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A simplified growing model for mixed black locust (*Robinia pseudoacacia* L.) and poplar (*Populus* spp.) plantations in the Danube-Tisza Interfluve

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SUMMARY

This study presents a static model of mixed black locust (Robinia pseudoacacia L.) plantation stand structures for inventory stand structures between 10 and 40 years of age. Due to its local character, the model can be advantageous in planning tending operations, making structural factor predictions for the standing stock (main stand) after tending cuts, and preparing local wood production and silvicultural models. The model data presented in this paper show that poplars account for 55–62 % of the volume per hectare due to their faster growth rate in mixed black locust and poplar plantations. Maintaining the black locust part of the stand necessitates harvesting the poplars by the age of 10 at the latest.

Keywords: *black locust; poplars; mixed plantations; stand-structure model*

INTRODUCTION

Using mixed-species plantations for commercial and restoration reforestation is gaining interest as an option to support wood supply and increase ecosystem service levels. Mixed forests contain trees of two or more species intermingled under the same canopy. Mixed-species forests are ecologically more valuable as versatile habitats. They also mitigate climate change and possess higher carbon sinks. Trees in mixed-species forests are usually better supplied with light, water, and soil nutrients via their complementary crown and root systems. Another advantage of mixed-species over monocultures is the promotion of diversifying production under different rotation periods. Mixed-species plantations are usually more resistant to damage caused by abiotic and biotic factors (Hartley, 2002; Nichols et al., 2006; Griess and Knoke, 2011).

The basic concept behind extensively establishing mixed black locust and poplar target stands dates back nearly 40 years. The idea emerged by observing that fast-growing, narrow-crowned hybrid poplar cultivars do not significantly inhibit the growth of light-demanding, slower-growing main species tree saplings in the first decade of growth. Matching suitable species for a site is vital in mixed stands. Determining whether a species will fulfill a temporary nursing role or whether the stand remains mixed over the long term or to the end of one rotation warrants consideration. Well-planned thinning helps control mixed stand composition and development. Based on these principles, the preliminary step for establishing mixed black locus and poplar stands involves examining site conditions and developing growing technology guidelines (Keresztesi, 1962; Danszky, 1973; Bajdó, 1975; Rédei et al., 2006, 2012; Pretzsch and Forrester, 2017; Oliveira et al., 2018; Marron and Epron, 2019; Rebola-Lichtenberg et al., 2021). At the same time, establishing mixed stands requires a thorough exploration of yield and stand structure characteristics of the main and admixed tree species, requiring planning and planting implementation that is more coordinated.

Studies of mixed-species plantations in the literature are rare and poorly documented. Few publications have financially analyzed mixed-species plantations or documented their operational costs. There is insufficient evidence around the mechanisms of interactions between species combinations. Finally, information scarcity and/or mixed results in the long-term performance of mixed stands have led to insufficient effort and investment in promoting mixed plantations.

Most of the evidence in our paper came from experimental/research plots. From this perspective, the current study serves as a stopgap publication.

MATERIALS AND METHODS

The data emerged from two sources:

- from detailed analysis of grey poplar (*Populus × canescens*) and Italian poplar (*Populus × euramericana* cv. I-214) mixed and unmixed black locust (*Robinia pseudoacacia* L.) sample plots from subcompartment Kunbaracs 6C;
- and from the evaluation of 18 additional inventories of black locust mixed with grey poplar and Italian poplar at the Kerekegyházi Forestry of the KEFAG forest enterprise.

All experimental stands are in the Danube-Tisza Interfluve, a region with a mean annual precipitation of 500–550 mm year^{-1} and annual average air temperatures of 10–11 °C. Extreme meteorological events, such as long drought periods and heavy rainfalls, occur with increasing frequency (Szabó et al., 2022).

Tree height, DBH, and tree species were registered in each 500 m^2 sample plot. IBM SPSS 25.0 statistical

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software calculated the stand structural factors, and we created the graphs using MS Excel 2016.

The surveyed stands ranged from 10 to 40 years. 'I-214' was not surveyed after it reached 30 years of age.

Depending on age, the mixture rate by stem number varied between 60–80% for black locust and 15–40% for poplars. All the studied stands were in a forest-steppe climate and were free-draining sites with humic sand soil, medium-deep tilth, and sand texture (based on Járó and Lengyel, 1988).

According to the main tree species classification (black locust), the stands were mostly in yield class III (Rédei, 1984). However, as this study notes later, several structural factors of mixed black locust differ significantly from those in unmixed stands; therefore, the classification can only be considered relative. The conceptual outline for constructing the model compiled from the recording data and presented in *Table 1* was as follows.

- mean height (H) of the main crop:

$$A \times H \rightarrow f\ (H), \tag{1}$$

where A – age of the plantation

- mean diameter (DBH) of the main crop:

$$D/H\% \rightarrow f\ (A);\ DBH = DBH/H[\%] \times H, \tag{2}$$

where A – age of the plantation

- Stem number per hectare (N) of the main crop:

$$N \rightarrow f\ (DBH), \tag{3}$$

- Basal area per hectare (BA) of the main crop:

$$BA = ba \times N, \tag{4}$$

where

$$ba - (dbh)^2 \times \pi / 4 \tag{5}$$

- Total volume per hectare (V):

$$V = BA \times (HF), \tag{6}$$

where HF – form factor (based on Sopp, 1974)

RESULTS AND DISCUSSION

Table 1 contains the most significant stand structural factors for mixed plantations established with black locust, grey poplar, and poplar I-214. The main findings from the data series in the table are as follows:

- Involving nitrogen-fixers (like black locust) in mixed plantations reveals that mixtures exceed black locust monoculture yields.
- After 15 years, black locust height and diameter growth are moderately lower than grey poplar and significantly lower than I-214. Leaving I-214 in the stand at this age or harvesting it to improve black locust growth is a vital question. In this case, I-214 poplars can be viewed as a premature part of the stand. If the poplars remain unharvested, black locust volume per hectare in the stand may decrease by up to 1.5 yield classes.
- From the above, poplar volumes in relation to age are as follows: 55% at age 10; 62% at age 15; 61% at age 20; 61% at age 25; and 60% at age 30.

Table 1: **Stand-structure factors for mixed plantations in Danube-Tisza Interfluve**

Age year	**H m**			**DBH cm**			**N stem ha^{-1}**			**BA m^2 ha^{-1}**			**V m^3 ha^{-1}**			
	R.p.	**P.x c.**	**I-214**	**R.p.**	**P.x c.**	**I-214**	**R.p.**	**P.x c.**	**I-214**	**R.p.**	**P. x c.**	**I-214**	**R.p.**	**P. x c.**	**I-214**	**R.p.+I-214+P.x c.**
10	11.9	9.8	15.6	10.3	8.3	17.5	1105	688	207	9.2	3.7	5	52	24	40	116
15	14.8	15.8	21.6	13.1	15.0	25.7	754	273	125	10.2	4.8	6.5	69	42	71	182
20	16.8	19.4	22.9	15.2	21.0	29.1	593	147	106	10.8	5.1	7.1	85	51	80	216
25	18.1	21.9	23.7	16.7	26.3	31.9	512	97	94	11.2	5.3	7.5	95	59	89	243
30	18.6	23.4	24.2	17.5	31.2	34.4	475	72	85	11.4	5.5	7.9	103	63	93	259
35	18.8	24.1	-	18.1	34.7	-	450	59	-	11.6	5.6	-	105	67	-	-
40	19.1	24.6	-	-	-	-	430	49	-	11.7	5.7	-	107	70	-	-

Tables note: R.p. = *Robinia pseudoacacia* (black locust); P. x c. = *Populus x canescens* (grey poplar); I-214= *Populus x euramericana* cv. I-214 (Italian poplar).

- The data used to create the presented production model were taken from stands with a medium mean annual increment (yield class III) for black locust. The basal area factor is used to determine the estimated volume of black locust and poplar mixed with better or poorer timber growth:

$$V_{model} = \frac{G_{model}}{G_{table}} \times V_{table} \tag{7}$$

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where
BA_{model} = basal area per hectare from the model
BA_{table} = basal area per hectare from yield table of Rédei (1984) as a function of age for a given tree species,
V_{table} = volume from the yield table of Rédei (1984) as a function of age for the tree species.

Figure 1 shows the number of black locust stems per hectare based on the model and the yield table of Rédei (1984).

Figure 2 shows the volume of black locust and mixed plantations with poplars based on the model and the yield table. The figure dependably expresses the significant volume surpluses of mixed plantations compared to unmixed black locust stands.

Figure 1: **Number of black locust stems based on the model and the yield table of Rédei (1984)**

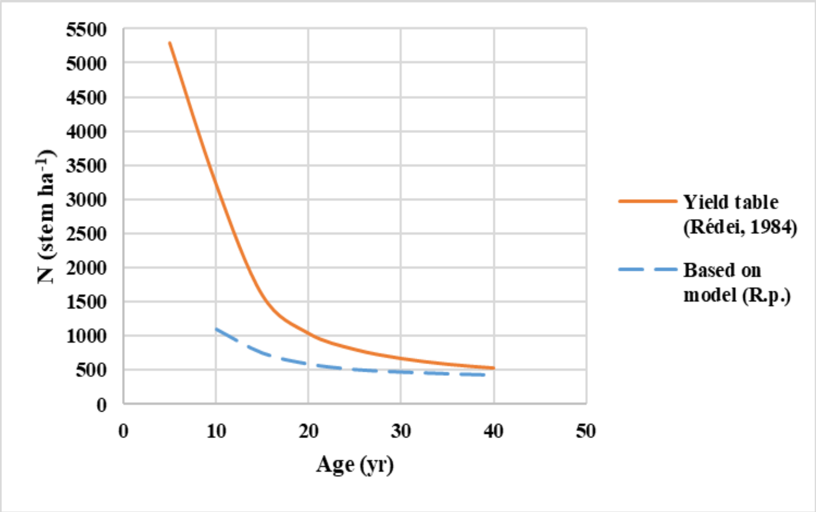
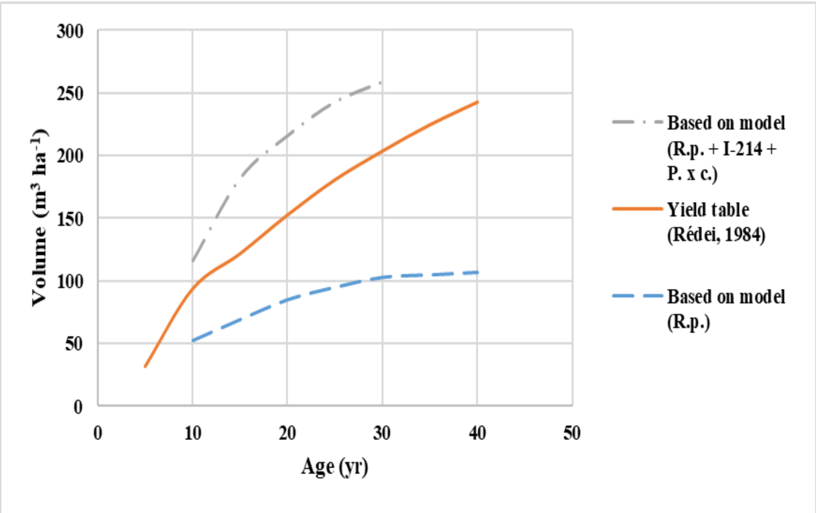


Figure 2: **The volume of black locust and mixed plantations based on the model and the yield table of Rédei (1984)**



CONCLUSIONS

In conclusion, the present study recommends documenting intentions and aims when establishing mixed stands. Such documentation would prevent the emergence of conflicting objectives during thinnings, especially in mixed black locust and poplar stands, where it could help deter one species from being favored during one thinning and the other being favored during a subsequent thinning, creating a situation that hinders both species from reaching their optimums.

Mixed black locust and poplar plantations have many advantages. For example, poplars in mixed stands use the beneficial nutrient supplementation effect of nitrogen-fixing bacteria associated with black locust. In this tree composition, a multi-level mixed forested black locust shrub forms creating a more favorable environment for neighboring agricultural land, reducing damaging wind effects, and effectively

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shading the soil, thus reducing the risk of grass encroachment.

With careful design and proper management, mixed-species plantations containing two, three, or four species can gain advantages over monocultures in biodiversity, economy, and forest health. Nevertheless, growth conditions in mixed plantations differ from those in pure plantations in many ways. Variances in the growth rhythm, root systems, crowns, light demand, temperature, and nutrient requirements mean that tree-to-tree competition in mixed plantations differs from that in pure stands. Further research is needed to explore these relationships in more detail.

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