crown base)	Thinning
Regeneration stage	Usable diameter	Final harvesting
	Species composition of the next generation	Choice of remaining seed trees
	Silvicultural goal(s) of the next generation	Fertilization
		Site preparation
		Weed control
		Pest control

the seedling/establishment stage and the young stage as follows:

a. Seedling/establishment stage

Natural regeneration. This regeneration method has important advantages as management is less expensive and regenerated species and provenances may be well-adapted to the site. Its choice and application is favoured if the parent trees are genetically valuable. Under such conditions an adequate growth performance can be expected combined with a high quality standard of timber.

Artificial regeneration. It is applied in situations with:
- An unsatisfactory natural regeneration dynamic because of density and/or quality;
- A change of targeted tree species;
- Afforestation of bare lands.

The following aspects are highly important for operating artificial regeneration of stands:

Choice of tree species
– Evaluation of site conditions (site mapping);
– Tree specific growth performance and/or pattern;
– Use of genetically suitable seed sources (provenance).

Tree number and spacing design
– Plant quality (provenance); the variation of „quality“ and the absolute quality standard determine the spacing (stocking), which is influenced by the tree species. Advantages and disadvantages of narrow and wide spacing are given in Table 2.

Table 2: Advantages and disadvantages of narrow and wide spacing
Tabelle 2: Vor- und Nachteile von Dichtstand und Weitstand

	Narrow spacing	Wide spacing
Costs	– *)	+
Canopy closing	+	–
Need for pre-commercial thinning	–	+
Need for artificial pruning	+	–
Diameter growth (young stage)	–	+
Chances for undergrowth, underplanting	–	+

*) + = advantage, – = disadvantage

Planned pruning process
– Natural pruning processes need close spacing, regardless the afforestation/reforestation design (total area, partial area); in general wide spacing has to be combined with artificial pruning (formative, high);
– Specific tree growth performance during the young stage determines the mixture type.

b. Young stage

Tending of young stage stands is carried out to promote the inclusion of the targeted tree species and tree specific growth pattern into naturally regenerated stands. Tending activities are also aimed at regulating tree mixture and/or stand density (to maintain/favour the vigour of future crop trees) especially for rare species and high quality trees. The use of the „treatment cell“ concept combined with a clearly defined tree hierarchy for favouring tree species and/or tree species composition can be helpful in reducing costs.

In artificially regenerated young stands, silvicultural operations (cleaning-respacing) are aimed at improving the establishment conditions, maintaining the desired tree species composition (tree mixture regulation), improving the tree quality by starting a *single-tree oriented treatment* procedure (stem shaping, for both close and wide spacing situations), and the start of artificial pruning (for widely-spaced trees). In addition, successional development processes should be integrated into the treatment concept. During the young stage, artificial pruning plays an important role in relation to the transition to *single-tree oriented silviculture.*

4 The most important measures: pruning and thinning

Pruning should take place at a very early stage, when tree and branch diameters are still small (Figure 3). Repeated artificial pruning or alternatively natural pruning by higher competition is needed. This leads to the early development of a clean bole, while in the second phase the crown base should be constant. Such management leads to an acceleration of pruning in the early phase and to a cessation of pruning in the second phase (Figure 4). In naturally regenerated stands, care should be taken to avoid the loss of the existing potential for valuable species and trees. Many target species (e.g., wild service tree, wild cherry) are not very competitive during the early stages and may rapidly disappear if a high competition level is maintained to enhance natural pruning. A good balance between these two constraints should be maintained.

Figure 3: Trees should be young and branches should have small diameters when starting the application of artificial pruning (above – before pruning; below – after pruning) (photos: V.N. NICOLESCU)

Abbildung 3: Zum Zeitpunkt der ersten Astung sollte der Baum jung und die Astdurchmesser noch gering sein (oben: vor, unten: nach der Astung) (Fotos: V.N. NICOLESCU)

Thinning. In the second phase, the diameter growth should be as high as possible. This goal can be achieved by thinning, which allow the trees to expand their crowns. Another important aspect to avoid is the dieback of the lower crown branches that can reduce the bole quality. Since there

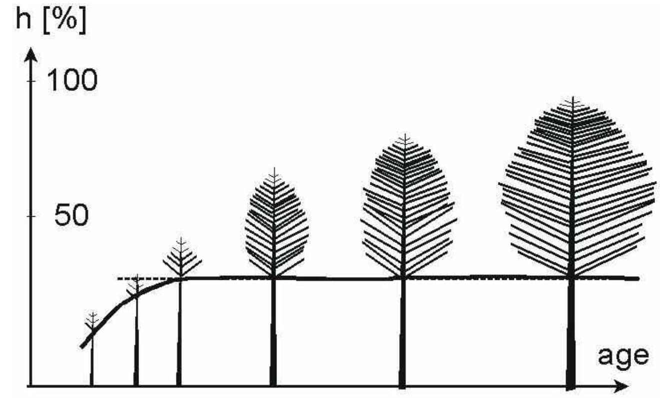

Figure 4: In order to improve the quality of trees a two-phase management system is needed. The natural pruning is stimulated in the first phase while the diameter growth is stimulated in the second phase (after SPIECKER and SPIECKER, 1988)

Abbildung 4: Ein „zweiphasiges Pflegekonzept“ wird für die Qualitätsverbesserung des Einzelbaumes benötigt: in der ersten Phase wird die natürliche Astung stimuliert, während das Durchmesserwachstum in der zweiten Phase angeregt wird. (nach SPIECKER and SPIECKER, 1988)

is a close correlation between crown diameter and stem diameter (dbh) (Figure 5), the release of tree crown means that the diameter growth will be accelerated. While the diameter growth may be lowered to some extent at the beginning of the pruning phase, it is maintained at a high level in the second phase (Figure 6).

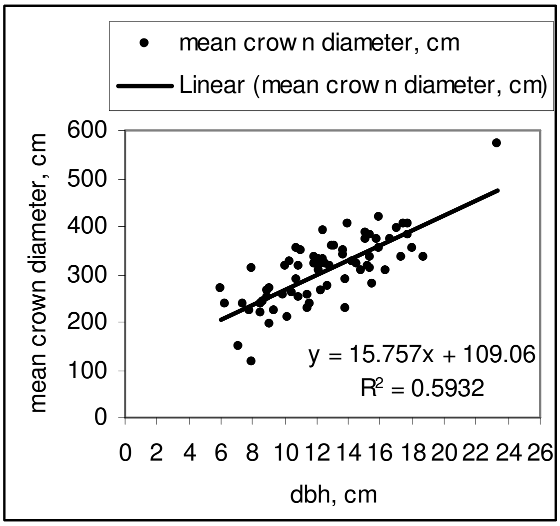

Figure 5: Correlation between stem diameter (dbh) and mean crown diameter in young common ash trees (data from NICOLESCU, unpublished)

Abbildung 5: Beziehung zwischen Stammdurchmesser (dbh) und durchschnittlichem Kronendurchmesser junger Eschen (Daten von NICOLESCU, unveröffentlicht)

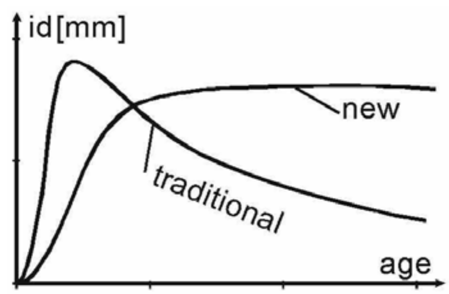

Figure 6: Diameter increment (id) within traditional management and new management. While, traditionally, the diameter increment slows down with age, with the new recommended management approach the diameter increment stays on a high level (after SPIECKER, 2003)
Abbildung 6: Entwicklung des Durchmesserzuwachses (id) für traditionelle und neue Pflegekonzepte (nach SPIECKER, 2003)

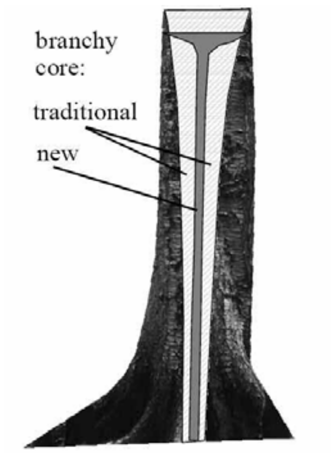

Figure 7: Comparison of the proportion of timber without internal defect branches in the traditional and new management systems. The two-phase management system increases the volume of clear timber (after SPIECKER, 2006a)
Abbildung 7: Vergleich von Stammanteilen ohne innere Astfehler für traditionelle und neue Pflegekonzepte (nach SPIECKER, 2006 a)

The result of this management approach is that, within the tree bole, the branchy core will be much smaller, especially in the upper part of the tree (Figure 7).

The time of harvesting depends on the current and expected net value production of the individual tree, the time preference of the forest owner expressed by the interest rate and other objectives and the expectations of the forest owner. As some timber defects are age-dependent and vary with tree species and site conditions, no single optimum rotation can be given for different valuable broadleaved tree species.

More species-targeted information on the best management practices for valuable broadleaved tree species will be found in a series of review papers, produced within the EU COST E42 Action "Growing valuable broadleaved tree species" (VALBRO) and due to be published in special issues of the journals *Forestry* (2009) and DIE BODENKULTUR (this issue).

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