Regeneration and Early Tending of Black Locust (Robinia pseudoacacia L.) Stands in the North-West of Romania

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ABSTRACT

Background and Purpose: The aim of this study is to highlight the importance of black locust (Robinia pseudoacacia L.), a North American-originating tree species of major importance in Romania, in extreme site conditions such as sand dunes. In this respect, a Research and Development (R&D) project has been carried out in Carei-Valea lui Mihai Plain (north-west of Romania) since 2016.

Materials and Methods: Three sub-compartments were selected in IV Valea lui Mihai Working Circle, Săcueni Forest District: two pure natural regenerations by root suckers of black locust at different ages (sub-compartments 3B and 52A%) and a mixed black locust - black cherry stand (sub-compartment 23D). Biometrical measurements and analyses as well as biomass estimations were performed. A thorough statistical analysis using the data on initial, extracted and residual trees/stands was also performed.

Results: The main outputs of the project are as follows: (1) Black locust was established naturally by root suckers and the stocking of newly established stands can be as high as 50,000 suckers·ha⁻¹; (2) The initial growth of black locust regeneration is quick and the young regeneration can close the canopy in 1-2 years, resulting in an appropriate dune fixation and wind erosion control; (3) The young pure or mixed black locust-dominated stands are left untended until the first cleaning-respacing (mean diameter 5-6 cm), when the stand shows high stocking/density and a wide variation in tree size. This intervention is from below, heavy (intensity over 25% by number of trees or basal area) and of negative selection type, removing mostly low Kraft’s class, dead or dying, and defective trees.

Conclusions: This R&D project has shown the high potential of black locust to establish naturally by root suckers after a low coppice cut and stump removal, as well as the fast initial growth of regenerated black locust. The quick canopy closure of young regeneration results in an appropriate dune fixation and wind erosion control.

Keywords: black locust, natural regeneration, release cutting, cleaning-respacing, initial growth

INTRODUCTION

Black Locust in the World, in Europe and in Romania

Black locust (Robinia pseudoacacia L.) originates from the eastern part of the United States, where it is found in two areas, in the eastern (Pennsylvania, Ohio, Alabama, Georgia and South Carolina) and western area (Missouri, Arkansas, and Oklahoma) [1]. Globally, black locust was introduced and became naturalized in all sub-Mediterranean and temperate regions: Asia (i.e. South Korea - over 1.2 million ha; China - over 1 million ha; India, Pakistan, Japan), Australia, New Zealand, Africa (North and South), South America (Argentina, Chile) [2-7]. Black locust is now rivaling poplar as the second most planted broadleaved tree species in the world, after the eucalypts [8-10]. This expansion worldwide is due to the fact
that black locust is an economically important multipurpose tree, in wood production (e.g. firewood, pulpwood, flooring, railway sleepers, boat building, fences, construction, barrel staves, veneer, solid furniture), fodder production, honey production, as a source of bio-oil, for biomass production and carbon sequestration, soil stabilization, erosion control, re-vegetation of landfills, mining areas and wastelands, in biotherapy, and landscape architecture [11-22].

Black locust was the first North American forest tree species to be imported to Europe at the beginning of the 17th century (1601) [12, 18, 23, 24]. Currently, black locust is naturalized in thirty-two European countries (Pyšek et al. 2009, in [21]), covering a total area of 2,306,607 ha [25], and it is the most used non-native broadleaved tree species on the continent.

In Romania, black locust was introduced as a park tree around 1750, probably from Turkey, in the southern and eastern provinces (Wallachia and Moldova), as well as through Serbia and Austro-Hungary in Transylvania (centre) and Banat (south-west) provinces [26]. The first forest planting including black locust was established in the south-west of Romania (Oltenia Plain) in 1852, in order to stabilize mobile sand dunes [26, 27]. After 1883, it was widely introduced throughout the country for the same purpose as sand dune systems extend to about 266,000 ha in Romania (about 1% of the national territory [28, 29]).

The area covered by black locust in 1922 was only 28,000 ha [30], expanding to ca. 100,000 ha by the mid-1950s [12] and further to approx. 250,000 ha at the present time (4% of national forest land, mostly in the south of the country, on sand dunes and areas with heavy soils in the forest steppe zone) [20, 31].

**Regeneration and Early Growth of Black Locust**

In different parts of the world, black locust is regenerated by one of three methods:

a) **Planting** in spring using 1-year-old seedlings, normally bare-rooted, 0.5-1.0 (or even 2) m tall, produced in conventional nurseries [3, 32, 33]. The initial stocking rate of black locust plantations in Europe is very variable: 1,100-1,900 seedlings·ha⁻¹ in France (Bourgogne) [34], 1,200-1,700 seedlings·ha⁻¹ (4×2 m, or 3×2 m) in France (Aquitaine and Poitou-Charentes) [35], 2,000-2,500 seedlings·ha⁻¹ (2.5×2.0 m, or 2.5×1.6 m) in Poland [10] to 4,000-5,000 seedlings·ha⁻¹ (2.0×1.25 m, or 2.0×1.0 m in Romania; 2.4×0.7-0.8 m, or 2.4×1.0 m in Hungary) [33, 36-38].

b) **Naturally by seed.** This is rare, as the hard and impermeable seed coat limits germination in the forest/natural environment. However, there are some examples of natural regeneration in the literature [12, 15], this process being facilitated by seed winding with heavy machinery, or natural thermal shock [24].

c) **Naturally by vegetative regeneration** from stool shoots and root suckers. As black locust coppices freely this is considered the most cost-effective management system for the species [21, 23]. The method is cheap, efficient and allows local people to collect stem wood, which is highly valued as firewood. Root suckers live longer and are healthier (i.e. show less rot at the same age) than stool shoots; however, the latter grow quicker up to 12-15 years of age than root suckers [12, 13]. The most common rejuvenation method is by root suckers since black locust develops horizontal, shallow and wide-spreading roots which can extend 15-20 m from the parent tree [3, 12, 15].

**Early Management of Black Locust Stands**

The application of early management operations such as release cutting and cleaning-respacing in black locust stands varies according to the regeneration method as follows:

a) **In plantations** with up to 5,000 seedlings·ha⁻¹ there is no need for any release cutting [10, 18, 40]. In such stands cleaning-respacing begins after canopy closure, at 4-5 years. and the stocking should be reduced to about 2,500 trees·ha⁻¹ [10]. The second cleaning follows 2-3 years later, with a further reduction to ca. 1,700 trees·ha⁻¹ [10].

b) **In black locust coppice stands** regenerated from stool shoots and root suckers, release cutting is necessary to reduce the number of shoots per stool to 1 or 2 and to protect root suckers from stool shoot competition [13, 39]. Normally two release cuttings are performed, the first one in the first or second year, followed by another 1-3 years subsequently [40, 41]. In Romania, two cleaning-respacing operations are performed in years 3-4 and 6-7, reducing the canopy cover to 80-85%.

In both black locust plantations and coppice stands cleaning-respacing operations are considered to be "the basis for all good management in black locust stands" [42]. These authors aimed to heavily reduce the number of stems, allowing the potential final crop trees sufficient space to grow. If this intervention is too late or too light, the remaining trees do not develop their crowns normally (they are deformed or very small) as this is a strong light-demanding species and is intolerant of shade/competition [12, 14, 16]. The cleaning-respacing is based on negative selections (particularly in the first intervention) removing defective trees, for example, those that are forked (this species is sensitive to early frosts, leading to forking [13, 43]), badly formed, wounded, bent-over (the effect of strong phototropism), combined with positive selections where even well-formed and healthy individuals are removed to provide additional growing space to those selected to remain [43]. Halupa and Rédei [42] highlighted the importance of cleaning-respacing to produce regular spacing of the remaining trees.

In the context of these characteristics of black locust stands and silviculture in the early stages, a Research and Development (R&D) project was launched in 2016, in order to evaluate the regeneration and early tending of black locust stands in the north-west of Romania. The objectives of this project are (1) to assess the regeneration potential of black locust by root suckers, (2) to assess the early growth of root sucker stems, and (3) to follow and evaluate the early results of these interventions in terms of quality, growth and yield of young black locust stands.
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**MATERIALS AND METHODS**

**Study Sites**

In order to achieve the objectives set out above, fieldwork was undertaken in black locust stands managed by the Săcueni Forest District, part of Bihor County Branch, National Forest Administration ROMSILVA. These stands are located in the north-west of Romania (Carei-Valea lui Mihai Plain; 46°58′ N, 22°16′ E), and comprise three sub-compartments which are part of the IV Valea lui Mihai Working Unit.

The study area had the following main characteristics. Landform is continental sand dunes, of river and wind origin, formed in the Holocene, with a SW-NE and NW-Spîrchez orientation and an elevation between 140 and 160 m [44]. According to Spîrchez et al. [44] and Târziu and Spîrchez [45], the local soils are part of the Psammments suborder, Entisols order (sandy soils), with the following characteristics: (i) very deep but poor, with low fertility and low nutrient (N, P, and K) content; (ii) light soil texture (85-90% sand, mostly fine); (iii) moderately acid to neutral (5 to 7) pH; (iv) maximum fraction of humus is 1% in the upper 25 cm of soil; (v) presence of a hard and poorly drained ortstein (ironpan) horizon, Al, Fe, Mn, and humus compounds-rich from the overlying shallow O horizon [44]. This horizon restricts water infiltration during the driest summer periods, when the sand gets very warm at the surface, and provides, to a considerable depth, important water supply for the forest vegetation.

The local climate is classified as temperate-continental, compared to a humid climate in the native range of black locust [1]. Mean annual temperature: 10.3°C; maximum monthly temperatures in July: 20.7°C; minimum in January: -1.6°C. Mean annual total precipitation: 573.3 mm. The monthly temperatures in July: 20.7°C; minimum in January: -1.6°C. Mean annual total precipitation: 573.3 mm. The maximum monthly precipitation is in June as 83 mm, and the minimum in March is 30 mm.

Potential mean annual total evapo-transpiration is around 600 mm, similar to the mean annual total precipitation. Maximum wind speed is 4.0 m·s⁻¹ (South), so no wind damage to forest vegetation normally occurs (the black locust stands have deep vertical roots to depths of 2-3 m or more [44]). The only exception was the event on August 3, 1988, when the wind speed reached 18 m/s and the volume of damaged black locust reached 1,087 m³ (3,599 trees) [46]. Meant length of frost-free period is 150-210 days [1]. The mean annual aridity (de Martonne) index is 28.2, so the area is considered to be between W and stem diameter was used according to:

\[
W = bD^c
\]

where W - biomass, D – root collar diameter, b and c – constant parameters.

Forest Vegetation

The first black locust plantations (200 ha, 2×2 m initial spacing) on sandy soils in the Carei-Valea lui Mihai Plain were established in 1892 [44, 47]. Until 1933 only small-scale plantations including Scots pine (*Pinus sylvestris* L.), black pine (*Pinus nigra* Arn.), pedunculate oak (*Quercus robur* L.), northern red oak (*Q. rubra* L.), pin oak (*Q. palustris* L.), or (ii) for replacing low-productive tree species such as cherry stand, 12-years old, originating from root suckers after a simple coppice cut (2013-2014) and the removal of stumps; (3) Sct. 23D - mixed black locust-black cherry stand, 12-years old, originating from root suckers after a simple coppice cut (2004) and the removal of stumps. No silvicultural interventions had been performed since the establishment.

**Experimental Material**

In this context, three sub-compartments (scpt.) - 3B, 23D and 52A% - were selected for the R&D project. The main characteristics of these stands are: (1) Sct. 3B - pure natural regeneration by root suckers of black locust, 1-year old, following simple coppice cut (winter 2015-2016) and the removal of stumps; (2) Sct. 52A% - pure natural regeneration by root suckers of black locust, 2-years old, following simple coppice cut (winter 2013-2014) and the removal of stumps; (3) Sct. 23D - mixed black locust-black cherry stand, 12-years old, originating from root suckers after a simple coppice cut (2004) and the removal of stumps.

**Experimental Design**

In order to carry out the fieldwork, different experimental plots were designed: (1) Sct. 3B - six plots of 25 m² (5×5 m) each, established in April 2017 (Figure 1); (2) Sct. 52A% - two plots of 25 m² (5×5 m) each, established in June 2016; (3) Sct. 23D - two plots of 150 m² (15×10 m), established in July 2016.

**Root Suckers/Tree Measurements**

Root collar diameter and total height were measured for all initial and remaining root suckers, after the release cutting carried out in all plots from scpts. 3B and 52A%. Diameter at breast height (DBH) and total height for all initial and remaining trees after cleaning-respacing were measured in sct. 23D. The location (x-y) of each remaining tree as well as four perpendicular crown radii for such trees was also measured.

**Biomass Estimation**

The suckers cut during the release intervention (sct. 3B) were bundled in each plot and transported to the laboratory. The dry matter content was determined by drying material at 105°C, until constant weight was reached. To assess biomass production, an allometric relationship between W and stem diameter was used according to:

\[
W = bD^c
\]

where W - biomass, D – root collar diameter, b and c – constant parameters.

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Silvicultural, Biometrical and Statistical Analysis

Using the data collected in the field the following calculations were performed: stocking (no. of trees·ha⁻¹) before and after release cutting and cleaning-respacing, in order to determine the intensity of the interventions; density (m⁻²·ha⁻¹) before and after cleaning-respacing, with the same purpose; mean collar diameter in release cutting, DBH in cleaning-respacing of the initial, extracted and remaining trees and their standard deviations; mean height (in both release cutting and cleaning-respacing) of the initial, extracted and remaining trees and their standard deviations; dry biomass of extracted, remaining and initial suckers in scpt. 3B; coefficients of variation of diameters and heights (initial, extracted and remaining suckers or trees); significant differences between means were tested using ANOVA and Duncan post hoc test [49].

RESULTS AND DISCUSSION

(A) Regeneration of Black Locust Stands

In the two sub-compartments analyzed with respect to natural regeneration of black locust by root suckers, the most relevant results are as follows:

(i) 1-year old natural regeneration (scpt. 3B)
The potential for natural regeneration of black locust from root suckers was very high and the initial stocking after one growing season ranged between 15,200 and 67,600 suckers·ha⁻¹ (50,800 on average). The initial stocking was higher than the one found in the study conducted in France, which recorded over 40,000 suckers·ha⁻¹ by using this regeneration method (Pagès 1985, cited in [35] – Figure 2).

This very high stocking allowed for very heavy interventions (over 25% of the number of trees [40]) with release cutting (from 68.42% to 91.89%, over 80% in the majority of plots), reducing the stocking per ha to between 4,800 suckers and 9,200 suckers (7,200 suckers on average) (Table 1).

Significant differences (F=4.735, p=0.0003) were registered in terms of root collar diameter for root suckers located on the dune top, in the middle of the slope and the bottom of the dune at the beginning of the experiment. The same pattern was observed for the removed root suckers (F=4.942, p=0.0002).

The suckers removed by release cutting were the smallest (or thinnest) ones. Consequently, the arithmetic mean collar diameter of black locust suckers increased from 7.36±3.91 - 9.81±5.32 mm to 11.67±4.12 - 14.72±6.76 mm, the coefficients of variation of diameters being the lowest in the remaining root suckers. No significant differences were registered for the remaining root suckers (F=1.010, p=0.416) (Table 2).

The suckers extracted through this intervention were also the shortest, so the arithmetic mean height of black locust suckers increased from 87.79±40.18 - 100.18±63.29 cm to between 126.33±35.06 and 175.67±44.88 cm, the coefficients of variation of heights being also the smallest in the remaining root suckers. In terms of root sucker height,
the analysis of variance showed no significant differences: F=0.896, p=0.483 for initial root suckers, F=1.193, p=0.311 for removed root suckers and F=1.469, p=0.207 for the remaining ones.

The aboveground dry biomass of initial, extracted, and remaining black locust root suckers in the six plots was calculated using the allometric formula $W=0.652D^{2.582}$, $R^2=0.9426$.

The initial aboveground dry biomass in all plots, except plot no. 4, exceeded 1.1 t·ha$^{-1}$ (1.384 t·ha$^{-1}$ on average), the maximum being measured in plots 3 (1.875 t·ha$^{-1}$) and 6 (1.939 t·ha$^{-1}$) (Table 3), which were both located close to the dune top.

As the release cutting intervention had very heavy intensity, the remaining aboveground biomass was less than 0.5 t·ha$^{-1}$, with the exception of plots 3 (0.699 t·ha$^{-1}$) and 6 (0.565 t·ha$^{-1}$), with a mean of 0.462 t·ha$^{-1}$.

(ii) 2-years old natural regeneration (sctp. 52A%)

This stand was regenerated identically to scpt. 3B and is located in very similar ecological conditions. In the two plots very strong competition between the suckers started immediately after the canopy closure of the newly established regeneration, i.e. at the end of the first growing season, producing an abrupt reduction in stocking of this 2-years old stand (12,000 suckers·ha$^{-1}$ in plot 1 and 22,000 suckers·ha$^{-1}$ in plot 2) (Table 4).

The mean collar diameters (6.9 mm and 6.7 mm respectively) and mean height (162 cm and 155 cm respectively) are similar in the two plots. The ranges in both of these parameters are similar and no significant

**TABLE 2.** Arithmetic mean collar diameters (mean), arithmetic mean height (mean), standard deviations (SD) and coefficients of variation (CV) of black locust root suckers (initial, extracted, and remaining) in the 1-year old regeneration.

| Plot no. | Initial root suckers | Extracted root suckers | Remaining root suckers |
|----------|----------------------|------------------------|------------------------|
|          | Mean ± SD CV         | Mean ± SD CV           | Mean ± SD CV           |
|          | Collar diameter (mm) |                        |                        |
| 1        | 7.36 ± 3.91 53.15    | 6.58 ± 3.35 50.92      | 12.38 ± 3.57 28.84     |
| 2        | 7.87 ± 4.84 61.44    | 7.30 ± 4.38 60.04      | 14.33 ± 5.21 36.35     |
| 3        | 9.81 ± 5.32 54.22    | 8.93 ± 4.53 50.66      | 14.72 ± 6.76 45.94     |
| 4        | 7.71 ± 4.01 52.02    | 5.89 ± 2.32 39.40      | 11.67 ± 4.12 35.31     |
| 5        | 7.71 ± 4.45 57.65    | 7.04 ± 3.98 56.57      | 11.96 ± 4.95 41.40     |
| 6        | 8.90 ± 5.85 65.76    | 8.07 ± 5.61 69.56      | 13.24 ± 5.24 39.61     |
| All plots | 8.20 ± 4.87 59.43   | 7.42 ± 4.37 58.88      | 12.99 ± 5.08 39.12     |

|          | Mean ± SD CV         |                         |                          |
|          | Height (cm)           |                         |                          |
| 1        | 89.08 ± 47.64 53.48  | 78.62 ± 40.67 51.73    | 156.33 ± 31.94 20.43    |
| 2        | 91.61 ± 51.15 55.83  | 84.20 ± 44.74 53.13    | 175.67 ± 44.88 25.55    |
| 3        | 95.58 ± 52.88 55.32  | 84.91 ± 45.51 53.60    | 155.44 ± 52.46 33.75    |
| 4        | 87.79 ± 40.18 45.77  | 70.00 ± 28.40 40.57    | 126.33 ± 35.06 27.75    |
| 5        | 96.81 ± 53.91 55.68  | 86.66 ± 46.81 54.01    | 161.22 ± 52.25 32.41    |
| 6        | 100.18 ± 63.29 63.18 | 89.19 ± 59.32 66.51    | 157.19 ± 52.55 33.43    |
| All plots | 100.18 ± 53.14 56.45 | 83.98 ± 46.83 55.77    | 156.21 ± 46.99 30.08    |

**FIGURE 2.** Aspect of young regeneration by root suckers in: (a) 20 April 2017, and (b) 18 May 2019. (Photos V.N. Nicolescu).
statistical differences occurred (F=0.132, p=0.717 for collar diameter and F=0.372, p=0.543 for height) between the collar diameter and the height of suckers in these two plots (Table 4).

**TABLE 3.** Dry biomass of root suckers in the 1-year old regeneration.

| Plot no. | Dry biomass (t·ha⁻¹) | Extracted | Remaining | Initial |
|----------|-----------------------|-----------|-----------|---------|
| 1        | 0.721                 | 0.422     | 1.143     |         |
| 2        | 1.129                 | 0.379     | 1.508     |         |
| 3        | 1.176                 | 0.699     | 1.875     |         |
| 4        | 0.087                 | 0.219     | 0.306     |         |
| 5        | 1.044                 | 0.488     | 1.532     |         |
| 6        | 1.374                 | 0.565     | 1.939     |         |
| Mean     | 0.922                 | 0.462     | 1.384     |         |
| Range    | 0.087-1.374           | 0.219-0.699 | 0.306-1.939 |     |

**TABLE 4.** Main characteristics of plots 1 and 2 in the 2-years old regeneration.

|                  | Plot 1 | Plot 2 | Overall |
|------------------|--------|--------|---------|
| Number of individuals ha⁻¹ | 12,000 | 22,000 | 17,000  |
| Basal area (m²·ha⁻¹)     | 0.53   | 0.93   | 0.73    |
| Collar diameter (mm)     |        |        |         |
| Arithmetic mean         | 6.9    | 6.7    | 6.8     |
| Maximum                 | 14.4   | 15.1   | 15.1    |
| Minimum                 | 3.0    | 2.8    | 2.8     |
| Height (cm)             |        |        |         |
| Arithmetic mean         | 162    | 155    | 158     |
| Maximum                 | 257    | 264    | 264     |
| Minimum                 | 60     | 50     | 50      |

**B) Cleaning-respacing of young mixed black locust-dominated stands**

This intervention was carried out in scpt. 23D, which showed the following main characteristics:

The stand initial stocking was very high (5,467 trees·ha⁻¹) in plot 1, and lower (3,533 trees·ha⁻¹) in plot 2. These trees had a similar basal area (14.30 m²·ha⁻¹ in plot 1 and 13.87 m²·ha⁻¹ in plot 2). This made a very heavy intervention possible, with the removal of over 25% trees, reducing the stocking to 2,333 trees·ha⁻¹ and the basal area to 9.33 m²·ha⁻¹ (plot 1) and 1,733 trees·ha⁻¹ and 9.10 m²·ha⁻¹ (plot 2) (Figure 3 and Table 5).

The remaining stocking in the two plots is similar to the one recommended in Hungary (1,800 trees·ha⁻¹ [48]) and Germany (2,350 trees·ha⁻¹ [50]) and marginally lower than the one in Bulgaria (ca. 2,500 trees·ha⁻¹ [51]).

As the intensity by the number of trees (57.3% in plot 1, and 50.9% in plot 2) was much higher than by the basal area (34.1% in plot 1 and 34.4 in plot 2), the intervention was from below in both plots, removing mostly trees from the lower diameter classes.

As the intervention removed mostly the smallest (thinnest and shortest) trees, the arithmetic mean diameter and arithmetic mean height increased in both black locust and black cherry, particularly in the former species (Table 6).

Even though black locust and black cherry have similar heights (F=3.781, p=0.054), significant differences were found in the case of diameter (F=67.051, p=0.000).

The intervention produced gaps in the canopy cover, which shows a value after cleaning-respacing of ca. 80% in plot 1, and 75% in plot 2, so that some trees have additional space at the canopy level to develop their crowns and consequently increase DBH.
TABLE 5. Main characteristics of stand and of cleaning-respacing carried out in the 12 years-old natural regeneration.

|                      | Black locust BL | Black cherry BC | Overall | Species composition (%) |
|----------------------|-----------------|-----------------|---------|-------------------------|
| **Number of trees·ha⁻¹** |                 |                 |         |                         |
| Plot 1               |                 |                 |         |                         |
| Initial              | 4,867           | 600             | 5,467   | 89BL11BC                |
| Extracted            | 2,933           | 200             | 3,133   | 94BL68BC                |
| Remaining            | 1,933           | 400             | 2,333   | 83BL17BC                |
| Intensity of intervention (%) | 60.3          | 33.3            | 57.3    |                         |
| Plot 2               |                 |                 |         |                         |
| Initial              | 2,400           | 1,133           | 3,533   | 68BL32BC                |
| Extracted            | 1,267           | 533             | 1,800   | 70BL30BC                |
| Remaining            | 1,133           | 600             | 1,733   | 65BL35BC                |
| Intensity of intervention (%) | 52.8          | 47.1            | 50.9    |                         |
| **Basal area (m²·ha⁻¹)** |                 |                 |         |                         |
| Plot 1               |                 |                 |         |                         |
| Initial              | 10.87           | 3.43            | 14.30   | 76BL24BC                |
| Extracted            | 4.25            | 0.72            | 4.87    | 87BL13BC                |
| Remaining            | 6.62            | 2.71            | 9.33    | 71BL29BC                |
| Intensity of intervention (%) | 39.1          | 21.0            | 34.1    |                         |
| Plot 2               |                 |                 |         |                         |
| Initial              | 5.61            | 8.26            | 13.87   | 40BL60BC                |
| Extracted            | 1.82            | 2.95            | 4.77    | 38BL62BC                |
| Remaining            | 3.79            | 5.31            | 9.10    | 42BL58BC                |
| Intensity of intervention (%) | 32.4          | 35.8            | 34.4    |                         |

TABLE 6. Biometrical characteristics of 12-years old naturally regenerated black locust and black cherry before and after intervention.

|                      | Black locust | Black cherry |
|----------------------|--------------|--------------|
| **Arithmetic mean diameter ± standard deviation (cm)** |              |              |
| Initial              |              |              |
| Plot 1               | 5.3 ± 1.82   | 8.0 ± 3.50   |
| Plot 2               | 5.4 ± 1.67   | 9.5 ± 2.88   |
| Extracted            |              |              |
| Plot 1               | 4.0 ± 1.44   | 6.7 ± 1.15   |
| Plot 2               | 4.4 ± 1.00   | 8.1 ± 2.21   |
| Remaining            |              |              |
| Plot 1               | 6.5 ± 1.44   | 8.5 ± 4.17   |
| Plot 2               | 6.5 ± 1.52   | 10.7 ± 2.95  |
| **Arithmetic mean height ± standard deviation (m)** |              |              |
| Initial              |              |              |
| Plot 1               | 8.6 ± 2.51   | 8.6 ± 3.00   |
| Plot 2               | 9.5 ± 2.88   | 10.3 ± 1.77  |
| Extracted            |              |              |
| Plot 1               | 7.0 ± 1.99   | 8.1 ± 1.79   |
| Plot 2               | 7.9 ± 1.62   | 9.5 ± 1.73   |
| Remaining            |              |              |
| Plot 1               | 10.6 ± 1.38  | 8.9 ± 3.60   |
| Plot 2               | 10.0 ± 1.33  | 11.0 ± 1.58  |
CONCLUSIONS

The R&D project, which began in 2016, focusing on pure and mixed black locust-dominated stands, has led to the following conclusions on regeneration and the early management of such stands:

- The potential of black locust to establish naturally by root suckers after a low coppice cut and stump removal is very high and the stocking of such newly established stands can exceed 50,000 suckers·ha⁻¹.¹
- Despite the unfavourable conditions in the case study area, the initial growth of regenerated black locust is fast and the newly established stand can close the canopy in 1-2 years, resulting in effective dune stabilization and wind erosion control.
- There are significant biometric differences, for example in collar diameter and height, between the young shoots, leading to a high level of natural mortality after canopy closure.

- Economic factors, such as lack of markets and/ or workforce, result in young pure or mixed black locust-dominated stands usually being untended in the early stages. The first commercial intervention (cleaning-respacing) occurs when the stand has reached the thicket stage (minimum mean diameter 5-6 cm) and exhibits high stocking and density as well as wide dimensional (diameter and height) variation. Consequently, the first cleaning-respacing intervention is from below, of high intensity and negative selection type, removing mostly low Kraft’s class (intermediate/ suppressed), dead or dying, and defective (for example forked, wounded, or bent-over) trees.

However, these are only preliminary results and during the next intervention different measurements (e.g. collar diameters and heights - stands for release cutting; diameters, heights and crown radii - stands for cleaning-respacing) will be taken. These will provide an assessment of natural dieback in young, naturally regenerated black locust stands, and the effects of the two silvicultural interventions on the early growth of this species in pure or mixed stands.

REFERENCES

1. HUNTYLEJC 1990 Robinia pseudoacacia L. Black locust. In: Burns RM, Honkala BH (tech. coord.) Silvics of North America, Volume 2 Hardwoods. Agriculture Handbook 654, Forest Service, United States Department of Agriculture, Washington, DC, USA, pp 755-761
2. KERESZTESI B 1988 Natural range of black locust and its distribution in other countries. In: Keresztesi B (ed) The black locust. Akadémiai Kiadó, Budapest, Hungary, pp 9-17
3. LUNA RK 1996 Robinia pseudoacacia Linn. In: Plantation trees. International Book Distributions, Dehra Dun, India, pp 633-639
4. DEMENTE JM, MERZEAU D 2007 Black locust. History and biological characteristics (in French). Forêt-entreprise 177: 10-12
5. SOFLETEA N, CURTU L 2007 Dendrology (in Romanian). Editura Universității “Transilvania”, Brașov, Romania, 418 p
6. TUBAVALANDA A, DU K, LU X 2007 Black locust in China (in French). Forêt-entreprise 177: 50-53
7. CIERJACKSA KGOWARIK J, JOSHI J, HEMPELS, RISTOM W, VON DER LIPPE M, WEBERE R 2013 Biological Flora of the British Isles: Robinia pseudoacacia. J Ecol 101 (6): 1623-1640. DOI: https://doi.org/10.1111/1365-2745.12162
8. SAVILL P 2013 The silviculture of trees used in British forestry. 2nd edition. CAB International, Wallingford, UK, and Boston, USA, 280 p
9. RÉDEIK 2013 The black locust (Robinia pseudoacacia L.) and its features. In: Rédei, K (ed) Black locust (Robinia pseudoacacia L.) growing in Hungary. Hungarian Forest Research Institute, Sárvár, Hungary, pp 7-11
10. WOJDA T, KLIŚ M, JASTRZĘBOWSKI S, MIONSKOWSKIM, SZYP-BOROWKA I, SZCZYGIEL K 2015 The geographical distribution of the black locust (Robinia pseudoacacia L.) in Poland and its role in non-forest land. Papers on Global Change-IGBP 22: 101-113. DOI: https://doi.org/10.1515/igbp-2015-0018
11. POSKIN A 1926 Handbook of Silviculture (in French). Jules Duculot, Gembloux, Librairie Agricole de la Maison Rustique, Paris, France, 439 p
12. NEGULESCU E, SĂVULESCU AL 1957 Dendrology (in Romanian). Editura Agro-Silvică de Stat, Bucharest, Romania, 457 p
13. HARALAMBA AT 1967 Culture of tree species (in Romanian). Editura Agro-silvică, Bucharest, Romania, 755 p
14. MCALISTER RH 1971 Black locust (Robinia pseudoacacia L.). U.S. Department of Agriculture. Forest Service, American Woods-FS-24, Washington, D.C., USA, 6 p
15. STĂNESCU V 1979 Dendrology (in Romanian). Editura Didactică și Pedagogică, Bucharest, Romania, 470 p
16. HARLOW WM, HARRAR ES, WHITE FM 1986 Textbook of dendrology. 6th edition. McGraw-Hill Book Company, New York-Sydney-Tokyo-Toronto, 510 p
17. GILMAN EF, WATSON DG 1994 Robinia pseudoacacia Black locust. Fact Sheet ST-570. Environmental Horticulture Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, Florida, USA, 4 p
18. CRPF 2007 The black locust (in French). Centre Régional de la Propriété Forestière de Poitou-Charentes, Smarves, France, 4 p
19. DINI-PAPANASTASI O, KOSTOPOULOU P, RADOGLOU K 2012 Effects of seed origin, growing medium and mini-plug density on early growth and quality of black locust (Robinia pseudoacacia L.) seedlings. J For Sci 58 (1): 8-20
20. ENESCU CM, DĂNESCU A 2013 Black locust (Robinia pseudoacacia L.) – an invasive neophyte in the conventional land reclamation flora in Romania. Bulletin of the Transilvania University of Brașov, Series II: Forestry • Wood Industry • Agricultural Food Engineering 6 (55): 23-30
21. SITZIA T, CIERJACKA A, DE RIGO D, CAUDULLO G 2016 Robinia pseudoacacia in Europe: distribution, habitat, usage and threats. In: San-Miguel-Ayanz J, de Rigo D, Caudullo G, Houston Durrant T, Mauri A (eds) A European Atlas of Forest Tree Species. Publications Office of the European Union, Luxembourg, pp 166-167
