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The Effects of Thinnings on Yield and Value Changes in Black Locust (*Robinia pseudoacacia* L.) Stands: A case study

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Abstract – Thinning experiments in black locust (*Robinia pseudoacacia* L.) stands have been conducted in Hungary for many years. Black locust is an economically important tree species supplying the domestic timber industry. This paper evaluates two effects of thinnings: the effect on yield and the effect on stand value. The case study has proved thinnings in black locust stands do not increase periodic total production, but do increase the stem-quality index by 11–24%.

Robinia pseudoacacia / tending cuts / periodical total production / stand value

Kivonat – A gyérítések hatása az akácállományok (*Robinia pseudoacacia* L.) fatermés- és értékváltozására: esettanulmány. Az akácállományok (*Robinia pseudoacacia* L.) gyérítésével kapcsolatos magyarországi kísérletek hosszú időszakra nyúlnak vissza. Ezen állományalkotó fafajnak meghatározó gazdasági jelentősége van az ország faanyag ellátásában. Jelen dolgozat a gyérítések hatását két aspektusból, a fatermés és a minőség vonatkozásában elemzi. Az esettanulmány azt igazolja, hogy akácállományokban gyérítésekkel a korszaki összes fatermés nem, a törzsminőséget kifejező jelzőszám viszont 11–24%-al is növelhető.

Robinia pseudoacacia / nevelővágások / korszaki összes fatermés / faállomány érték

1 INTRODUCTION

Thinning is the removal of a proportion of the trees in a stand. It is usually implemented to provide more growing space for the remaining trees, to increase the total yield of usable timber over the life of the stand, and to provide wood from thinnings. Thinning affects stand growth and yield, diameter distribution, quality, and stability. In forestry practice, the effect of thinning on the average tree size or future crop trees is more important than its effect on stand growth and yield, particularly for species like black locust. Obviously, total production is only one factor influencing stand value. Volume distribution in different size classes is often of much greater importance because stem size and number influences harvesting costs and the markets to which the timber assortments can be sold.

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Thinning should be a central part of any mitigation strategy implemented to reduce the impact of future climate change. There are three main reasons for this. First, wood products from stands that are thinned and pruned are more likely to be used in long-term end uses. Second, thinning helps maintain healthy, resilient forests able to sequestrate carbon from the atmosphere and store it as woody biomass. Finally, material produced in thinning can be used as fuelwood, which is a source of renewable energy, to help reduce fossil emissions.

Over the years, many studies have addressed the question of whether forest growth or yield can be increased or decreased through thinnings. Testing Wiedemann's hypothesis helps provide an answer to this question. The hypothesis states that volume growth is constant among a wide range of stand densities (Wiedemann 1943). This relationship varies among species, but also depends on stand age and site conditions (Pardé 1965, Assmann 1970, Persson, 1986, Kuiper – Schoenmarkers 1990, Pretzsch, 2009), so quantifying it for each forest species is necessary.

Most of the relevant publications in Hungary declare that thinnings cannot increase total stand production with various tree species; however, in many cases, thinnings can increase stand value (Majer 1969, Béky 1983, Halupa 1987, Béky – Solymos 1991, Rédei – Meilby 2009).

The following will present a thinning experiment, namely the effects of thinnings on black locust stand yield and value. The paper also verifies and confirms the above-mentioned statements in the case of black locust.

2 MATERIALS AND METHODS

The experiment was established at NEFAG Nagykunság State Forest Company (Szolnok), Pusztavacs forest estate, in the forest subcompartment Pusztavacs 201 E (*N 471017; E 193004*) (*Figure 1*). The site type was a free-draining humus sand soil in the forest-steppe climate zone (annual precipitation is normally less than 550 mm). The yield class of the particular black locust stand was III (Rédei 1984). Three thinning treatments were executed when the stand age was 22 years. We used a one-factor experimental design with two thinning grades without replicates. Each plot area was 2500 m^2. Treatment 1 is the control plot ($N = 770$ stems·ha^{-1}) with no thinning. In treatment 2, the usual density in the Hungarian black locust management ($N = 550$ stems·ha^{-1}) was applied (EMI 1984). In treatment 3, it is supposed that the growing space is more favorably used by an individual tree at a lower density ($N = 400$ stems·ha^{-1}).

The following parameters were measured at the ages of 22, 27, 32 and 36: stem number, diameter at breast height, and tree height. The calculated parameters were the following: basal area, stem volume, volume of dead trees, stand volume (living stock), total production, mean annual increment, and stem-quality index (SQI). Stem volume was calculated using the volume function based on the volume table for black locust (Sopp - Kolozs 2000):

$$v = \frac{d^2 \cdot h^{po+1}}{(h-1{,}3)^{po} \cdot 10^8} \cdot \left(p_1 \cdot d \cdot h + p_2 \cdot d + p_3 \cdot h + p_4\right)$$

where

d is the diameter at breast height (cm),

h is tree height (m),

$p_o = 4$, p_l=-0.6326,

$p_2 = 20.23$, p_3=0.00 and

$p_4 = 3034$.

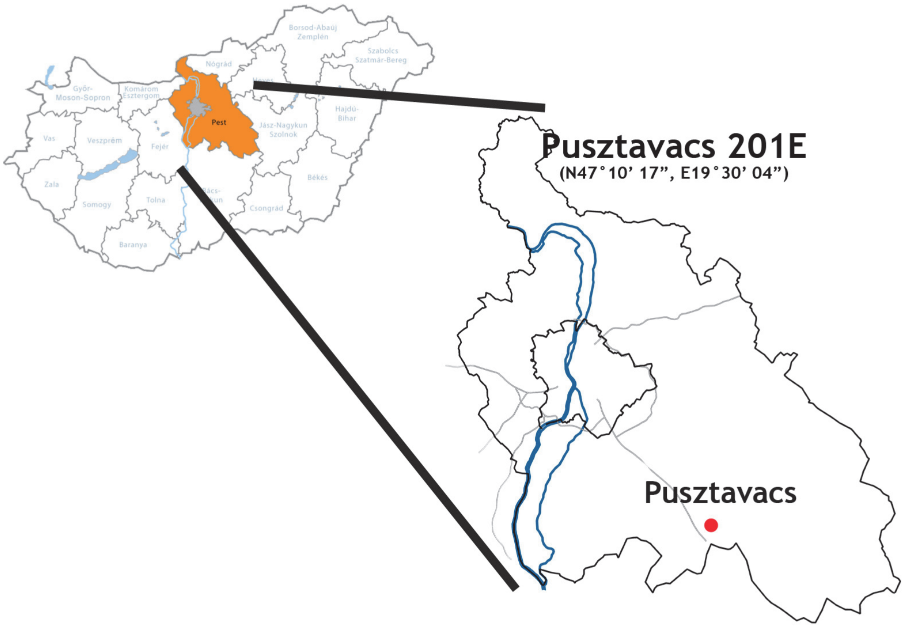

Figure 1. Location of the trial

Living stock (V) has been determined by means of a computer program developed by the Hungarian Forest Research Institute (HFRI) for calculating wood volume; the volume of the average tree (v_m) is computed according to the relation:

$$v_m = V \cdot N^{-1}$$

where N = number of stems per hectare.

The stem quality classes at the age of 36 are as follows (for calculating the stem-quality index):

- (x_1) Straight, cylindrical, healthy stems. Crooks are tolerated in one dimension only.
- (x_2) The stem is straight, forks are tolerated. Crooks are tolerated in one dimension only.
- (x_3) The stem is crooked and leaning. Minor crookedness in a second dimension is tolerated.
- (x_4) Very crooked in more than one dimension. Forked trees with stem defects.

The stem-quality index (SQI) was determined based on the following formula:

$$SQI = \frac{x_1 n_1 + x_2 n_2 + x_3 n_3 + x_4 n_4}{n_1 + n_2 + n_3 + n_4}$$

where

x_1, x_2, x_3, x_4 = tree quality classes,

n_1, n_2, n_3, n_4 = tree numbers belonging to the single tree quality classes.

3 RESULTS AND DISCUSSION

Table 1 contains the most important yield and stem-quality data. The table was compiled using data obtained from the stand surveys conducted between 22 and 36 years.

Table 1. Yield and stem-quality data at the age of 22–36 years (subcompartment Pusztavacs 201 E) Yield Class: III. (Based on Rédei, 1984)

Factors	Number of treatment		
	I. (control)	II.	III.
1. Initial wood stock before carrying the thinning (m^3ha^{-1})	182.1	244.3	219.4
– in percentage of the control (%)	**100.0**	**134.2**	**120.5**
2. Volume removed during the thinning (m^3ha^{-1})	0.0	64.0	77.6
3. Wood or living stock after thinning (m^3ha^{-1})	177.9	180.3	141.8
4. 14 years later:			
– living stock (m^3ha^{-1})	276.4	260.2	226.9
– in percentage of the control (%)	100.0	94.1	82.1
– mortality (m^3ha^{-1})	11.1	12.3	6.3
– wood stock (living stock + mortality) (m^3ha^{-1})	287.5	272.5	233.2
– in percentage of the control (%)	100.0	94.8	81.1
5. Change in living stock 14 years later (m^3ha^{-1})	98.5	79.9	85.1
– in percentage of the control (%)	100.0	81.1	86.4
6. Periodic total volume (m^3ha^{-1})	287.5	336.5	310.8
– in percentage of the control (%)	100.0	117.0	108.1
7. Mean ann. incr. of the periodic total vol. ($m^3 \cdot ha^{-1} \cdot yr^{-1}$)	7.5	6.6	6.5
– in percentage of the control (%)	100.0	88.0	86.7
8. Stem-quality index (SQI) at the age of 36 years	2.15	1.92	1.63
– in ratio of the control	1.00	0.89	0.76

The following conclusions may be drawn from the data in the *Table 1*:

- Based on the black locust thinning experiment presented above, *no increase of the periodic total production increment due to the thinnings could be observed*. The thinnings with different intensities did not increase the amount of total production in absolute terms as compared to the control plot. The percentage relations of the initial volumes to the control plot before thinning (row 1 in *Table 1*) are always higher than those after thinning (row 3 in *Table 1*).
- According to the experiment, thinnings had no effect on the periodic volume change. The periodic volume change ratio related to the control was dependent on the factors mentioned in the previous paragraph. More investigations are needed to give a more precise description of the changes.
- The periodic total production increment values also clearly indicate the thinnings do not have an increasing effect on the periodic increment of the total production. It is unlikely total production can be increased significantly (exceeding 5%) with thinnings in any regime; intensity and frequency in the case of black locust managed with relatively low average rotation ages. This does not exclude different results with different species and circumstances.
- In black locust stands, the *stand quality can be improved with thinnings* based on careful individual selection. In the present study, the related stand quality indicator exceeded the indicator of the control stand by 11–24%. Thus, the effect of the thinnings manifests primarily in improving stand quality and increasing stand value.

Two figures are presented to show the effects mentioned above. *Figure 2* presents the volume change 14 years after the thinning as a percentage of the control plot (100%), and *Figure 3* shows the increase in stand quality indicator as a percentage of the control plot value.

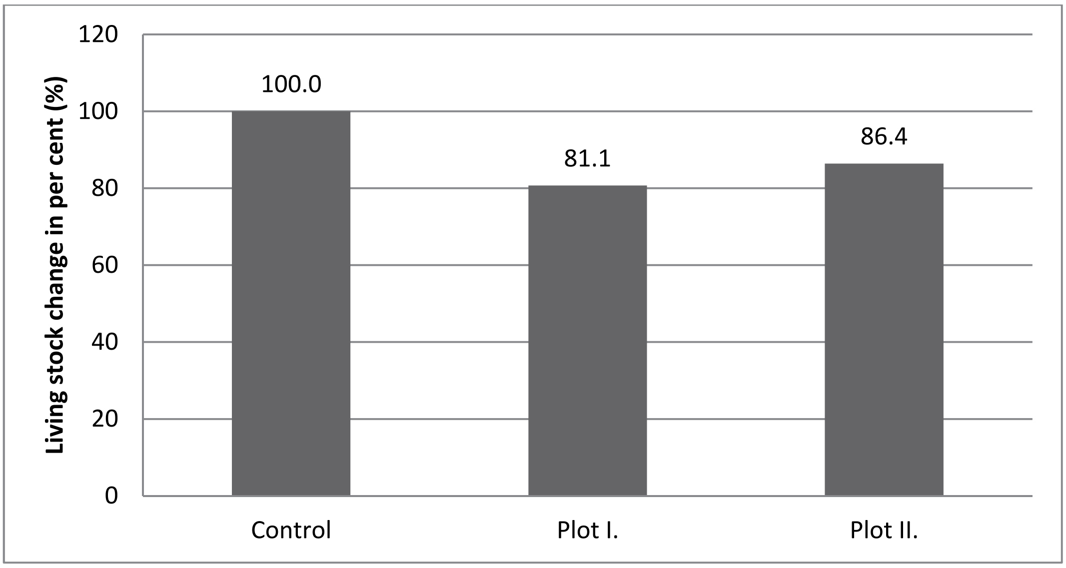

Figure 2. Living stock change 14 years after thinnings were completed in percent (subcompartment Pusztavacs 201 E)

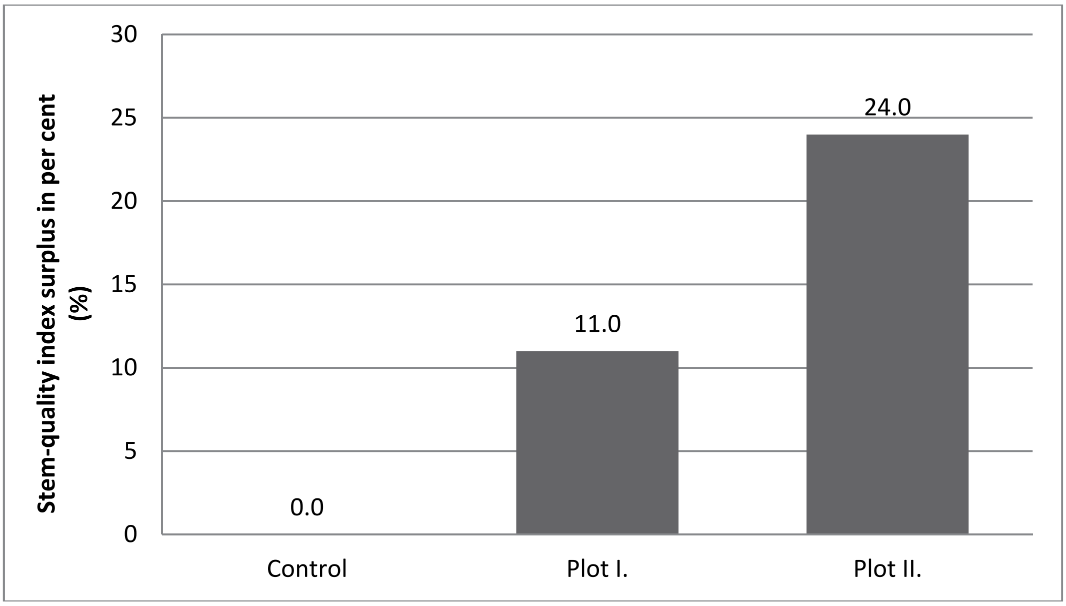

Figure 3. The percentage of stem-quality index change in comparison to the control (subcompartment Pusztavacs 201 E)

4 CONCLUSIONS

Thinning is a silvicultural operation where the main objective is to reduce tree density in a stand, improve the quality and growth of the remaining trees, and produce a marketable product. Thinning can also achieve other objectives such as changing stand species composition, improving the health of the remaining trees, or disturbing an established ground vegetation to enhance opportunities for natural regeneration.

The tree growth rate in a stand depends on the species cultivated, the environmental circumstances of the site on which a stand is established, and the applied silvicultural practices. Provided the site is fully occupied, with a reasonably intact canopy, where by trees can fully utilize the available resources, a stand will produce approximately the same amount of wood/yield at various stocking densities.

According to the investigations presented in this paper, stand volume growth varied slightly among the treatments. It was also verified that thinnings do not increase total production in black locust stands, but can improve stand value.

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