

# Increment analysis in black locust (*Robinia pseudoacacia* L.) stand – A case study

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**Summary:** The study on the diameter and volume increment of black locust (*Robinia pseudoacacia* L.) stand (age 10-27 years, yield class II) have shown that in comparison to the periodic annual increment of the breast height diameter of tree in height class I, trees in height class II have reached 83.3%, while in class III only 43.9. The same relations for volume were found 59.0% and 24.5%, respectively. The mean values of the whole stand were close to those of height class II. According to the distribution of the periodic annual increment of volume between 10 and 27 years of age, 50% of the values were between 2.00 and 13.88 dm<sup>3</sup>, 73% were between 2.00 and 19.82 dm<sup>3</sup>, and 96% were between 2.00 and 37.64 dm<sup>3</sup>. The range of 13.88–19.82 dm<sup>3</sup> had the highest occurrence (24.5%).

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**Key words:** *Robinia pseudoacacia*, tree-growth, increment, periodic annual increment

## Introduction

A less explored sub-area of the research on stand structure and yield is the distribution of the diameter and volume increment (hereinafter: increment) formed on the specimens of the stand. The increment considered to be the most important for the tree yield, is affected by several factors.

The two main variables on which volume factors of a tree depend, and also have a decisive effect on the growth are age and site. In addition, the environment plays a considerable role in the development of trees. Trees in a closed forest grow differently compared to the free-grown trees or at the edge of the forest. In fact, the site should be interpreted differently in relation to the individual tree than to the stand. Furthermore, the position of the tree should also be perceived as a factor of the site. The amount of light reaching the tree is the most important accessory of life and development. Trees under different environmental conditions develop differently on soils of same quality. While, in addition to shading, root competition of adjacent trees is also a determinative factor (Assmann, 1961; Clutter et al., 1983; Cameron, 2002; Petráš & Mecko, 2011; van der Maaten, 2012; Rédei et al., 2012; Remeš et al., 2015).

The assessment of the increment distribution for each tree within a stand on long-term experimental plots allows, inter alia (Rédei et al., 2014) the followings, mathematical-statistical analysis of increment distribution by tree height classes, a more precise exploration of the links between the increment and the main factors affecting it, a more accurate demonstration of the value-adding effects of selection-based stand improvement as well as the improvement of methodological research in dendrometry.

Black locust (*Robinia pseudoacacia* L.) is one of the most important forest tree species in Hungary, covering approximately 24% of the forest land and providing 25% of the

annual timber supply (Rédei et al., 2008). Research on yield of black locust stands proceeds in nearly 170 long-term experimental plots (Rédei, 1984; Rédei & Gál, 1985). In spite of this, there are only few national and international research results on the increment distribution of specimens in a black locust stand. The aim of this study is to contribute to the up-to-date knowledge on increment study of black locust.

## Materials and methods

### Experimental site

One of experimental plots is in the Pusztavacs 215 E forest subcompartment, located in sandy ridges between the rivers Danube and Tisza. In the stand, an experimental plot was designated at the age of 10 years for yield studies. Following the first stand inventory, the next took place at the age of 22 as well as 27 years of age. The yield class is II (Rédei, 1984), while the characteristics of the site are the followings, forest-steppe climate, free-draining site, humic sand soil, medium deep, sand (**Figure 1**).

### Assessed parameters

The numbering of the trees made it possible to evaluate the data on the increment and growth of 425 final crop trees/ha (113 trees/plot) and on the distribution of the increment. For each tree, diameter at breast height (dbh), height (h), basal area (g), as well as its spatial distribution were measured (Avery & Burkhart, 1994; Laar & Akça, 2007). The stem volume (v) was calculated using the volume function based on the volume table

for black locust (Sopp & Kolozs, 2000) according to the following equation:

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

where  $v$  is the stem volume ( $m^3$ ),  $d$  is the diameter at breast height (cm), and  $h$  is the tree height (m).

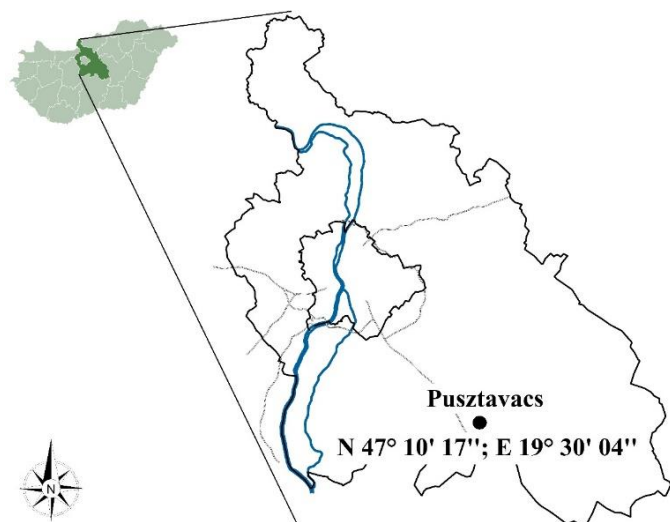


Figure 1. Location of Pusztavacs 215 E forest subcompartment

In the experimental black locust stand, a full inventory and the determination of different stand structure and yield factors were carried out according to tree height classes as follows, (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; (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; and (III) intermediate trees, shorter than those in the two preceding classes, but with crowns either below or extending into the canopy of co-dominant and dominant trees.

General methods of mathematical statistics and biometrics were used during data processing and assessment.

## Results and discussion

The structural and yield changes in the five years between the last tending cutting and the most recent stand inventory are shown in **Table 1**. In terms of age, even after the last tending cutting, the periodic annual increment (p.a.i.) of the volume exceeded the value of  $8 m^3/ha/year$ . Regarding the periodic annual increment of the diameter at breast height, the increment of the trees belonging to the height class I exceeded the height class II and III trees by 22.7% and 42.1%, respectively. 40.2% of the periodic annual increment formed in this period was created by trees belonging to the tree height class I, and 48.1% in class II. That is, 88.3% of the periodic annual increment originated in trees belonging to the height class I and II. Dead tree originated only in height class III trees and made up 1.1% of the total wood stock.

It was possible to accurately assess the diameter and volume increment of marked final crop trees between 10 and 27 years (17 years). The tree height class was considered constant, 87% of the tree specimens included in the study had

no class change. The development of the periodic annual increment of each tree by dbh and mean tree volume, as well as the related mathematical-statistical indicators are shown in **Table 2**.

The periodic annual increment of the breast height diameter of the trees of Class II reached 83.3%, compared to the average of the trees of class I, while class III trees reached only 43.9%. For volume, these ratios were found 59.0 and 24.5%, respectively. The average values for the whole stand were close to the averages of the tree height class II.

The ratio of the extreme values of the ranges (R) were 1: 8.5 and 1: 35.6. It proves a strong manifestation of the effect of natural excretion and increment factors. Based on the skewness index (SI), the distribution of the periodic annual increment by dbh and the volume showed a weak right skew.

The histogram of the distribution of the periodic annual increment (between 10 and 27 years) by volume is shown in **Figure 2**. 50% of the increment values were found between 2.00 and  $13.88 dm^3$  and 96% of it between 2.00 and  $37.64 dm^3$ . The range of 13.88–19.82 had the highest incidence rate (24.5%).

The distribution of the number of stems per hectare and the periodic current increment by 17-year volume per hectare by dbh groups is shown in **Figure 3**. Within the diameter range of 12–36 cm up to the 20 cm diameter size group, the ratio of the number of stems exceeded the increment value in the group, while above this, the ratio of the distributions were found reversed. In the larger groups, there were a considerable increase in the growth rate compared to the number of stems.

It should be noted here that according to the relevant literature (Antanajtisz & Zagreev, 1981), the value of the coefficient of variation concerning the diameter increment of the trees in a stand can vary between 30 and 60%. This high degree of variability is influenced by several factors, such as tree species, age, site conditions, canopy closure, tending cuttings, and the type of the distribution of trees according to thickness groups within the tree stand, etc. In **Table 3**, a matrix of correlation coefficients for thickness ( $i_d$ ) and volume ( $i_v$ ) correlation coefficients as a function of breast height diameter (d), tree height (h) and age are provided. Though, it is not possible to classify stands according to coefficients of variation.

## Conclusions

Among the internal i.e. genetic and external i.e. environmental factors affecting the growth, the division of trees according to tree height classes is of special importance. This fact also points to the importance of natural selection based tending cuttings.

However, it should be noted that the mode of action of the above-mentioned factors effecting the size of the increment, mainly the current increment, is different and complex, thus, it is hardly possible to study them directly in practice. However, the cumulative impact of environmental factors is mainly manifested in the change in the annual ring width of tree trunks, hence research should also focus on this factor. Analysis of the data from the relevant yield tables also suggested that the increment of light-demanding tree species peaked earlier than in case of shade tolerant specimens, and the same trend could be observed when comparing stands growing on more suitable site conditions with those growing on poorer sites. The culmination of current increment occurred first at

Table 1. Stand characteristics and periodic annual increments (Pusztavacs 215 E)

Facts	Age (yr)	N (stems/ha)	H (m)	DBH (cm)	G (m <sup>2</sup> )	V (m <sup>3</sup> )	Dead tree (m <sup>3</sup> )	Periodic annual increment			
								I <sub>h</sub> (m)	I <sub>D</sub> (cm)	I <sub>v</sub> (m <sup>3</sup> )	I <sub>v</sub> (%)
I.	22	128	22.7	22.3	4.999	56.24		0.34	0.54	3.35	40.17%
	27	128	24.4	25.0	6.284	73.00					
II.	22	212	21.2	18.3	5.576	58.98		0.22	0.44	4.01	48.08%
	27	212	22.3	20.5	6.998	79.04					
III.	22	120	18.4	14.3	3.191	17.46	1.89	0.14	0.18	0.98	11.75%
	27	112	19.1	15.2	3.209	22.37					
Mean	22		21.3	18.6			1.89	0.28	0.38		
	27		22.7	20.5							
Sum	22	460			13.766	132.68				8.34	100.00%
	27	452			16.491	174.41					

Note: N = Number of stems, H = Height, DBH = Diameter at breast height, V = Volume, I<sub>h</sub> = Height increment, I<sub>D</sub> = Diameter increment, I<sub>v</sub> = Volume increment

Table 2. Mathematical-statistical indicators of periodic annual increments (Pusztavacs 215 E)

Facts	Periodic annual increment (DBH)						Mo	SI
	x (cm)	s	V = s/x (%)	x <sub>max</sub>	x <sub>min</sub>	R		
I. (n=30)	0.66	0.164	24.85	1.19	0.42	0.77		
	100%							
II. (n=53)	0.50	0.119	23.80	0.98	0.27	0.71		
	83.3%							
III. (n=30)	0.29	0.090	31.03	0.49	0.19	0.30		
	43.9%							
I. - II. - III. (n=113)	0.49	0.185	37.76	1.19	0.14	0.05	0.43	0.32

Facts	Periodic annual increment (v)						Mo	SI
	x (dm <sup>3</sup> )	s	V = s/x (%)	x <sub>max</sub>	x <sub>min</sub>	R		
I. (n=30)	27.32	12.104	44.30	71.12	15.00	56.12		
	100%							
II. (n=53)	16.11	6.518	40.46	51.35	7.29	44.06		
	59.9%							
III. (n=30)	6.69	3.228	48.25	14.94	2.00	12.94		
	24.5%							
I. - II. - III. (n=113)	16.58	10.843	65.40	71.12	2.00	69.12	11.15	0.50

Note: n = Number of stems, x = Increment, s = Standard deviation, V = Volume, x<sub>max</sub> = Maximum increment, x<sub>min</sub> = Minimum increment, R = Range, Mo = Mode, SI = Skewness index

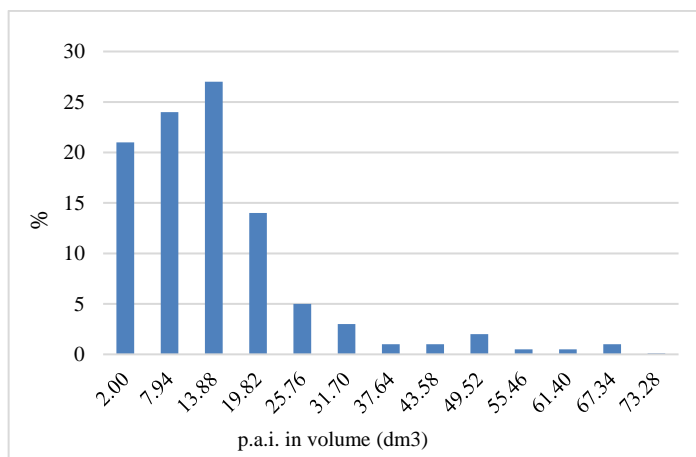


Figure 2. Frequency distribution of periodic annual increment (p.a.i.) in volume (dm<sup>3</sup>) between 10 and 27 ages (Pusztavacs 215 E)3

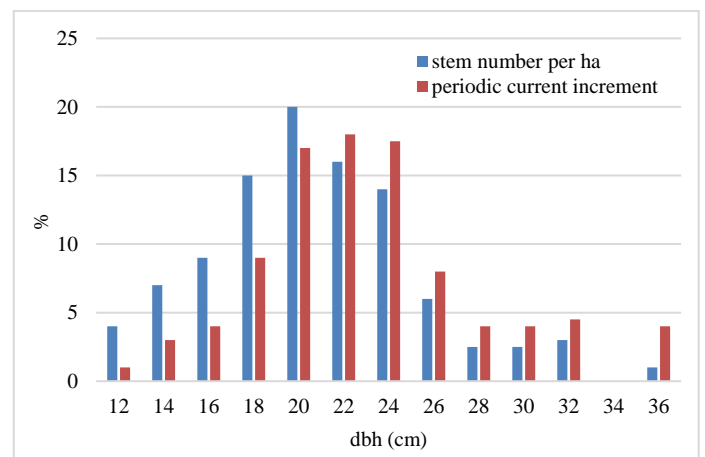


Figure 3. Frequency distribution of stem number per hectare (ha) and the periodic current increment in volume between 10 and 27 ages in the function of breast height diameter (dbh) groups (Pusztavacs 215 E)

Table 3. Correlation coefficient matrix table (based on Antanajtisz &amp; Zagreev, 1981)

	$i_v$ (m <sup>3</sup> )	$i_d$ (cm)	$d$ (cm)	$h$ (m)	Age (yr)
$i_v$ (m <sup>3</sup> )	1	0.88	0.85	0.77	0.23
$i_d$ (cm)	0.76	1	0.67	0.66	0.26
$d$ (cm)	0.79	0.70	1	0.83	0.30
$h$ (m)	0.69	0.66	0.86	1	0.34
Age (yr)	0.52	0.42	0.71	0.65	1

Note: The innovation value of the reported parameters is manifested in the forecast of the growth of tree stands, as the rate of increase in the volume is 2/3 partly determined by the development of the diameter increase.

height growth, followed by width growth (breast height diameter), then basal area growth and volume culmination (Antanajtisz & Zagreev, 1981).

The results of our preliminary investigation proved that the increment can be affected by the stand improvement.

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