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Methodological basis of Black Locust (*Robinia pseudoacacia* L.) regeneration by coppicing: case studies

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SUMMARY

In countries struggling with timber shortage, including Hungary, fast-growing tree species such as black locust (Robinia pseudoacacia L.) offer the possibility of meeting an increasing proportion of timber demand from domestic sources through more efficient use of cultivation opportunities. Coppice forest management is the oldest, but also the simplest and, in most cases, the most cost-effective method of operation. In this paper, we present the timber production criteria for the coppice regeneration method, including the accelerated determination of the timber stock of black locust parent stands through case studies.

Keywords: *forest management; rootstock; criteria of coppicing*

INTRODUCTION

Due to its widespread cultivation, black locust covers approximately 24% (458,296 hectares) of the country's forest area and accounts for 13.9% of the total timber stock of Hungarian forests. One-third of black locust stands are seed-grown, while two-thirds are coppice-grown (NLC, 2025). The advantageous cultivation characteristics of this tree species (rapid growth, relative plasticity in the face of unfavourable growing conditions, excellent sprouting ability, versatile usability of its wood, etc.) are widely known, and these characteristics are also of increasing importance in mitigating the adverse effects of climate change in future forest management (timber production) (Nicolescu et al., 2020).

It is also important to note that black locust is considered one of the most important tree species for plantation-type timber production (forestry) both now and in the future. This is especially true when working with improved (selected) black locust varieties (Ábri et al., 2023). Forest management methods that are in harmony with nature and mainly involve slow-growing deciduous tree species are rarely or never applicable in black locust plantations, so we cannot expect black locust plantations to provide the same forest conditions as those of native and natural tree species in our country (Vítková et al., 2017; Nicolescu et al., 2018; Slabejová et al., 2019).

Over the past decades, forestry research has precisely determined the site requirements of black locust. Studies on this subject have confirmed the earlier practical experience that this tree species can be grown successfully in a wide range of habitats. In addition to its outstanding habitat utilization, its annual absolute dry wood production can reach 8–12 t ha^{-1} in good sites, and assuming approximately the same ecological conditions, only hybrid poplars surpass it. At the same time, the high Ca content of black locust foliage also plays a significant role in maintaining the base balance of the soil. The N content of black locust foliage is also significant, with N bound by Rhizobium bacteria returning to the soil through fallen foliage (Keresztesi, 1988; Nicolescu et al., 2020).

This publication presents the biological basis of black locust coppicing with authoritative background literature, as well as accumulated practical experience (case studies) and the latest research, development, and innovation results.

A short overview of Black locust coppicing in Hungary

The first scientifically rigorous description of the natural regeneration of black locust (from sprouts) can be found in Vadas's work entitled Az ákácfa monográfiája (The Monograph of Black Locust) (1911). The author states that black locust sprouts best from roots among all tree species. This ability of black locust should not be ignored, but rather put to good use in forestry. It owes its rapid spread to this beneficial characteristic. With this in mind, the trees are either uprooted or the stump is dug around and the tree is cut down at the root. When removing the trees, great care had to be taken to ensure that the thicker, easily removable roots of the tree, which spread far into the upper layer of the soil, remained in the ground, because it was from these roots that the new forest had to be created. Another advantage of clear-cutting was that this method allowed larger areas to be reforested than with stump sprouts. This is because only one or two of the shoots originating from stumps could be grown into trees. The root shoots sprouted more densely, completely covering the area in most cases, and thus the closure of the coppice occurred earlier (usually at the age of two). The renewal of black locust by clearing or cutting around was only possible on more compact soils. In areas with shifting sands, water erosion, and soil slippage, the author continued to recommend the clear-cutting method of renewal. Among black locust forests originating from coppicing (coppice forest types), the author recommended regular coppice forests (cutting cycle of 20–25 years, with the highest average growth at age 25), the pollarding coppice forest (coppice shoots formed around the cutting area are cut

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at the age of 3–6 years) and the pruned coppice forest (with a cutting cycle similar to the former). The latter two forest types did not belong to the actual forest management types, as they mainly served a protective function.

One of the key issues in black locust management in the first decades of the 20th century was choosing the right method of regeneration (Roth, 1953). One of the most advanced cultivation techniques of the time was developed by Forgách (1926, 1939) on the sandy soils of the Nyírség region. The basis of cultivation was the principle of high forest systems and rotation. The question of whether to renew black locust trees by planting seedlings or by coppicing was the subject of much debate. Mainly because it was observed on the sandy soils of the Great Hungarian Plain that after the second or even more so after the third cutting, the growth rate of the shoots decreased significantly, which was reflected not only in a decrease in wood production but also in a deterioration in soil condition and quality (Roth, 1953). In the meantime, it was also observed that this decline was caused by the "exhaustion" of the roots, and it occurred even when the black locust was not cut to stumps but to root shoots. Leaving the stumps was already considered a mistake at the time (in the first decades of the 20th century) for several reasons. The stumps of older black locust trees sprouted less and less well with age, and rot spread easily in them. Stump sprouts usually started from a very small area and were densely located around the cut surface. The root sprouts, which densely covered the soil, took away a lot of nutrients from the stump sprouts. The shoots on the stumps could easily break off, and the wind or snow also broke many of them. However, the roots remaining after the stumps were removed by stump grinding sprouted over a much larger area. The latter initially grew faster than the trunks grown from seed, producing a larger wood volume (wood mass). Roth believed that the black locust stands should only be coppiced once, and then the stumps and roots should be completely removed after the second cutting cycle. After that, the area should be kept clean for two years with intermediate agricultural cultivation, and then in the third year, the regeneration should be carried out with one-year-old seedlings, while maintaining the intermediate agricultural cultivation.

The profession's previous viewpoint, which generally prohibited multiple coppicing, was justified as long as stump pruning was common practice. The deterioration of the heartwood (heart rot), the decline of its technical properties and usability, the loss of stability of multiple coppiced stands, the gradual decline of health, and the spread of canker and other diseases justified the negative opinion of professional circles at the time.

The next major figure in Hungarian black locust research in the early 1930s was Zoltán Fekete (1938, 1951, 1955, 1960). He used the results of his extensive studies of tree stand structure and wood production in black locust stands, including those of coppice origin, to compile his wood volume and wood production tables. He also wrote a comprehensive study on the stand structure of black locust stands of coppice origin. In addition to the aforementioned Fekete, other well-known experts in the field expressed their opinions on the cultivation and development of this tree species, including Béky (1955), Fehér (1955), Keresztesi (1955) and Roth (1955). Babos (1965) and Járó (1953, 1979) achieved outstanding results in determining the site requirements of black locust.

Keresztesi (1988) was one of the leading figures in the comprehensive cultivation and development of black locust. His scientific and practical work covered all forestry disciplines related to this tree species. In the meantime, coppicing technology has continued to develop. The invention of a deep-tilling machine with loosening wings that ensure root removal has reduced the need for mechanical stump removal, which requires a large amount of energy and costs (Danszky, 1972). Experiments in forest regeneration without stump removal, ensuring spatial order, were also launched, as a result of which Kapusi (1981) developed this technology in the Nyírség region. Using various mechanical tools, shredders, and soil cultivation discs (initially forestry roller), soil cultivation was also made possible between the parallel cut root shoots.

In 1986, the Hungarian Forest Research Institute (FRI) published a research report examining the composition and value of the forest stand and the health status of the tree population using different restoration methods in the parcels of the forest subcompartment 2F Ófehértó, Baktalórántháza Forestry, Nyírerdő Ltd. as a result of the third coppicing. The results partly confirmed the practice but came as a great surprise to the researchers. The coppiced black locust stands did not deteriorate in terms of quality or wood yield; in fact, the volume of final timber stock improved by one timber production class compared to the previous stands. Their health was no worse than that of the seed-grown trees, and their selection distribution and value yield were also better than those of the seed-grown tree stands. The above results can be explained in part by professional factors. Over several generations, the proportion of individual trees with better trunk quality has steadily improved as a result of professional thinning (cleaning, thinning). This conscious selection proved to be effective, as the forester's intervention and forest cultivation activities created higher-quality, stable genetic populations (Bujtás et al., 1987; László, 1993).

Based on more than two decades of practical experience and research and development results, views on coppicing should be reconsidered and evaluated using decision-making tools that strive for objectivity (László, 1993; Rédei, 2015). Where the final harvest of the parent stands to be coppiced is justified by the phenotypical characteristics of the majority of trees meeting the requirements of quality timber production and by economic necessity, regeneration from root suckers should not be prevented. Contrary to the general negative attitude, the decision to do so must be made after careful consideration. If the coppice stock consists of poor-quality trunks in a good black locust growing site, it should be renewed from

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seed or selected varieties. If coppicing is justified in a given location, it should be applied.

Criteria for regeneration of black locust stands

The topic of black locust forest restoration is one of the cornerstones of the tree species' cultivation and development. Choosing the method of regeneration requires a detailed analysis of the forest stand. It is well known that most forest managers prioritize natural regeneration (from root suckers) over artificial regeneration, which still largely requires complete soil preparation, primarily for the purpose of cost savings.

Recurring questions during the coppicing of black locust stands:

- which stands with what wood production capacity are worth coppicing,
- how many times is it worth coppicing, taking into account ecological and stand conditions,
- which indicator(s) should be used to determine the coppicing criterion(s),
- what effect repeated thinning has on the tree stand structure and timber production factors of black locust stands.

Below (in the section of Materials and Methods), we describe a method for determining thinning criteria based on wood production, which, due to its relative simplicity, can be easily applied to the planning and implementation of black locust stand regeneration (Rédei, 1987, 2015; Honfy et al., 2021).

Aims of the study

This publication presents the biological foundations of black locust coppicing, supported by authoritative background literature, extensive practical experience, and the latest research, development, and innovation findings. Although the cultivation technology discussed has long been used successfully in Hungarian black locust cultivation (Keresztesi, 1988; Rédei, 2015), the authors nevertheless intend their work to fill a gap by helping with these case studies to make the cultivation of this tree species more productive and to effectively meet the quality requirements of timber production.

MATERIALS AND METHODS

Determining the wood stock of the parent stand

Several indicators can be used to determine the timber production criteria for the regeneration method. Among these, the final timber stock can be determined relatively quickly in practice. This purpose is served by the standard basal area (BA) – timber volume (V) table, compiled on the basis of black locust stands – timber production studies (*Table 1*).

Table 1. **Table for determining the timber stock of black locust stands, indicating the possible number of coppicing (based on Rédei, 2015 and Honfy et al., 2021)**

H (m)	BA (m^{-2}/ha)	V (m^{-3}/ha)	N (pcs ha^{-1})	Average tree spacing (Δ structure, m)	Comments
7	*5.0*	*25*	*3 300*	*1.8*	In the case of protective forests, it can be coppiced, or tree species replacements are necessary for restoration.
8	*6.2*	*33*	*2 510*	*2.1*	
9	7.3	42	2 020	2.4	
10	8.4	52	1 680	2.6	
11	9.5	63	1 435	2.8	
12	10.4	73	1 250	3.0	
13	11.4	85	1 100	3.2	
14	12.5	98	985	3.4	
15	13.5	111	890	3.6	
16	14.5	125	810	3.8	
17	*15.3*	*138*	*740*	*4.0*	May be coppiced once
18	16.3	154	685	4.1	
19	17.2	170	635	4.3	
20	*18.2*	*187*	*590*	*4.4*	To be coppiced once
21	19.1	205	550	4.5	
22	19.9	221	520	4.7	
23	20.8	241	490	4.8	
24	*21.8*	*260*	*460*	*5.0*	To be coppiced twice
25	22.7	280	440	5.1	
26	23.5	299	416	5.3	
27	24.4	321	396	5.4	
28	25.3	343	377	5.5	
29	26.2	366	360	5.7	
30	27.1	390	345	5.8	

H = mean height, BA = basal area per hectare, V = volume per hectare, N = number of stems per hectare

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These tables are widely used in several countries (Pretzsch, 2009; Nicolescu et al., 2020; Kraszkiewicz, 2021; Ciuvăț et al., 2022) for the accelerated determination of timber volume using the basal area ratio (BA_{actual}/BA_{table}), where $V_{actual} = V_{table} \times (BA_{actual}/BA_{table})$. Their advantage is that their use does not require knowledge of the age and growth class of the tree stand, only the average tree height.

The basal area per hectare of the tree stand can be determined either directly (using some measuring device) or by calculation based on the planting pattern (number of stems) and the average breast height diameter weighted by the basal area.

The equation describing the relationship between the volume per hectare (V) and the basal area (BA) is as follows:

$$V=6.6524+1.4232\times BA+0.4692\times BA^2 \quad (1)$$

The data provided are in line with the national black locust cultivation guidelines, taking into account the economic aspects of black locust management. An important additional consideration is that repeated generations of coppice, especially in weaker wood production classes, result in lower total wood production.

The choice of regeneration method in black locust (*Robinia pseudoacacia* L.) stands was evaluated based on stand height and gross above-ground wood volume, following published tables and experimental results (Rédei, 2015; Honfy et al., 2021). Stands exceeding 24 m in height and 260 m³ ha⁻¹ in volume were classified as suitable for two coppicing cycles, whereas those between 20–24 m and 190–260 m³ ha⁻¹ were considered suitable for one coppicing cycle under profitable management. Stands with 17–20 m height and 140–190 m³ ha⁻¹ volume were assessed individually, and coppicing was recommended only under specific conditions. Stands below 17 m height and 140 m³ ha⁻¹ volume were designated for thinning or regeneration with tree species replacement, particularly in protective forests. Coppicing (root suckering) was considered applicable where stands were healthy, structurally uniform, and productive, or where site/topographical limitations precluded more valuable alternatives.

Stand inventories were conducted by NEFAG Ltd. in the Monor and Pusztavacs Forest Districts, specifically in stands located near the settlements of Csévharaszt, Üllő, Kóka, and Pusztavacs (Central Hungary) (*Figure 1*). The sites are characterized by forest-steppe climate, free-draining site, humous sandy soils with medium depth. The inventory data, derived from these experimental stands, were used to compile a data series and were further supplemented with regeneration recommendations based on an auxiliary evaluation table.

Figure 1. **Location of the study sites**

RESULTS AND DISCUSSION

The forest management plan requirements for the method of regeneration in the case of the black locust stands examined near settlements of Csévharaszt, Kóka and Üllő are entirely consistent with those recommended in the auxiliary table (*Table 2* and *Figure 2*).

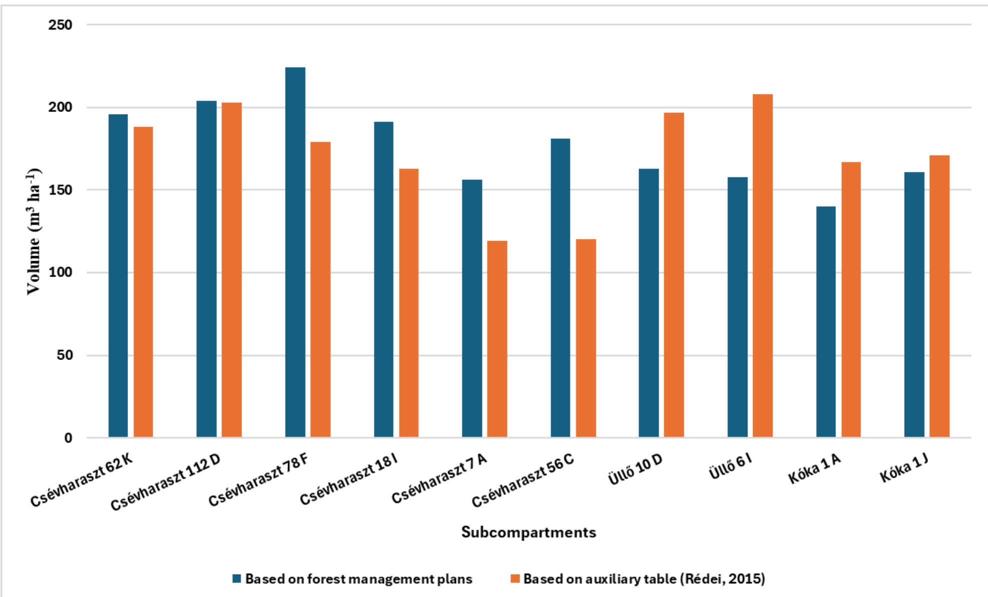
DOI: 10.34101/ACTAAGRAR/2/16120

Table 2. **Regeneration ability of the examined black locust trees from root suckers (NEFAG Ltd., branch office Monor)**

Subcompartment	**Actual**		**Based on the Forestry's forest management plan**			**Calculated volume based on the auxiliary table**	**Calculated total basal area based on the auxiliary table**	**Proposal for the regeneration of the examined black locust stand based on the auxiliary table**
	Tree species	**Age (yr)**	**Regeneration**		**V (m^3 ha^{-1})**	**V (m^3 ha^{-1})**	**BA (m^2 ha^{-1})**	
			Tree species	**Method**				
Csévharaszt 112 D	R. p.	37	R. p.	C	204	203	22.3	To be coppiced once
Csévharaszt 78 F	R. p.	31	R. p.	C	224	179	22.6	May be coppiced once
Csévharaszt 18 I	R. p.	34	R. p.	C	191	163	20.5	May be coppiced once
Csévharaszt 7 A	R. p.	32	R. p.	C	156	119	16.0	In the case of protective forests, it can be coppiced, or tree species replacements are necessary for restoration
Csévharaszt 56 C	R. p.	33	R. p.	C	181	120	17.5	In the case of protective forests, it can be coppiced, or tree species replacements are necessary for restoration
Üllő 10 D	R. p.	34	R. p.	C	163	197	22.2	To be coppiced once
Üllő 6 I	R. p.	30	R. p.	C	158	208	23.4	To be coppiced once
Kóka 1 A	R. p.	33	R. p.	C	140	167	20.5	To be coppiced once
Kóka 1 J	R. p.	33	R. p. -G. p.	C	161	171	21.6	To be coppiced once

Tree species: G. p. – Grey poplar (*Populus* × *canescens*), R. p. – Black locust (*Robinia pseudoacacia*). Method: C – Regeneration by coppicing (root suckers) after clean cutting

Figure 2. **Volume of the examined black locust stands (NEFAG Ltd., branch office Monor)**



DOI: 10.34101/ACTAAGRAR/2/16120

Based on *Table 3* and *Figure 3*, in the following seven forest subcompartments near settlement of Pusztavacs, the regeneration of black locust stands from root suckers can be recommended as an alternative to the forest management plan.

In the case of black locust stands in good growing sites (Pusztavacs 9A and Pusztavacs 233A forest subcompartments), coppicing is unlikely to result in a decline in timber volume, but at the same time, regeneration through tree species replacement (primarily pedunculate oak) is also fully justified and legitimate.

Based on the examination of black locust stands growing in medium-quality sites (in addition to ecological conditions) (Pusztavacs 69C, Pusztavacs 161A, Pusztavacs 161C forest subcompartments), one-time (additional) coppicing is a realistic alternative. In the black locust stands where we may recommend coppicing (Pusztavacs 163B, Pusztavacs 163C, and Pusztavacs 219A forest subcompartments), the success of tree species replacement, especially in the case of pedunculate oak (*Quercus robur* L.), may involve risks. In our opinion, coppicing the black locust trees in these sites and artificially restoring them with native poplars [Grey poplar (*Populus × canescens*)] may be more effective in the long term.

Table 3. **The regeneration ability of the examined black locust trees from root suckers (NEFAG Ltt., branch office Pusztavacs)**

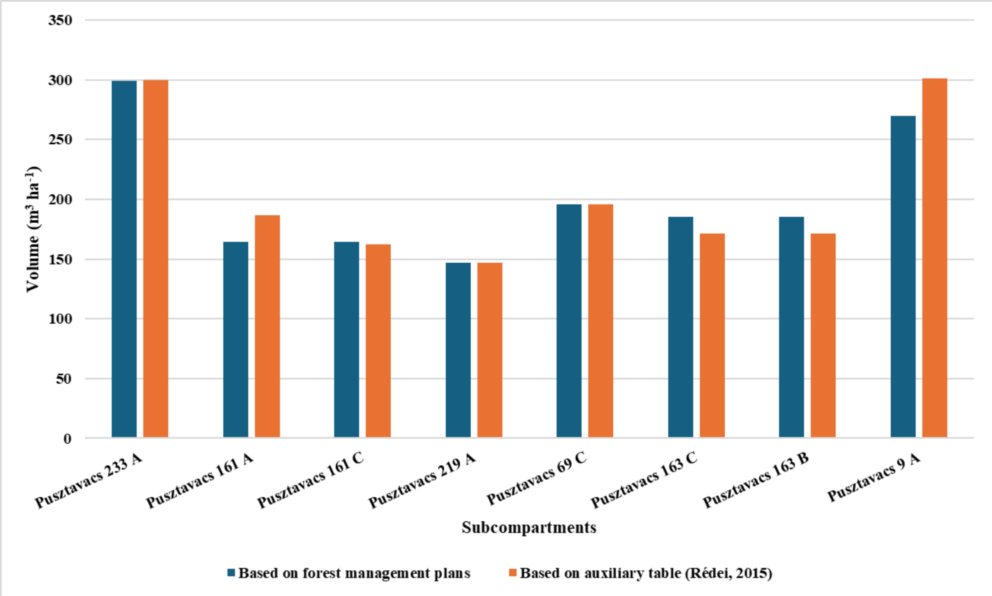
Subcompartment	**Actual**		**Based on the Forestry's forest management plan**			**Calculated volume based on the auxiliary table**	**Calculated total basal area based on the auxiliary table**	**Proposal for the regeneration of the examined black locust stand based on the auxiliary table**
	Tree species	**Age (yr)**	**Regeneration**		**V (m^3 ha^{-1})**	**V (m^3 ha^{-1})**	**BA (m^2 ha^{-1})**	
			Tree species	**Method**				
Pusztavacs 233 A	R. p.	44	Q. r.	A. R.	299	300	28.8	Expected to be coppiced twice
Pusztavacs 161 A	R. p.	32	R. p.-G. p.	A. R.	164	187	22.1	To be coppiced once
Pusztavacs 161 C	R. p.	32	R. p.-G. p.	A. R.	164	162	18.8	May be coppiced once
Pusztavacs 219 A	R. p.	28	Q. c.-Q. r.	A. R.	147	147	18.3	May be coppiced once
Pusztavacs 69 C	R. p.	42	R. p.	A. R.	196	196	22.7	To be coppiced once
Pusztavacs 163 C	R. p.	33	Q. c.-Q. r., R. p.-G. p.	A. R.	185	171	21.2	May be coppiced once
Pusztavacs 163 B	R. p.	33	Q. c.-Q. r.	A. R.	185	171	21.2	May be coppiced once
Pusztavacs 9 A	R. p.	47	R. p.	A. R., C	270	301	28.8	Expected to be coppiced twice

Tree species: G. p. – Grey poplar (*Populus × canescens*), Q. c. – Turkey oak (*Quercus cerris*), Q. r. – Pedunculate oak (*Quercus robur*), R. p. – Black locust (*Robinia pseudoacacia* L.). Method: A. R. – artificial reforestation, C – Regeneration by coppicing (root suckers) after clean cutting

Summarizing our results and experiences gained during the field surveys, we recommend that the following general guidelines be considered. (1) The forest stands to be coppiced should be uniform, approximately evenly closed, healthy and well-grown, but not overgrown or genetically defective. (2) Do not coppice black locust trees that have been harvested during the intensive growth phase (June, July) or in areas that have been cut for more than a year. (3) Avoid coppicing three or more times, even if the primary goal is not timber production. It should be noted here that it is not always possible to determine the exact number of generations. (4) Genetically valuable black locust trees with seed origin should be coppiced everywhere where tree replacement is not justified, provided that other criteria are also met.

DOI: 10.34101/ACTAAGRAR/2/16120

Figure 3. **Volume of the examined black locust stands (NEFAG Ltd., branch office Pusztavacs)**



CONCLUSIONS

In Hungary, black locust coppicing plays the most important role and is expected to remain so in the future. This tree species regenerates excellently from both stumps and roots. Even in protective forests, no more than two coppicing cycles (stump coppicing) should be allowed. The aim is to prevent the subsequent complete deterioration of the stand. Repeated coppicing is one of the reasons why such large areas of degraded tree stands have been created in Hungary. Notwithstanding this fact, root coppicing is an acceptable method of black locust regeneration, especially if the spatial arrangement of the sprouts is established by tearing up the roots. Root sprouts appear scattered and irregularly in the area even without tearing, but in most cases not in sufficient numbers.

The soil protection role of black locust can be indispensable in the recultivation of mines and the stabilization of sloping areas. It can provide protection (against wind, snow, sand, etc.) for natural formations, plant groups, and inanimate formations. Given that black locust is not a native tree species in Europe, it may only be present in protected forests in exceptional cases and may not replace our native tree species.

The conversion of coppice forests has often been part of Hungarian forestry tasks over the past half-century due to the high proportion of coppice stands (sessile oak, turkey oak, beech, hornbeam, black locust). Intensive forest management achieved significant results relatively quickly in Hungary after World War II. This was largely due to the conversion of coppice forests. Regulations prescribed and financially encouraged the conversion, which was subject to a deadline. In the future, it will still be necessary to replace coppice forests with high forests in larger areas where justified. Forest regeneration is the most important method of conversion, which in this case must also be preceded by a thorough examination of the growing site and forest stand.

Artificial regeneration is a radical method of converting coppice forests, which is mainly used when the tree species composition of the stand to be regenerated also needs to be changed. In the past, a significant proportion of coppice forests in Hungary were classified as "degraded forests". The multi-purpose use of forests and, in particular, the growing importance of the forest ecosystem approach have somewhat changed this perception. When deciding on the conversion of coppice forests, the ecological characteristics and long-term purpose of the forest stand in question must therefore be carefully considered.

Finally, we can conclude that the quality of a country's forest management cannot be determined by the extent of coppice forest management. Their size does not indicate technological backwardness, but is partly related to the historical situation of forest management in Hungary. According to future plans, forestry work must strive to produce larger volumes of timber, larger sizes and better-quality wood, and consequently reduce coppice forests to a reasonable extent.

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