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Plantation Silviculture of Black Locust (*Robinia pseudoacacia* L.) Cultivars in Hungary – A Review

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ABSTRACT

Background and Purpose: Black locust (*Robinia pseudoacacia* L.) is the most widespread tree species in Hungary, occupying approximately 24% of the forested land and providing 25% of the annual timber output of the country. Due to the demands of consumers new cultivars are to be produced by improvement techniques and introduced into practical forestry use. This review provides a practice-oriented survey on black locust cultivar's management in Hungary.

Material and Methods: There are several cultivars and cultivar-candidates for high volume, high quality saw logs; for pole and prop, fuelwood and fodder production, of which there are several multipurpose varieties. Tending guidelines of stands established with the selected black locust cultivars are in some ways different from stands established by seedlings or regenerated by coppicing.

Results and Conclusion: It is important to know how stand density influences production and how it can be manipulated. This has already been worked out for most of the major European tree species that can be grown plantation-like. Many countries have some form of production or yield models based on various spacing and thinning regimes, which are usually entered via site index curves based on height and age. Black locust plantation silviculture can come to be synonymous with high-input intensive management of monocultures for the production of a relatively narrow range of industrial products. However, there is no doubt that plantation silviculture will become increasingly important in more and more countries with special regard to the marginal site conditions.

Keywords: clonal approach, growth, growing space, yield

INTRODUCTION

Black locust (*Robinia pseudoacacia* L.) is the most widespread tree species in Hungary, occupying approximately 24% of the forested land (465 thousand hectares) and providing 25% of the annual timber output of the country [1]. The mean wood volume of all black locust forests is 125 m^3·ha^{-1}, with a mean volume of 190 m^3·ha^{-1} at the final cutting age (31 years on average). Black locust forests in Hungary have been established on good, medium and poor quality sites. The production of good-quality timber is only possible on sites where adequate moisture is available and the soil is loose, well aerated, and rich in nutrients and organic matter. Black locust forests on medium and poor quality sites are managed for the production of fuel wood, fodder, poles, props, and for amelioration [2, 3].

Black locust can be regenerated naturally, from root suckers, or artificially, with seedlings. To establish new black locust plantations (stands) seedlings are used. There are some favourable biological features of black locust, which make both regeneration methods possible. For seedlings production seeds are produced in a wide range of climatic conditions, they germinate rapidly, and preserve their germination capacity for a long time. Black locust cannot be regenerated by seeds in natural way due to its very hard seed coat. On the other hand, the root system is very plastic, its vegetative growth from fragments is intensive and it is hard to uproot [4].

Besides Hungary, Romania, and Bulgaria where black locust has a great importance in forestry practice, there are two big regions where the fast spread of this tree species can be expected: in the Mediterranean countries of Europe (Italy, Greece and Turkey) and in Asia, where China and Korea may be the most prominent black locust growers. In these regions, black locust has been widely valued as a tree species that performs well in reclaiming disturbed lands as well [5].

MATERIAL AND METHODS

Black Locust Selection Programme in Hungary

Since the introduction of black locust into Hungary this tree species has been closely associated with agriculture, since its wood can be utilized for many agricultural and domestic purposes. After World War II its significance changed, because large-scale farms had less demand for wood and the timber industry was not willing to buy black locust wood. It was necessary to improve the quality of final products of black locust forests in order to meet the demands of consumers. Therefore, new cultivars had to be produced by improvement techniques introducing them into the practical forestry use [5].

To fulfil the above-mentioned tasks, a new strategy of several stages started in the Hungarian Forest Research Institute in 1961. The improvement strategy aimed to improve the quality of black locust stands, which were considered to be separate provenances. In the best black locust stands, tree groups of shipmast stem forms, and then plus trees were selected by B. Keresztesi and his colleagues [6]. The offspring of these selected trees were vegetatively propagated and grouped together into cultivars. Thus, cultivars are mostly composed of several clones, but there are also some one-clone-cultivars, too [7].

Grafts with shoots taken from plus trees were made and planting stocks were raised from them by green cuttings. The basic material produced in this way served as starting material with the help of a variety trial established in the Arboretum of the Hungarian Forest Research Institute in Gödöllő, on a rusty brown forest soil developed over sand. The development of this trial continues up to date. In the meantime, breeding aims were widened by taking the demands of bee-keeping into consideration, such as the onset and length of flowering, and nectar yields [6, 8]. Some trees were selected abroad and others in Hungary and were chosen by beekeepers, due to their excellent honey production.

The main target of improvement is to improve the quality of stem, so to increase the output of industrial wood. Based on timber volume at felling age the following cultivars may be assessed as best: *'Jászkiséri'*, *'Üllôi'*, *'Nyirségi'*, *'Kiskunsági'*, *'Kiscsalai'* and *'Pénzesdombi'*. At the moment 7 black locust cultivars are approved by the competent Hungarian national office.

Propagation of cultivars was first planned by seedlings, but seed orchards produced small quantities of seed, and therefore it was necessary to develop techniques for vegetative propagation (with green cuttings, root cuttings and micropropagation) [6].

Site Requirements for Successful Black Locust Plantation Silviculture

The variable nature of geographical conditions in Hungary and the large area of black locust stands have made it possible to determine its site demands and to characterize suitable sites. This task has been solved by the Hungarian system for forest site classification [9, 10]. The classification is based on four dominant factors, which are: climate, hydrologic conditions (non-precipitation water resources, such as ground-water, inundation waters etc.), genetic soil type, physical make up and rootable depth.

The climatic conditions in the sessile oak - Turkey oak (Table 1) and forest-steppe zones of Hungary (Table 2) cover the black locust's requirements [11]. It is susceptible to late and early frosts, and therefore it is not recommended for sites in higher hilly zones and in areas where frost hollows are present. Good results can be attained in regions where the mean annual temperature is over 8˚C.

The genetic soil type, soil depth and physical properties of the soil are the factors which must be regarded before the planting operation as well. From this point of view soils of shallow rootable depth, of poor water regime and coarse sand or with many stones are unfavourable. Clay texture is also unfavourable due to poor aeration and compact condition. Fine sands and light loamy soil types are good for black locust, provided the depth of the soil is enough [10].

RESULTS

Recommendations for Tending Operations (Enlargement of Growing Space) for Black Locust Cultivar Plantations

Tending guidelines of stands established with the selected black locust cultivars are in some ways different from the stands established by seedlings or regenerated by coppicing. It is harder to separate the tending phases (cleaning, thinning), which are typical for common black locust stands, because growth properties of monoclonal cultivars are theoretically identical, while multiclonal ones are similar to each another. The aim of certain tending cuttings particularly is to form the growing space for optimal growth of the trees [12].

On good and excellent sites altogether two enlargements of growing space are applicable to produce basic material of sawmilling industry in stands planted in 2.5×2.0 m spacing (5 m^2·tree growing space^{-1}) (Table 3). During the first enlargement of the growing space (at the age of 9-10) stem number reduction is approximately 50%, so spacing will be 2.5×4.0 m (10 m^2·tree growing space^{-1}) after the tending. The second enlargement of the growing space (at the age of 16-17) also reduces the number of stems by 50%. During this, the greater part of the yield is already suitable for industrial utilization, so growing technology can be considered economically profitable.

Prospective tree plantations of the selected black locust cultivars with tending according to the demonstrated model in Table 4 are rentable only on excellent and good sites. In case of planning to reduce harvest rotation ages (20-25 years) the aim of the growing can be manufacturing pole, or saw log of lower size limit.

TABLE 1. Site types suitable for black locust in the sessile oak - Turkey oak climate zone [8].

Site type variety				Expected yield and rotation age
Genetic soil type	**Hydrology**	**Rootable depth**	**Physical make-up**	
Humic sand	free draining	shallow	sand	poor
Rusty brown forest soil	free draining	shallow medium deep deep	sand sand sand loam	poor medium, 25 years good, 30 years good, 30 years
„Kovárvány” brown forest soil	free draining	shallow medium deep deep	sand sand sand	medium, 25 years good, 30 years good, 30 years
Chernozem brown forest soil	free draining	shallow medium deep	loam loam	poor medium, 25 years
Brown forest soil with residual carbonate	free draining	medium deep	loam loam	medium, 25 years good, 30 years
Colluvial forest soil	free draining	medium deep	loam	good, 30 years
Rusty brown forest soil	periodic water influence	medium deep deep	sand sand	good, 25 years good, 30 years
„Kovárvány” brown forest soil	periodic water influence	medium deep deep	sand sand	good, 25 years good, 30 years
Meadow soil	periodic water influence	shallow	sand	medium, 25 years
Meadow forest soil	periodic water influence	medium deep	sand	medium, 25 years

TABLE 2. Black locust site types in the forest-steppe climate region [8].

Site type variety				Expected yield and rotation age
Genetic soil type	**Hydrology**	**Rootable depth**	**Physical make-up**	
Humic sand combinations	free draining	medium deep deep very deep	sand sand sand	poor medium, 25 years good, 30 years
Colluvial soil	free draining	medium deep	sand loam	medium, 25 years medium, 25 years
Rusty brown forest soil	free draining	medium deep deep	sand sand	poor (afforestation) medium, 25 years
„Kovárvány” brown forest soil	free draining	medium deep deep	sand sand	poor (afforestation) medium, 25 years
Leached chernozem soil	free draining	medium deep deep very deep	loam loam loam	medium, 25 years good, 30 years good, 30 years
Lime-carbonate coated chernozem	free draining	medium deep deep	loam loam	medium, 25 years good, 30 years
Meadow chernozem	free draining	medium deep deep very deep	loam loam loam	medium, 25 years good, 30 years good, 30 years
Alluvial chernozem soil	free draining	medium deep deep very deep	sand loam sand loam sand loam	medium, 25 years medium, 25 years good, 30 years good, 30 years good, 30 years good, 30 years

Yield of the Selected Black Locust Cultivars

Based on growth examinations of the selected black locust cultivars, mainly with shipmast locust character, characteristics of their growth pattern are similar to the common black locust's [8]. A yield table has been compiled for those black locust cultivars that are suitable for log production (’Nyírségi’, ’Kiskunsági’, ’Jászkiséri’, ’Appalachia’, ’Üllői’ black locust) by using the data of the growing trial established in the Arboretum of the Forest Research Institute in Gödöllő, and other areas of the country (Tét, Szentkirály,

TABLE 3. Models of enlargement of the growing space of the selected black locust cultivars. The aim of growing: saw log. Initial spacing: 2.5x2.0 m. Initial number of seedlings: 2000 stems·ha^{-1} [3].

	Label	**Age** (year)	**H** (m)	**DBH** (cm)	**N** (stems·ha^{-1})	**V** (m^{3}ha^{-1})
	Yield Class I					
1.	Enlargement of growing space	9–10	14	12	1000	90
2.	Enlargement of growing space	16–17	20	17	500	120
3.	Harvest cutting	30	25	25	400	300
	Yield Class II					
1.	Enlargement of growing space	9–10	14	12	1000	90
2.	Enlargement of growing space	16–17	20	17	500	120
3.	Harvest cutting	30	25	25	400	300
	Yield Class III					
1.	Enlargement of growing space	9–10	12	10	1000	60
2.	Enlargement of growing space	16–17	18	16	500	100
3.	Harvest cutting	30	23	23	500	240

H – height; DBH – diameter at breast height; N – number of stems per hectare; V – expected total volume
Notation: Data are referred to the dominant stand, that is stand part, after finishing enlargements of the growing space. Yield table: Rédei *et al.* [8].

TABLE 4. Models of enlargement of the growing space of plantations established by the selected black locust cultivars. The aim of growing: poles, perspectively saw log. Initial spacing: 3.0 x 3.0 m. Initial number of seedlings: 1100 stems·ha^{-1} [3].

Label	**Age** (year)	**H** (m)	**DBH** (cm)	**N** (stems·ha^{-1})	**V** (m^{3}ha^{-1})
Model I					
Before enlargement of growing space	10	13	10	1100	65
After enlargement of growing space	10	14	11	700	55
Harvest cutting	20	20	18	700	180
Model II					
Before enlargement of growing space	8	10	8	1100	40
After enlargement of growing space	8	11	9	750	35
Before enlargement of growing space	15	17	14	750	105
After enlargement of growing space	15	18	15	500	85
Harvest cutting	25	22	20	500	180

H – height; DBH – diameter at breast height; N – number of stems per hectare; V – expected total volume

Ófehértó). Table 5 shows informative data on the yields of the main stands of selected black locust cultivars suitable for saw log production.

Height growth related to the age of the main (dominant) stands of the mentioned cultivars can be seen in Figure 1 for five yield classes. The explanatory equation of the relative growth pattern is:

$$H_{gmean}=19.4669 - 57.08546 \times [\log(A)] + 73.57742 \times [\log(A)]22.80025 \times [\log(A)]3 + 28.08599 \times x [\log(A)]4,$$

where: A = age (year), and H_{gmean} at the age of 20 = 100%.

Height values at the age of 20 (base age, 100%) are: yield class I: 22 m; yield class II: 20 m; yield class III: 18m; yield class IV: 16 m; yield class V: 14 m.

Volumes related to the age of the main stands of the same varieties are shown in Figure 2. The explanatory equation for describing the relationship between mean height (H_{mean}) and volume (V_{mean}) is the following:

$$V_{mean}= 23.750 – 2.325H_{mean} + 0.512H^2_{mean}$$

DISCUSSION AND CONCLUSIONS

Since spacing influences the total production and the dimensions of forest products, it can have a profound effect on the value of a crop. It is important to know how stand density influences production and how it can be manipulated.

In practice, there are two main aspects of spacing to consider – the effects of early or initial spacing and the effects of thinning. Initial spacing are quite often the densities at which plantations remain, except for mortality, especially where thinning is uneconomic or leads to windthrow. Since the initial spacing of forestation by the selected black locust cultivars is concerned with the basis

FIGURE 1. Height of the main stands of the selected black locust cultivars for saw log production related to the age in different yield classes.

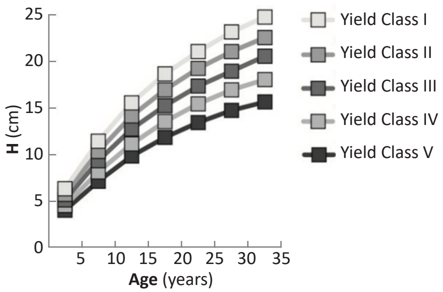

FIGURE 2. Volume of the main stand of the selected black locust cultivars for saw log production in different yield classes.

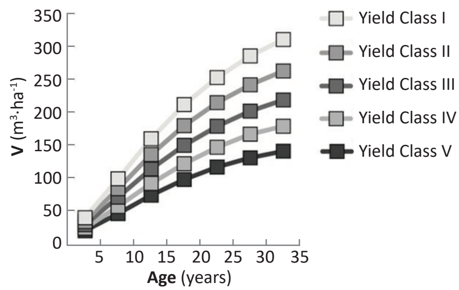

TABLE 5. Yield of the main stands of the selected black locust cultivars suitable for saw log production [3].

Yield class	Age (year)	Mean DBH (m)	Mean H (m)	V ($m^3 \cdot ha^{-1}$)	G ($m^2 \cdot ha^{-1}$)	N ($stems \cdot ha^{-1}$)
I	5	8.7	6.4	40	7.5	2327
	10	14.8	11.5	99	12.6	1214
	15	19.2	15.6	160	16.5	863
	20	22	18.7	212	19.4	703
	25	23.8	21.2	253	21.6	612
	30	25	23.2	286	23.4	554
	35	25.7	24.8	311	24.9	513
II	5	7.9	5.8	34	6.9	2588
	10	13.5	10.4	84	11.5	1350
	15	17.4	14.2	136	15.1	960
	20	20	17	180	17.8	782
	25	21.7	19.3	215	19.9	681
	30	22.7	21.1	242	21.5	616
	35	23.4	22.6	263	22.9	571
III	5	7.1	5.2	29	6.2	2911
	10	12.1	9.4	71	10.5	1518
	15	15.7	12.8	114	13.9	1080
	20	18	15.3	150	16.2	880
	25	19.5	17.4	179	18.2	766
	30	20.5	19	202	19.6	693
	35	21	20.6	219	20.8	642
IV	5	6.3	4.6	24	5.6	3374
	10	10.6	8.2	57	9.3	1769
	15	13.8	11.2	92	12.3	1249
	20	16	13.6	122	14.6	1006
	25	17.4	15.5	147	16.4	869
	30	18.3	17	167	17.8	784
	35	18.7	18.1	179	18.8	731
V	5	5.6	4.1	20	5.1	3834
	10	9.3	7.2	46	8.3	2046
	15	12.1	9.9	74	11	1343
	20	14	11.9	98	13	1168
	25	15.2	13.5	117	14.5	1014
	30	15.9	14.8	131	15.7	915
	35	16.2	15.7	141	16.6	857

of growing experiments in the Danube–Tisza sandy soil region (Central Hungary) and in the Nyírség (East Hungary), 2.5×2.0 m spacing seems to be most appropriate [12]. In forestation, those are established on sites that expectedly enable medium growing (the cultivars) varieties in wider spacing than the recommended which cannot close sufficiently because of their loose crown. Therefore, the soil is extremely weedy, even in the case of soil cultivation that corresponds to regulation, too.

It is very important to execute the stem and crown shaping according to the technological prescription. In base spacing recommended by us [5], first crown shaping is to be carried out when the mean height of the plantation reaches 5-6 metres. The second crown shaping should be done in time when the mean height of the plantation is 8-10 metres (reach of about 4 m branch-free stem is desired).

Forest tending technologies applicable for different cultivars have not yet been elaborated sufficiently. A useful indicator of the size of the removed tree, and hence for describing the thinning type, is the ratio of the mean volume of thinnings (v) to the mean volume of the main stand found before thinning (V) [5]. There are three types of thinning which can be distinguished: systematic, selective and combination [6]. According to our experiences the selective thinning method is to be used mostly in the plantations established with selected black locust cultivars. The best trees (superior trees) are marked when they are young and favoured in subsequent thinnings. Because some inevitably become damaged or do net grow as well as expected, it is necessary to work at the outset two or three times the number that will actually form the final crop.

Black locust plantation silviculture can come to be synonymous with high-input intensive management of monocultures for the production of a relatively narrow range of industrial products. But, there is no doubt that plantation silviculture will become increasingly important in even more countries with special regard to the marginal site conditions.

At the moment the total area of black locust globally is about 2.5 million ha. In the near future there are two continents, where the fast spread of black locust can be expected. The first is the Asian continent, in China and South and North Korea, while in the European continent France, Turkey, Romania and Germany may be the most prominent black locust growers.

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