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A simplified method for application of natural regeneration in black locust (*Robinia pseudoacacia* L.) stands in Hungary

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Abstract: 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. One third of these black locust stands are high forests (planted with seedlings) and the remaining stands are coppices. An auxiliary table was developed for planning the black locust natural regeneration in order to determine the sprouting criteria based on stand volume at the final cutting age. Twenty forest subcompartments were selected for investigating the possibility of black locust regeneration by root suckers. The basic yield and stand structure factors were determined using the numerical yield table for black locust stands. The results show that the regeneration of black locust stands from root suckers can be recommended on good and medium quality sites without a decrease in yield or stem quality. Black locust stands of good and medium quality (yield classes I, II, III and IV) may be regenerated from suckers in general until their growing stock attains and if their health is adequate. The simplicity of the practice-oriented auxiliary table based on the black locust yield table may further the development of management and wood utilization of the species.

Keywords: exotic tree species; coppice; regeneration

Coppice is a forest regenerated from vegetative shoots that may originate from the stump and/or from the roots, depending on the species. In contrast to forests originating from seed (the so-called high forest), the rotation period of coppice forests can be significantly shorter (approx. 5–30 years, depending on the type of coppice system). The potential for shoot production mainly depends on the species, tree age, season of cutting and site conditions (Birlanescu, Belu 1968; Borde 2011; Rédei 2013a; Wojda et al. 2015; Nicolescu et al. 2018).

Black locust (*Robinia pseudoacacia* L.) is one of the most valuable hardwoods in Hungary, covering approximately 24% of the forest land and providing 25% of the annual timber supply of the country. The regeneration of black locust stands is one of the crucial points in the improvement of the tree species. Choosing a way how to regenerate black locust stands requires an in-depth analysis (Rédei et al. 2012). It is well known that most of the foresters prefer the cost-saving natural regeneration (by root suckers) to the artificial reforestation, which still requires complete soil preparation. Always recurring questions about the sprouting of black locust stands are as follows:

– what production of black locust stands is worth to regenerate,

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– how many times is it worth regenerating, considering the ecological and stand conditions,
– what kind of parameters are to be used for determining the regeneration criteria, and
– what are the effects of repeated sprouting on the stand structure and yield of black locust stands.

This paper provides a simplified method for the application of natural regeneration of black locust stands of coppice origin based on the relevant Hungarian experience and innovative results.

MATERIAL AND METHODS

Twenty black locust forest subcompartments at five locations at the final cutting age were selected in order to evaluate the possibility of carrying out natural regeneration (Figure 1). The estimated final cutting volume data and the proposals for the regeneration technique were taken from the forestry plans. This information was used to compile the auxiliary table to determine the regeneration technique based on volume.

So called "auxiliary" table for basal area (BA) – volume (V) was compiled for this purpose on the basis of the following formulas (Rédei 1984):

H = mean height of the main crop weighted by the basal area (m):

$$H\% = 123.12\,(1 - e^{-0.070333A})^{1.111638} \tag{1}$$

where:
A – age of stand in years;
H – at the age of 20 = 100%.

DBH = the diameter at breast height of the main crop (cm):

$$\text{DBH} = (69.9675 + 1.00625A) \times H/100,\quad (r = 0.8092,\ n = 200) \tag{2}$$

N = number of trees per hectare of the main crop:

$$N = e^{9.81801 - 1.15147 \times \ln\text{DBH}},\quad (r = 0.9421,\ n = 200) \tag{3}$$

V = volume of the main crop ($m^3 \cdot ha^{-1}$):

$$V = G \times HF$$

where:
G – BA (basal area of the stand, $m^2 \cdot ha^{-1}$)
$HF = 2.05778 + 0.4177 \times H$ (HF – top height)

RESULTS AND DISCUSSION

Several indicators can be used to determine the yield criterion for selecting a regeneration technique. In practice, the final harvest volume as an indicator can be determined relatively quickly. The auxiliary tables mentioned above are widely used in many countries for fast volume determination using a basal area factor, where

$$V_{\text{estimated}} = V_{\text{tabulated}} \times (BA_{\text{estimated}}/BA_{\text{tabulated}})$$

The advantage of these tables is that they do not require the knowledge of the age of the tree stand and the yield class, only its mean height (Laar, Akca 2007).

The total basal area of the stand can be determined either directly (by a measuring instrument) or by using the spacing (tree number) and the mean diameter at breast height weighted by the basal area.

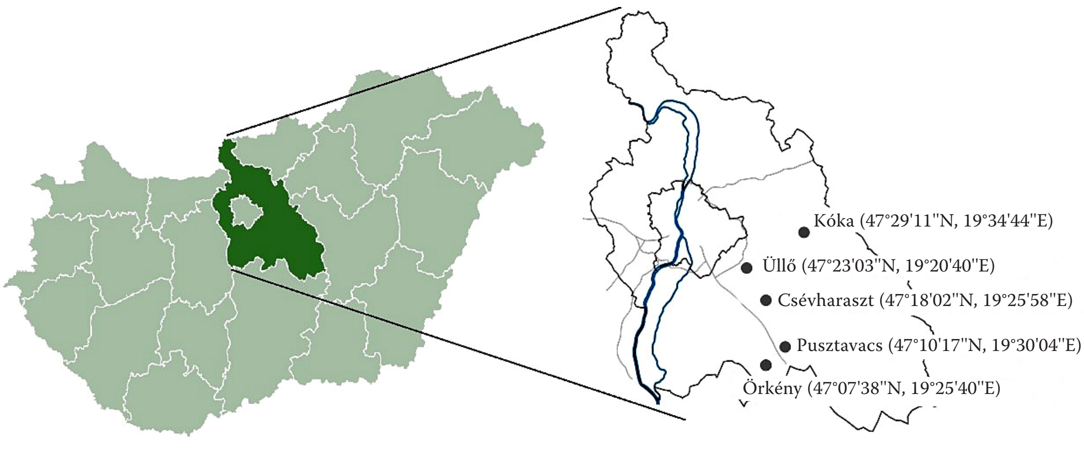

Figure 1. Location of forest subcompartments selected for the study

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The approximated equation describing the relationship between the volume (V) per hectare and the basal area (BA) is as follows:

$$V = 6.6524 + 1.4232 \times BA + 0.4692 \times BA^2$$

The cited numbers and remarks indicated in Table 1 are based on the Hungarian black locust growing directive system, also taking into account the economic aspects of black locust management. An important additional aspect is that recurring generations of coppice, especially in lower yield classes, produce lower total yield.

There are no limits for the sprouting of black locust stands where the height of the stand destined for final harvest is > 24 m and the gross aboveground volume is > 260 $m^3 \cdot ha^{-1}$. The sprouting of black locust stands with a height of 20–24 m at the time of final harvest and gross aboveground volume of 190 to 260 $m^3 \cdot ha^{-1}$ is possible and economically profitable in most cases. The sprouting of black locust stands with a height of 17–20 m at the time of final harvest and gross aboveground volume of 140 – 190 $m^3 \cdot ha^{-1}$ may be possible once, based on individual judgement. Sprouting can be carried out in protective forest or when species conversion is needed if the height is < 17 m at the time of final harvest and gross aboveground volume is < 140 $m^3 \cdot ha^{-1}$.

For many species, like in the case of black locust, it is possible to simply allow the trees to re-sprout from the root system of the stand left after harvesting. Stem form and wood quality of the trees which grow eventually from coppice may be just as good as in the trees grown from seedlings (Figure 2). Re-

Table 1. Auxiliary table for planning the natural regeneration of black locust stands

Height (m)	Basal area (m^2/ha)	Volume (m^3/ha)	Number (trees/ha)	Average distance of trees (▲) (m)	Remarks
7	5.0	25	3 300	1.8	Sprouting can be carried out in protective forest or if species conversion is needed. Regeneration by species conversion should be applied, so instead of black locust, depending on the quality of the site, it should be solved with another tree species.
8	6.2	33	2 510	2.1	
9	7.3	42	2 020	2.4	
10	8.4	52	1 680	2.6	
11	9.5	63	1 435	2.8	
12	10.4	73	1 250	3.0	
13	11.4	85	1 100	3.2	
14	12.5	98	985	3.4	
15	13.5	111	890	3.6	
16	14.5	125	810	3.8	
17	15.3	138	740	4.0	Sprouting of black locust stands may be possible one time. This means that after possible re-sprouting, the tree stand must be regenerated (generatively) with seedlings.
18	16.3	154	685	4.1	
19	17.2	170	635	4.3	
20	18.2	187	590	4.4	Sprouting of black locust stands is possible and economically profitable in most cases.
21	19.1	205	550	4.5	
22	19.9	221	520	4.6	
23	20.8	241	490	4.8	
24	21.8	260	460	5.0	There are no limits for the sprouting of black locust stands.
25	22.7	280	440	5.1	
26	23.5	299	416	5.3	
27	24.4	321	396	5.4	
28	25.3	343	377	5.5	
29	26.2	366	360	5.7	
30	27.1	390	345	5.8	

The rows marked in red are boundary rows that indicate the categories of regeneration options by the root suckers; ▲ – triangle planting

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Figure 2. Black locust stand of yield class II at the age of 35 years
Photo: Forest Research Institute, Hungary

establishment of a plantation or a stand by coppice may be repeated a number of times.

Where it is possible to re-establish a plantation or a stand using coppice, a great deal of expense can be avoided (Rosenqvist, Dawson 2005; Rédei 2013b). Variation in the environmental circumstances of different sites may affect coppice development of different species in different ways (Little, Gardner 2003). The coppice from different genetic strains of the same species can develop rather differently (Robinson et al. 2004).

In Hungary, one-third of the black locust stands are high forest (seed origin), and the remaining stands are of coppice origin. To choose the most suitable regeneration method is a part of the black locust management. In the country, according to the forestry regulations, black locust stands can be regenerated by root suckers and by means of seedlings (Rédei et al. 2008; Rédei 2013b). In the case of simple coppice (suckering), after the tree felling, the stools are removed from the ground, the resulting pits are levelled and the soil is loosened to a depth of 10–15 cm in order to wound the shallow roots and promote the production of root suckers (Rădulescu 1956; Matula et al. 2012; Nicolescu et al. 2018). Root suckers grow very quickly and can form a new stand (close the canopy) one year after cutting in black locust stands (Negulescu 1959; Nicolescu et al. 2018).

In some countries due to the very much diversified site conditions, under better ones, black locust is to be replaced with other tree species, among others with native tree species (Nicolescu et al. 2018). The yield of black locust stands is very variable comparing plantations and stands originating from stump sprouts and root suckers (1st, 2nd, and 3rd generations). The stump and root sprouts significantly differ in the yield development within the 1st, 2nd and 3rd rotation. The yield decreases quite sharply as the stumps get older, while the yield of stands originating from root suckers (Figure 3) does not always change from generation to generation (Rédei et al. 2012). The rotation age in simple coppices ranges generally between 15 and 25 years (Stajic et al. 2009). The rotation can be longer, approaching the maximum of 30–35 years in black locust (Magagnotti, Schweier 2017; Nicolescu et al. 2018) (Figure 2). The rotation age is also influenced by the wood production target (wood assortment). In Hungary, 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.

Figure 3. Black locust natural regeneration by root suckers at the age of 2 years
Photo: Forest Research Institute, Hungary

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CONCLUSION

The method published in this paper can be used in black locust management and forest inventory, such as harvest scheduling and further development of silvicultural (tending and cutting operation) models for black locust stands as well as their growth and economic analyses. Our further data also show (Rédei et al. 2012) that under suitable site conditions for black locust, professional and careful regeneration from root suckers there is no considerable difference between the average quantity and quality of stems as well as the health of trees in stands regenerated from root suckers and seedlings. On the basis of these results and considering the economic requirements, the regeneration of black locust stands from root suckers may be recommended on sites of yield classes I–III (Rédei 1984) on a larger scale.

By using up-to-date silvicultural technology, including improved stand regeneration methods, the possible negative environmental effects of black locust can also be significantly reduced (Nicolescu et al. 2018).

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