DOI: 10.34101/ACTAAGRAR/2/13293

Growth and yield patterns of black locust (*Robinia pseudoacacia* L.) sample trees affected by site conditions: case studies

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SUMMARY

The trees removed from the long-term experiment plots are available for the measurements as lying trees. Through the determination of the volume in sections along the stem, the stem form, the stem volume and other factors can be specified. The comparison of the stems of individual trees of first and third yield classes of black locust (Robinia pseudoacacia L.) stands shows that site conditions have a main effect on the yield (mean tree volume). The difference can be as high as 53% at the age of 30 depending on the sites. To determine the growth patterns based on tree volume is rather a new approach in the light of the relevant literature. The obtained results also highlight the importance of choosing the appropriate tree species for a given site.

Keywords: *Robinia pseudoacacia; stem analysis; volume*

INTRODUCTION

Black locust (*Robinia pseudoacacia* L.) is a widely planted tree species in many countries. It is an economically remarkable stand forming, fast growing tree which produces valuable water- and rot-resistant timber, firewood, fodder and honey. It is a suitable tree species for erosion control, amelioration and reclamation of disturbed sites due to its drought tolerance. Black locust's role in combating the negative effects of global and/or local climate change is increasing continuously (Nicolescu et al., 2020). Establishing black locust energy plantations has become a wide trend over the last few decades thanks to its high yields (fast rate of growth) (Vítková et al., 2017). In Hungary, black locust is the most significant exotic tree species. Its rate is app. 35% (percent) in the area of new afforestation (Rédei, 2020; NLC, 2022). In our opinion, the invasiveness of black locust can be reduced effectively by introducing an improved growing technology, as it is applied by the Hungarian forest management.

Considering the above-mentioned issues, stem analysis is an effective tool to assess the impact of intensive forest management and silvicultural practices on tree growth and wood quality. In Serbia, the influence of thinning on diameter structure of black locust stands was studied in comparison with common hackberry (presented in the same stand), and the authors found that after thinning, common hackberry had a higher biological potential than black locust. They also stated that by thinning natural succession can be enhanced (Andrašev et al., 2013).

By investigating the relationship between the growth pattern of the stem and the site makes it possible to determine the main effects of the site on the growth and the expected yield. In a study implemented in Poland by Kraszkiewicz (2021), the volume of black locust stands was determined by dividing the stems (through the sectional method) to trunks and branches and wood thickness classes. Based on the investigation of the volume of 14 black locust stands on marginal soils with different age and habitat conditions, it was found that mainly sunlight and moisture affected the volume of the stands. He also noted that regarding eroded, poor soils where black locust still grows very well, the nutrient content of the soil has only a minor effect.

The data used for stem analyses can also be applied as inputs for modelling the growth patterns of the stands, and to validate the fundamental relationships between tree age and tree height. Stankova et al. (2022) studied the height-diameter relationship in young black locust trees, and also investigated whether the tree height can be accurately predicted at stand level from the breast-height diameter to find the formula which fits the best. The results showed that the height–diameter relationship (for the investigated data) was best specified at plot level, distinguishing the stands based on their growth rate. A positive correlation between the height-increase and the growing space was also described.

The application of complete stem analyses is not a widely used method. However, it provides the most reliable results regarding the growth of an individual tree in the past. It can also be used to accurately determine foliage dry mass and biomass (Tziaferidis et al., 2022). Stem analyses is also the basis of dendrochronology, which is the science of investigating the relationship between the meteorological parameters and the growth of the trees. A study (Moser-Reischl et al., 2019) which analyzed the data of 26 years, determined past inter-annual tree growth of black locust trees in the urban environment of Germany, based on increment core collection. The authors found that black locust trees have barely displayed any familiar patterns when they looked at the relationship of temperature and growth, only that high temperature may have a negative effect on the formation of tree rings, mainly in the summer. Another study investigated the link between climate change and the radial growth of black locust in two climatic zones

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of the Loess Plateau of China (Keyimu et al., 2021). In the northern semi-arid region, the results showed increasing hydraulic stress on black locust radial growth, whereas in the southern semi-humid region the increasing influence of thermal stress on black locust radial growth was recorded. Regarding others species, the results of a tree-ring research on *Pinus cembra* conducted at the edge of its species distribution range (in the Alps) found that growth-climate interactions were mainly determined by temperature (and mean annual precipitation amongst others), and less to genetic diversity (Housset et al., 2021).

This study provides the detailed results of the stem analyses sampled from the dominant height class of black locust stands and their comparison based on two different sites. These results can be considered gap-filling in the international literature. The results clearly indicated the determinant effect of the basic (ecological) site characteristics on tree growth. Therefore, these results help to decide on the species selection and consequently to choose an economically appropriate tree cultivation.

MATERIALS AND METHODS

In the field the stem of the sample trees were sectioned at the following above ground points: 0.15 m, 1.30 m, and at 2.0 m intervals along the entire stem. The height of the stump, interval lengths, and the cutting method were recorded. The inside and outside bark diameters for each cross-sectional sample was measured and recorded. For each cross section, two geometric mean diameters were marked (Van Laar and Akça, 2007; Burkhart et al., 2019) Using a computer and a scanner equipped with an analysis system specifically designed for tree-ring measurements, the age of each cross-sectional disc was defined. Using this system, the width of each annual ring along each diameter-based radius was determined. Based on the measurements the following information about growth analysis was defined:

- Mean radius diameter and area for all disks.
- Tree height, basal area and volume as a function of age

Volume was calculated by the volume table for black locust (Sopp and Kolozs, 2013)

The location of the black locust stands, their site characteristics (according to Járó, 1972) and the yield class (based on Rédei, 1984) of the sample trees for complete stem analyses are shown in *Table 1.*

Table 1. **The site type, the age and the yield class of the studied stands**

Sample tree	Subcompartment	Age (year)	Site type (based on Járó, 1972)					Yield class (based on Rédei, 1984)
			Climate	Hydrology	Soil type	Rootable depth	Texture	
1	Pusztavacs 222A	37	forest-steppe	periodic water effect	rusty brown forest soil	deep	sand	I
2	Mélykút 40A	38		free-draining site	chernozem brown forest soil	medium deep		III

RESULTS

The growth pattern of the sample trees originating from the black locust stands of yield class I and III are shown is *Table 2* and *3*, respectively.

The height growth (h) of black locust is the highest between age 1–5 and it decreases after 15–20 years.

The diameter growth at breast height (dbh) reaches its maximum between age 1–10. The width of the tree ring is the highest in this time period and often reaches 7–10 mm yr^{-1}. Later on, the thickening diameter growth slows down greatly and the width of the tree rings level off around 1–1.5 mm yr^{-1}.

The growth of the basal area (ba) starts slowly and culminates between the year 25–35.

The volume of the trees (v) also increases slowly and culminates between the year 30–35.

Table 2 and *3* shows that site conditions have a main effect on the growth pattern of the black locust trees.

Based on the tables above, felling at the age of 30 the average tree volume according to each site are the following:

1. site type: 0.339 m^3 – 100%
2. site type: 0.145 m^3 – 43%

This means that the site determines the yield at a given age. The difference can be as high as 53% when comparing the average tree volume of black locust stands on an optimal and medium quality site. The growth pattern of the sample trees by the mean tree volume is shown in *Figure 1*.

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Table 2. **Growth of the sample tree from the black locust stand yield class I**

age	dbh	i_d[1]	ba	i_{ba}[2]	h	i_h[3]	v	i_v[4]
(year)	(cm)	(cm)	(m^2)	(m^2)	(m)	(m)	(m^3)	(m^3)
5	5.0		0.00196		7.5		0.010	
		3.8		0.00412		3.2		0.027
10	8.8		0.00608		10.7		0.037	
		3.2		0.00523		4.9		0.057
15	12.0		0.01131		15.6		0.094	
		2.4		0.00498		4.4		0.073
20	14.4		0.01629		20.0		0.167	
		2.0		0.00483		1.9		0.067
25	16.4		0.02112		21.9		0.234	
		2.4		0.00664		2.5		0.105
30	18.8		0.02776		24.4		0.339	
		2.0		0.00622		2.0		0.106
35	20.8		0.03398		26.4		0.445	
		0.4		0.00132		1.9		0.032
37	21.2		0.03530		27.3		0.477	

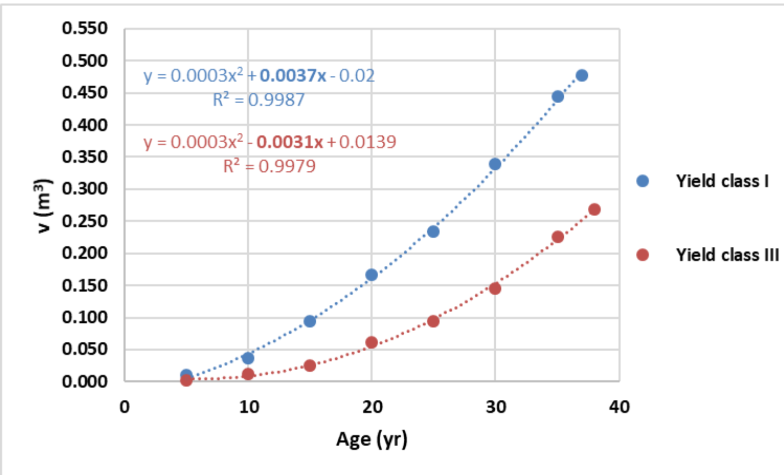
[1] diameter increment, [2] basal area increment, [3] height increment, [4] volume increment.

Table 3. **Growth of the sample tree from the black locust stand yield class III**

age	dbh	i_d[1.]	ba	i_{ba}[2.]	h	i_h[3.]	v	i_v[4.]
(year)	(cm)	(cm)	(m^2)	(m^2)	(m)	(m)	(m^3)	(m^3)
5	2.4		0.00045		3.8		0.002	
		3.2		0.00241		2.6		0.010
10	5.6		0.00246		6.4		0.012	
		1.6		0.00161		3.3		0.013
15	7.2		0.00407		9.7		0.025	
		3.2		0.00442		3.3		0.036
20	10.4		0.00849		13.0		0.061	
		2.0		0.00359		1.7		0.034
25	12.4		0.01208		14.7		0.095	
		1.8		0.00466		1.8		0.050
30	14.6		0.01674		16.5		0.145	
		2.6		0.00650		2.3		0.081
35	17.2		0.02324		18.8		0.226	
		1.2		0.00335		0.9		0.043
38	18.4		0.02659		19.7		0.269	

[1] diameter increment. [2] basal area increment. [3] height increment. [4] volume increment.

Figure 1. **Mean tree volume (v) of the sample trees. Yield classes based on Rédei, 1984**



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CONCLUSIONS

Using stem analysis method, we quantified site-specific growth patterns. Our results showed clear differences in productivity among the two sample trees. The growth patterns were governed by site conditions. The sample tree growing on rusty brown forest soil with periodic water effect showed different growth patterns compared to that on chernozem brown forest soil with free water draining.

Differences in growth are characterized in forest yield study by yield classes. Considering stem volume, stem-analysis were conducted to investigate the effects of different site conditions on the height, dbh, basal area and volume of black locust (*Robinia pseudoacacia* L.) trees. The results showed that the growth characteristics were significantly different based on the site conditions. The conclusion of our case study is another proof of site-dependent productivity of black locust.

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