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TENDING OPERATION MODELS FOR BLACK LOCUST (*ROBINIA PSEUDOACACIA* L.) STANDS GROWING ON SANDY SOILS IN HUNGARY

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Abstract: A more intensive integrated research and development approach to the work carried out on the growth on sandy soils of stands of black locust (*Robinia pseudoacacia* L.) has been adopted in recent years, revealing several factors influencing stand growth. The fact that certain ecological factors influencing fundamentally the growth of trees have become unfavourable in Hungary in recent years has led to the more extensive use of black locust in the course of afforestation and forest regeneration schemes. The study presents a new, simplified tending operation model for black locust stands and age, growing space and target diameter models suitable for quality log production and for mass assortments. The simplicity of these practice-oriented models may foster the qualitative development of black locust management in Hungary and in some other countries where this tree species may gain greater acceptance by landowners and the forest industry.

Key words: *Robinia pseudoacacia*, tending, model

MODELI MERA NEGE U SASTOJINAMA BAGREMA (*ROBINIA PSEUDOACACIA* L.) NA PESKOVITIM ZEMLJIŠTIMA U MAĐARSKOJ

Izvod: Prihvaćen je intenzivniji integrisani pristup istraživanjima i razvoju rasta sastojina bagrema (*Robinia pseudoacacia* L.) na peskovitim zemljištima, pri čemu je otkriveno nekoliko faktora koji utiču na rast sastojine. Činjenica da su pojedini ekološki faktori koji utiču fundamentalno na rast drvenastih vrsta postali nepovoljni poslednjih godina dovela je ekstenzivnijem korišćenju bagrema u vezi sa šemama pošumljavanja i obnavljanja šume. Studija predstavlja novi i pojednostavljen model mera nege za sastojine bagrema, kao i modele zasnovane na starosti, gustini zasada i ciljanom prečniku, koji su pogodni za proizvodnju kvalitetnih trupaca i sortimenata za biomasu. Jednostavnost ovih modela koji su namenjeni praksi bi mogla da podstakne kvalitativni razvoj uzgoja bagrema u Mađarskoj i u drugim zemljama gde bi ova drvenasta vrsta mogla da bude više prihvaćena od strane zemljoposjednika i šumarskih preduzeća.

Ključne reči: *Robinia pseudoacacia*, nega, model

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INTRODUCTION

Black locust (*Robinia pseudoacacia* L.) is one of the most important exotic stand-forming tree species in Hungary. Due to its favourable silvicultural and growth characteristics, as well as the possibilities for the utilisation of its wood, the area it occupies is increasing continuously (Keresztesi, 1988). The most important task facing Hungarian black locust growers is to improve the quality of its stands for wood production (Rédei et al., 2002). The area occupied by black locust in 2011 was 425 000 ha (23.8 % of the total forest area), with a standing volume of 48.1 million m³ (13.4% of the total). Its importance will continue to increase across the large areas of marginal land not suitable for the native tree species but able to accommodate black locust. Other species that may be used for the purposes of plantation forestry in addition to black locust are poplar species, red oak and black walnut. Common walnut plantations may also play a role, but the silvicultural significance of this tree species is negligible.

Black locust plantations and stands can be successfully established in response to a range of ecological and economic opportunities. Plantation survival and productivity are maximized by matching the species' growth characteristics with silvicultural options and land management needs (Rédei, 1992, 2001). From among the above listed tree species, the models for tending operations and the tables for age-growth space-target diameter models are suitable for production of large, quality wood material as well as mass assortments produced in black locust stands.

MATERIAL

The models developed are based on a yield table for black locust (Rédei, 1984, 2003). It was constructed from data gathered from 150 permanent and 50 temporary yield study sample plots (500-1000 m²). The stands sampled were located in the vicinity of N 45° 48' to 48° 35' and E 16° 5' to 22° 58'. The age of the stands varied between 5 and 45 years.

METHODS

The following parameters were measured and calculated: number of stems, dbh (diameter at breast height), basal area, tree height, stem volume and stand volume. The stem volume was calculated using the volume function based on the volume table for black locust (Sopp and Kolozs, 2000):

$$v = 10^{-8} d^2 h^1 (h/[h-1.3])^2 (-0.6326dh + 20.23d + 3034),$$

where v is stem volume (m³), d is diameter at breast height (cm) and h is tree height (m).

The collected data were analysed using STATISTICA 8.0 software (StatSoft Inc., 2008), i.e., correlation and regression analysis. The yield model was constructed using the following formulas and coefficients (Rédei, 2003; Rédei et al., 2011).

1. A = age of stand in years
2. H= mean height of the main crop weighted by the basal area (m).
 $H = 123.12 (1 - e^{-0.070333A})^{1.111638}$,
 with R= 0.995.
 H at the age of 25 = 100% .The expected height values of the main stands at the reference age according to the six yield classes are: 23.8 m, 21.3 m, 18.8 m, 16.3 m, 13.8 m and 11.3 m.
3. DBH = the diameter at breast height of the main crop (cm):
 $DHB = (69.9675 + 1.00625A) \frac{H}{100}$
 with R=0.809.
4. N = number of stems per hectare of the main crop:
 $N = e^{9.81801 - 1.15147 \times \ln DBH}$
 with R=0.942.

SIMPLIFIED TENDING OPERATION MODEL FOR BLACK LOCUST STANDS

The black locust is a fast-growing tree species, which, up to the age of 10-15 years, is able to quickly close canopy openings caused by tending operations, but the closure is much slower in later years. Height growth peaks within the first five years, while diameter growth peaks in the first decade. The peak of current annual increment is at about age 20, whereas that of the mean annual increment is at about age 35-40. To find the right cleaning and thinning intensity, the so-called growing space index is a good method. This index expresses the mean distance between trees (in a triangular pattern) as a percentage of mean height after cleanings and thinnings. The mean value of the index for black locust stands should be 23-24%. Pruning of crop trees should also be carried out. After finishing selective thinnings, stems must be free of branches up to a height of 4-6 m (Rédei, 2003).

Table 1 contains a simplified tending operation model for black locust stands. The table was compiled using data obtained from 80 long term yield and experimental tending operation plots. The choice of the most suitable spacing depends on the quality of the planting material and the particular site conditions. In the table, all of the data are presented by six yield classes. Yield (site) index curves are commonly used in forestry to quantify yield (site) quality differences. This method uses mean tree height of the main crop which is the most important model factor, because it determines the timing of the particular tending operation. Thinnings (to expand the available growing space) must be carried out when the stocking density approaches the stem number quoted in the table.

The objective of tending is to produce a high proportion of good quality sawlogs from stands of yield class I and II; some sawlogs and a high proportion of poles and props from stands of yield class III and IV; and poles, props and other small-dimension industrial wood from other yield stands. Tending operations for stands of selected black locust varieties have not yet been elaborated. Based on investigation results gained up to now, on good sites the stocking at final felling could be 500 to 600 trees per hectare, where the initial tree density was 2000 to 2500 stems per hectare. The tree density for final felling (35 to 40 years) can be attained by two thinnings. On medium good sites the initial tree density may be 3500 to 4000 stem per hectare and at felling age it may be reduced to 900 to 1000 per hectare at the age of 25 to 30 (Rédei, 2003).

Table 1. Simplified tending operation model for black locust stands^{*)}

Tabela 1. Pojednostavljeni model operacije nege za sastojine bagrema^{*)}

Tending operation <i>Operacija nege</i>	Number of tending operation <i>Broj operacije nege</i>	Tending operation <i>Operacija nege</i>			Stocking density (stems ha ⁻¹) <i>Gustina zasada stabala ha⁻¹</i>	
		To be carried out in year ... <i>Da se izvede u godini...</i>	To be carried out at H _m (m) and yield class... <i>Da se izvede pri H_m (m) i prinosnoj klasi...</i>		Tending operation <i>Operacija nege</i>	
			6-7	I-V (VI)	before <i>pre</i>	after <i>posle</i>
Cleaning <i>Rana proreda</i>	1.	5-8	6-7	I-V (VI)	>3500	2500-2700
	2.	9-13	11-12	I-IV	2500-2700	1500-1600
Thinning <i>Kasna proreda</i>	1.	14-19	15-16	I-IV (V)	1500-1600	700-800
	2.	22-24	21-22	I-III	700-800	450-550
Final cutting <i>Završni sek</i>		35-40 30		I-II III-IV	-	400-500 600-700
		25 (20)		V (VI)	-	(<1000) (<1300)

^{*)} Remarks for the use of the tending operation model: When planning the thinning operation, the better the estimated yield class, the lower the stem number value after thinning to be applied. Black locust stands in yield classes V-VI are not suitable for quality wood production. The thinning 2 is not to be carried out in these stands.

^{*)} Napomene za korišćenje modela operacije nege: Kada se planira operacija prorede važi da što je bolja procena klase prinosa, manja je vrednost broja stabala nakon prorede koja treba da se primeni. Sastojine bagrema klase V i VI nisu pogodna za proizvodnju kvalitetnih drvnih sortimenata. Kasna proreda 2 ne treba da se sprovodi u ovim sastojinama

AGE, GROWING SPACE AND TARGET DIAMETER MODELS FOR BLACK LOCUST STANDS

In plantation forestry the timing of the expansion of the available growing space is significant with respect to reaching the target assortments by maintaining the near optimal stocking density per hectare (growth space). The site (ecological) factors essentially define the target assortments; for example, whether the opportunity for

the production of sizeable, quality wood material (panel log, sawlog) exists or merely thinner wood assortments (cutting, pallet and box basic material), pulp, fibre, chippings and basic wooden board materials.

Table 2 Age-target diameter model for black locust stands targeted for quality sawlog production (DBH=18, 20 and 25 cm) and for mass assortments (DBH=10, 12, 14 and 16 cm)

Tabela 2 Starost-ciljni prečnik model za bagremove sastojine namenjene proizvodnji trupaca za mehaničku obradu (DBH=18, 20 i 25 cm) i za sortimente za biomasu (DBH=10, 12, 14 i 16 cm)

Planned target diameter (DBH) (cm) <i>Planirani ciljni prečnik (DBH) (cm)</i>	Factors <i>Faktori</i>		
	Yield class <i>Prinosne klase</i>	Years required to reach target diameter <i>Godine potrebne da se dostigne ciljni prečnik</i>	Stocking density (stems per ha) <i>Gustina zasada (stabala po ha)</i>
25	I	21	450±5%
25	II	25	
20	I	16	590±5%
20	II	18	
20	III	23	
18	I	14	660±5%
18	II	17	
18	III	21	
16	IV	26	1150±5%
16	V	-	
16	VI	-	
14	IV	22	1310±5%
14	V	27	
14	VI	-	
12	IV	18	1530±5%
12	V	22	
12	VI	32	
10	IV	10	1840±5%
10	V	16	
10	VI	22	

The data in *Table 2* show that an opportunity for the production of quality, sizeable logs is possible in black locust stands classified yield class I to III. For black locust stands in yield class IV – assuming an average harvesting age of 30 years – a target diameter of 18 to 20 cm can be planned with great certainty. The sustainable stocking density per hectare depending on the yield class varies from 450 to 660 stems per hectare.

The table also shows that stands of yield classes IV and V are suitable for the production of mass assortments, and possibly even black locust stands of yield class

VI with a target diameter of 10 to 12 cm. However, the management of stands characterised by these two lowest yield classes are usually loss producing and so are unsuitable for plantation forestry.



Figure 1. Thinned black locust stand in the Nyírség region(East-Hungary)
Slika 1. Proredena sastojina bagrema u regionu Nyírség region (Istočna Mađarska)



Figure 2. Stacked black locust wood (Mikebuda Sawmill, Central Hungary)
Slika 2. Skladište bagremovih trupaca (Pilana Mikebuda, Centralna Mađarska)

Black locust stands growing under unfavourable ecological conditions also have an earlier harvesting age (generally between 25 and 30 years). The sustainable stocking density varies between 1100 and 1800 stems per hectare depending on the yield class. In these stands – based on our yield studies – the

reduction in stem number (thinning) carried out at age 15 to 17 does not lead to a significant increase in diameter growth.

CONCLUSIONS (POSSIBLE UTILIZATION OF THE MODELS)

Silviculture has been defined as the art of producing and tending a forest. As scientific silvicultural principles are developed, and as the likelihood of success increases, hardwood plantation production will become more attractive.

Black locust plantation management for improved growth is becoming ever more significant in lowland forestry. This fact was partly taken into account in the conception of this study, and fed into the novel planning tools developed to help increase the value of the material produced in black locust stands. In recent decades, growth models based on stand level data have gradually been replaced by stand growth models predicated on stem number frequencies and individual tree growth models. Nevertheless, traditional tending operation models will remain very useful tools for forest management and forest inventory. The published models can be used in black locust management and forest inventory, such as:

- statistical appraisal of black locust stands (according to yield classes),
- harvest scheduling for black locust stands,
- further development of silvicultural (tending operation) models for black locust stands, and
- growth and economic analyses of black locust stands.

On global basis, the black locust has been extensively planted in some Asian countries (Turkey, China, Korea) for various purposes, such as fuel, forage, honey production, soil erosion control, windbreak and landscape. Recently, the usefulness of black locust in timber production and agriculture has been newly recognized by some European and South-American countries as well, which has promoted new introduction and research on black locust.

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Rezime

MODELI MERA NEGE U SAS TOJINAMA BAGREMA (ROBINIA PSEUDOACACIA L.) NA PESKOVITIM ZEMLJIŠTIMA U MAĐARSKOJ

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Zahvljujući intenzivnijem pristupu putem integrisanih istraživanja i razvoja radu na rastu na peskovitim zemljištima zasada bagrema, usvojenom prethodnih godina, otkriveno nekoliko faktora koji utiču na rast zasada. Činjenica da su pojedini ekološki faktori koji su od fundamentalnog značaja za rast i razvoj drvenastih vrsta u poslednje vreme postali nepovoljni u Mađarskoj je dovela do sve ekstenzivnijeg gajenja bagrema pošumljavanja i planovi regeneracije šuma. Studija predstavlja novi, pojednostavljeni model operacija nege za zasade bagrema i daje modele zasnovane na starosti, razmaku sadnje i ciljanom prečniku stabla, pogodnim za proizvodnju kvalitetnih trupaca i sortimenata za dobijanje biomase. Modeli obuhvataju preporuke za prinose klase od I do VI, zatim operacije: rane i kasne prorede i završnog seka, i ciljni prečnik od 10 do 25 cm. Jednostavnost ovih modela koji su namenjeni praksi bi mogla da podstakne kvalitativni razvoj uzgoja bagrema u Mađarskoj i u drugim zemljama gde bi ova drvenasta vrsta mogla da bude više prihvaćena od strane zemljoposjednika i šumarskih preduzeća.