JOURNAL OF FOREST SCIENCE, *64*, 2018 (2): 96–100

doi: 10.17221/118/2017-JFS

Yield and crown structure characteristics in a black locust (*Robinia pseudoacacia* L.) stand: A case study – Short Communication

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Abstract

Rédei K., Bakti B., Kiss T., Takács M., Keserű Z. (2018): Yield and crown structure characteristics in a black locust (*Robinia pseudoacacia* L.) stand: A case study – Short Communication. J. For. Sci., 64: 96–100.

The paper provides the results of a detailed analysis of timber volume and the most important crown variables of black locust (*Robinia pseudoacacia* Linnaeus) based on an experimental plot in southern Hungary. At the age of 20 years the crop trees belonged to different height classes. If the volume of the mean tree from height class I is considered as 100%, the volume of the mean tree of class II is 44.0%, and the mean tree of class III is only 30.3%. In case of timber volume per 1 m^2 crown surface, the values are 72.9 and 61.7%. The DBH of trees showed a positive linear correlation with crown diameter (r = 0.942). Additionally, there were also positive linear relationships between crown diameter and volume (r = 0.901), between crown length and volume (r = 0.721) as well as tree height and crown length (r = 0.661). The variation of crown indices is height even within the same stand and indicates the importance of following a selective thinning operation method.

Keywords: forest regeneration; crown indices; crop tree selection; volume production; non-native tree species

There is a long tradition of using *Robinia pseudoacacia* Linnaeus (henceforth black locust) in afforestations in Europe. This non-native tree species is currently widespread across European forests and plays an important role for the economy of several countries. The main reasons are its fast growth, valuable and resistant wood, suitability for amelioration, reclamation of disturbed sites and erosion control, honey-making and more recently, biomass production (Rédei et al. 2002, 2011, 2015). On the other hand, the reasons against planting this nitrogen-fixing, pioneer tree species, very tolerant to the nature of the substrate, is its aggressive spread and colonisation of open ground by means of seed and root suckers, which cause a problem for nature conservation (Vítková et al. 2017).

Hungary has the largest forest area covered by black locust in Central-Europe (446,832 ha, 24%). Smaller areas are in Poland (273,000 ha, 3.4%), Slovenia (55,189 ha, 4.7%), Germany (34,000 ha, 0.3%), Slovakia (33,448 ha, 1.7%). In the Czech Republic, *R. pseudoacacia* makes up only a small part of the total forest area (14,087 ha, 0.5%) compared to other Central European countries (Vítková et al. 2017).

Yield trends and the absolute value of yield at a given age are determined by complex interactions of environmental and site factors (Rédei, Meilby 2000). Many researchers have focused on the structure of stands and individual tree, but few prior studies have addressed the issue of the analysis of correlations between crown parameters and volume production in black locust stands (Rédei, Veperdi 2001). They are frequently required for growth modelling with tree growth estimated from crown and other tree characteristics. The methods described (and stand structure modelling possibilities as well) can help the practical establishment of stands with an optimal structure on the basis of known or previously determined parameters.

MATERIAL AND METHODS

The experimental plot (1,000 m^2) was established in the Danube and Tisza Interfluve (Forest Subcompartment: Kaskantyú 12D) in a 20-years-old black locust stand (Fig. 1). According to the Hungarian site classification, the main ecological characteristics of the study area are as follows:

(*i*) forest steppe climate zone (humidity below 50% in July at 2 pm; annual precipitation sum below 550 mm);
(*ii*) hydrology: free draining site (with no influence of groundwater);
(*iii*) genetic soil type: sand with average humus content.

The most important black locust growing regions in Hungary are located in southern and south-western Transdanubia (hill ridges of Vas and Zala County, hill ridges of Somogy County), the Danube-Tisza Interfluve (central Hungary) and north-eastern Hungary (Nyírség region). The species requires loose to slightly compacted soils, well-aerated without too much moisture, with physiologically favourable depths over 60 cm, and humus content from moderately high to very high. Sites with periodic water supply, as well as those that are well-drained (i.e., a groundwater table deeper than 150 cm), are favourable for black locust (Keresztesi 1988).

The sample plot contained 50 trees. For each tree DBH, height, basal area, as well as its spatial distribution were measured. Three height classes were recognized in the sample plot (Kraft 1884):

(*i*) Dominant trees, with crowns extending above the general level of the crown layer and receiving full light from above and partly from the side; larger than the average trees in the stand, with well-developed crowns but sometimes crowded on the sides by neighbours;
(*ii*) Co-dominant trees, with crowns forming the general level of the crown layer and receiving full light from above, but comparatively little light from the sides; usually with medium-sized crowns and more or less crowded on the sides;
(*iii*) Intermediate trees, shorter than those in the two preceding classes, but with crowns either below or extending into the canopy of codominant and dominant trees. They receive little direct light from above and none from the sides. As a result, they usually have small crowns and are considerably crowded on the sides.

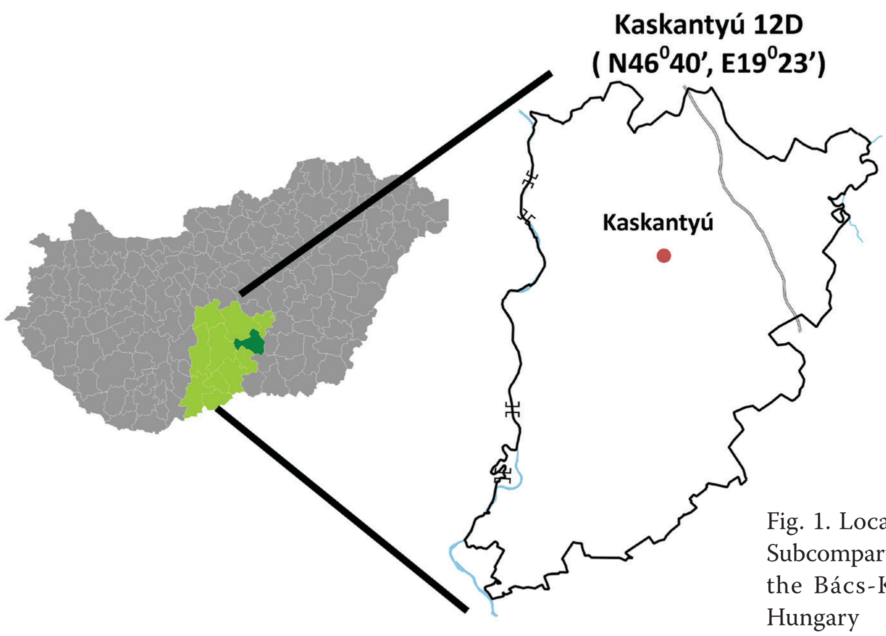

Fig. 1. Location of the study site (Forest Subcompartment: Kaskantyú 12D) within the Bács-Kiskun county in southern Hungary

Tree volume (v, m^3) was calculated based on Eq. 1 (Kolozs, Sopp 2000):

$$v = 10^{-8} d^2 h \left[h(h-1.3) \right]^2 (-0.6326dh + 20.23d + 3{,}034) \quad (1)$$

where:
d – DBH (cm),
h – tree height (m).

Based on the estimated individual tree volumes, stand volume (V, $m^3 \cdot ha^{-1}$) (Eq. 2) and mean tree volume ($\overline{v}$, m^3) (Eq. 3) were also derived:

$$V = (v_1 + \dots v_{50}) \times 10 \quad (2)$$

$$\overline{v} = \frac{V}{N} \quad (3)$$

where:
N – number of stems per hectare.

The most important structural factors and variables in connection with the crown are the followings (van Laar, Akça 1997):
(*i*) crown diameter – CD (m);
(*ii*) crown length – CL (cm);
(*iii*) crown projection area – CPA (m^2) (Eq. 4):

$$\text{CPA} = \text{CD}^2 \frac{\pi}{4} \quad (4)$$

(*iv*) crown ratio (Eq. 5):

$$\text{crown ratio} = \frac{\text{CL}}{h} \times 100 \quad (5)$$

(*v*) crown spread ratio (Eq. 6):

$$\text{crown spread ratio} = \frac{\text{CD}}{h} \times 100 \quad (6)$$

(*vi*) crown thickness index (Eq. 7):

$$\text{crown thickness index} = \frac{\text{CD}}{\text{CL}} \quad (7)$$

(*vii*) linear crown index

$$\text{linear crown index} = \frac{\text{CD}}{d} \quad (8)$$

RESULTS

The most important stand structure parameters by height classes are shown in Table 1.

The data of the table shows clear significant differences between the mean trees of different height classes. There are differences in height and DBH, similarly there are differences in total volume and mean tree volume. If the volume of the mean tree in height class 1 is taken as 100%, then class 2 is only 44.0% and class 3 is not more than 30.3%.

Differences in crown diameter and crown length are less pronounced (Table 2). The differences in crown surface values are obvious, due to the differences in the base data used for their calculation. Dominant trees have the largest crown ratio, while there is no great difference between co-dominant and intermediate trees. The crown spread ratio is decreasing from one height class to another, while the crown thickness index is very similar. The linear crown index is higher in the lower height classes.

In order to make the analyses as complete as possible, several linear regressions were fitted: between DBH and crown diameter; crown diameter and volume; crown length and volume and tree height and

Table 1. Stand level attributes grouped by height classes (Forest Subcompartment: Kaskantyú 12D)

Height class	No. of stems per hectare		Mean height	Mean DBH	Basal area	Volume per hectare		Volume of
	(–)	(%)	(m)	(dm)	($m^2 \cdot ha^{-1}$)	(m^3)	(%)	mean tree (m^3)
1	70	14	23.5	22.4	2.76	30.72	20.2	0.439
2	270	54	21.2	19.6	8.14	86.36	56.8	0.193
3	160	32	18.8	16.9	3.59	34.89	23.0	0.133
Total or average	500	100	21.2	19.1	14.49	151.97	100.0	0.291

Table 2. Crown parameters by height classes (Forest Subcompartment: Kaskantyú 12D)

Height class	Diameter (m)	Length (m)	Ratio (%)	Spread ratio (%)	Thickness index	Linear index	Projection area (m^2)
1	5.1	11.5	48.9	21.7	0.44	19.48	20.42
2	4.0	8.1	38.2	19.9	0.49	20.47	12.56
3	3.6	7.0	37.1	19.1	0.51	21.23	10.14
Average	4.2	8.2	38.8	19.6	0.50	20.89	13.85

Table 3. Statistical evaluation of different crown-related relationships (Forest Subcompartment: Kaskantyú 12D), number of trees = 50

	Statistical parameter			
	b_0	b_1 (X)	R	R^2
X: DBH = 19.1 cm Y: crown diameter = 4.2 m	–0.48337	0.24017	0.94170	0.88680
X: crown diameter = 4.2 m Y: volume 0.291 m^3	–0.32830	0.15674	0.90120	0.81220
X: crown length = 8.2 m Y: volume 0.291 m^3	–0.02181	0.04280	0.72650	0.66080
X: tree height 21.2 m Y: crown length 8.2 m	–12.37470	0.99974	0.52780	0.43670

b_0, b_1 – regression coefficients, R – correlation coefficient, R^2 – coefficient of determination

crown length. The estimated coefficients and statistical summaries for these models are shown in Table 3.

There is a positive linear relationship between DBH and crown diameter. The strong correlation (R = 0.942) suggests a high accuracy for predicting crown diameters from DBH. Crown diameter and length also show positive linear correlations with volume (R = 0.901 and 0.727). There is also a positive linear correlation between tree height and crown length (R = 0.661).

DISCUSSION

This publication is a case study. The tree crops inside the experimental plot give us the analysis of the stand structure. A part of our conclusions could have a general view in the reference of the black locust. The results show that there is a relationship between the structural setup and the yield of individual trees and the overall yield from stands. The complex analysis of these relationships can help us better understand the drivers of black locust productivity.

The study of trees by height classes allows the accurate separation of production levels as well as an exact determination of the structural parameters for trees with the highest productivity rates.

From the data presented here, it appears that there is a significant correlation between crown indices and yield. There also appears to be a strong correlation between DBH (which affects the volume) and crown diameter (Eq. 9):

$$\mathrm{CD} = -0.483379 + 0.240171 \times d \tag{9}$$

Assuming that the targeted DBH is 22 cm, the suggested N is as follows (Eq. 10):

$$N = \frac{10,000}{\mathrm{CPA}} \tag{10}$$

In our case, N is as follows (Eq. 11):

$$N = \frac{10,000}{18.09} = 552 \tag{11}$$

According to our investigations it is also clear that height class is the most important factor in tree diameter growth. Height class is the result of the competitive pressure that takes places as trees increase in size. Black locust trees rarely increase their height class over time unless a timber harvest/thinning operation or other significant stand disturbance remove larger competitors and release growing space. Based on our repeated measurements in other black locust stands if a tree achieves a dominant or codominant height class, it must maintain that canopy position by growing faster than its competitors or it will eventually subside under the competitive pressure of its neighbours. The reserved results have built upon the main stand component species referring to the black locust as a comparison on silvicultural treatment models. We can use these models effectively in the phase of planning, implementation and verification. The task of thinnings is to manipulate height classes and growing space to favour trees that satisfy management objectives. To fulfil this requirement tending operation models can be available in the Hungarian forest management practice.

Acknowledgement

The authors would like to thank D. Houlihan (Timberland Forestry, Ireland) for improving the English version of the text.

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Received for publication August 28, 2017
Accepted after corrections January 31, 2018