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Róbert Németh, Christian Hansmann, Holger Militz, Miklós Bak, Mátyás Báder

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Comparing the blossoming and wood producing properties of selected black locust clones

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ABSTRACT
Black locust (*Robinia pseudoacacia* L.) is a tree species introduced from North America, and it's well known for its positive economical and negative ecological properties, making it one of the most widely distributed tree species in European countries. Despite its rapid growth, its wood is hard and weather-resistant so it can be used, for example, as sawn wood products, barked or belted poles and vineyard posts among others and also as planting material for short rotation energy plantations. Its nectare producing ability is excellent as well, black locust honey can make up to 50% of the whole honey production of Hungary. Unfortunately, increasingly hectic weather conditions, late frosts and the rising frequency of destructive storms caused by climate change, which are nowadays more and more noticeable, have a negative impact not only on nectar production but also on the shape of stem (Jovanović 1967, Herman 1971, Vajda 1974, Rițiu et al. 1988). Consequently, fast-growing species with good stem suckers and high nectar production potential are recommended, taking into account the variable future distribution of black locust in Europe (Boer 2013, Kutnar & Kobler 2013, Guoqing et al. 2014, Giuliani et al. 2015, Dyderski et al. 2017). To decide which cultivars can be used to help the beekeepers as well as foresters, which ones are more resistant to climate change and the biotic and abiotic damages, we need to compare their growth and their blossoming properties. The height of the tree is determined firsthand by genetics, the diameter at breast height is defined by growth space according to most authors but in a recent study Ábri and Keserű (2023) found that the linkage wasn't significant in terms of juvenile black locust cultivars. There is a trade-off in most plants regarding growth and generative reproduction on the edges of distribution unrelated to whether it's the dry (South) or the cold (North) end of it (Willy and Buskirk 2022). We must therefore need to find the correlation breakers which won't show the traits of not only these trade-offs, but those regarding resistant and resilient traits and can be selected by phenotype.

INTRODUCTION
Black locust (*Robinia pseudoacacia* L.) is native to the eastern parts of North America and is imported into Europe from only a small number of populations (Bouteiller et al. 2018). Within Europe, it was mainly introduced by human activity in the 17th and 18th centuries, which led to its expansion in e.g. Germany, Hungary and the Czech Republic one century later (Hegi 1924, Nožička 1957, Böhmer et al. 2001, Bartha et al. 2008). The last boost to its spread in Europe came from the devastation of the world wars (Kohler & Sukopp 1964). In terms of its ecological requirements, black locust is highly drought tolerant in Europe and can survive with only 500-550 mm of total annual precipitation instead of the 1020-1830 mm usually required in its original distributional area (Nicolescu et al. 2020). The decline in the allelic diversity of black locust in its new habitat following its introduction into Europe was also driven by its small population size, which included only a few import activities (Uller & Leimu 2011, Bouteiller et al. 2018). This allelic decline may have implications for its future response to climate change (Enescu & Dănescu 2013).
Black locust is demanding on soil aeration, grows sluggishly on compacted clayey soils, and does not tolerate waterlogging (Rédei 2020). Future alternatives to the areas currently occupied by beech and

silver fir will include the expansion and planting of black locust, red oak, turkey oak, and fluttering elm species if the predicted northward shift occurs due to a temperature increase of 2.9°C or 4.5°C (Thurm et al. 2018). Despite its rapid growth, black locust wood is hard and weather resistant. Black locust covers up to 24% of the forested area in Hungary. It provides a livelihood for tens of thousands of people in the forestry, sawmill, and beekeeping sectors, but the native range of North American black locust populations are located 5-10° further south (Bartha et al. 2008) than the current habitat in Hungary. The increasing frequency of late frosts and destructive storms exert negative impacts on both nectar production and stem structure (Jovanovič 1967, Herman 1971, Vajda 1974, Riťiu et al. 1988). This sensitivity usually results in second flowering, drastically reducing the annual black locust honey production. Increasingly volatile, climate change-induced weather conditions are the main problem facing black locust today. Consequently, fast-growing species with good stem suckers and high nectar production potential are recommended. The economic aspects of using black locust include the widespread belief of a trade-off phenomenon between the long and abundant flowering of the species and its ability to produce quality wood for the sawmill industry. Trade-off is based on the observation that the life cycles of organisms are paired, so they can only enhance one at the expense of the other. Nevertheless, we must mention that no one has found any significant correlation in the case of tree species like pines or poplars. The hypothesis of this study is that there is no trade-off phenomenon between the intensive flowering capacity and the height growth of black locust when it's not on the dry edge of its distribution, using height as a measuring point since it is mostly determined by genetics.

MATERIALS AND METHODS

We performed the measurements in four forest subcompartments, namely Isaszeg 8/C, Isaszeg 8/E, Debrecen 17/C and Kecskemét-Méheslapos. The two subcompartments at Isaszeg are both located outside of the Gödöllő Arboretum, near the former Forest Research Institute's (hereinafter: FRI) experimental station. The plots at the Gödöllő Arboretum are at 200–220 m altitude, the subcompartment near the city of Debrecen is at an altitude of 121 m and Kecskemét-Méheslapos is at 105 m. All four subcompartments contain state-approved cultivars, candidate cultivars, clones selected for timber production, apiculture purposes, or a combination of both. Using the flowering and timber production values of the commercial black locust individuals in the plots as standard, we can measure the economic advantage of the selected clones and cultivars. The planting network is 2.5 x 1.0 m in all the subcompartments. There is a significant correlation between the average intensive flowering period (which occurs when the flowering is in its third or fourth stage and the average length of flowering (Isaszeg 8/C *p=0,879773*, Isaszeg 8/E p=*0,918902*) (Porcsin et al. 2021). The common black locust trees were planted from seedbed plants.

There are four different clones in the *Debrecen 17/C* subcompartment. We marked 30 stems altogether with the common black locust on the area. These include a clone (*R. p. 'Guth-189'*), a previously state-approved clone (*R. p. 'Szajki'*), and state-approved cultivars (*R. p. 'Appalachia' and R. p. 'Nyírségi'*). The state approved cultivars and the *R. p. 'Szajki'* clone were planted from root suckers; the clones are planted from micropropagated planting material.

There are two subcomparments in the Gödöllő Arboretum, *Isaszeg 8/C* and *Isaszeg 8/E*. We marked 78 stems in these plantations. The age difference isn't significant (3 years), so we can assume their flowering capacity is the same. Since there isn't common black locust in the Isaszeg 8/E subcomparment, we use the data from the Isaszeg 8/C one. The state-approved cultivars were planted from root suckers as well as some of the clones registered as state-approved in previous years, but not listed as them in 2024. The candidate cultivars (*R. p. Oszlopos', R. p. 'Homoki', R. p. 'Szálas', R. p. 'Vacsi')* and the clones *(R. p. 'Nyírségi-12', R. p. 'PV-BORZ', R. p. 'PV 201 E 2/3', R. p. 'Rózsaszín-A', and R. p. 'Rózsaszín-B'*) have been planted from micropropagated planting material.

The Kecskemét-Méheslapos subcompartment was planted in 1996 and expanded by 5 clones in 2000 and added 8 more in 2002. We marked 48 stems in it. This place clearly shows the signs of the dry end of the black locust's ditribution area, since from the 45 parcels we found living plants (at least 3 to mark for study) only in 31. Besides climate change, the main reason for this was probably the damage which was caused by the locust digitate leafminer (*Parectopa robiniella*) and *Phyllonorycter robiniella*. The clones have been planted from micropropagated planting material as well as in the other experimental areas.

Methods

During the measurements, we observed the flowering stages and the extent and abundance of blossoming in May and June and recorded tree height and diameter outside of the vegetation period. Measurements of the flowering stages and the abundance should occur at the same time every day to ensure accuracy, preferably from more than one angles at least every two days. The stems were around 20 m in height, so we measured the flowering qualities with a telescope. The method follows the work of Imre Csiha.

The extent of flowering of the stems was determined based on the following criteria:
I. extent: No flower (no inflorescence is visible in the crown of the stem).
II. extent: Few flowers (flowering can be seen on 1/3 of the crown of the stem).
III. extent: Medium amount of flowers (the inflorescence can be seen on 2/3 of the crown of the stem).
IV. extent: Abundant flowers (the flowers are visible on the whole crown of the stem).
V. extent: Abundant flowering on each branch of the tree

The criteria below separate the flowering stages:
First flowering stage: Only green buds in a closed stage are visible.
Second flowering stage: The white ends of the flowers are visible at the end of the buds.
Third flowering stage: Most of the flowers are white and in an open-bud stage.
Fourth flowering stage: The flowers are fully open, and the entire inflorescence is white.
Fifth flowering stage: Wilted flowers appear in the crown; the white and brown colors are mixed and the petals beginning to fall. Scattered fallen flowers appear on the ground.

We used a Vertex height-measuring instrument with a measuring unit and an associated transponder to measure tree height. We employed a π-tape to measure the diameter at breast height (DBH) because it allowed us to read the measurement immediately.

RESULTS AND DISCUSSION

The criteria to be classified as "better" is to reach a flowering period that is at least two days longer and to have a higher height than the common black locust stems. We took common black locust stem volume to be 100% to determine the superiority of the clones and cultivars (Table 1). We used different values to determine the clones' volumes because of their straighter trunk shape and smaller crowns (Veperdi 2001).

Table 1: Performance of the clones compared to common black locust in their subcompartment

Subcomparment	Name of the clone	Average flowering period (day)	Intensive blooming period (day)	Average diameter at breast height (cm)	Average height (m)	Performance (%)	Average volume (m^3)	Performance (%)
Isaszeg 8/C	Common black locust	18	7	12.9	16.3	100	0.12	100
	R. p. 'Oszlopos'	22	11	14	16.5	101	0.14	117
	R.p. 'PV-BORZ'	23	11	14.6	17.4	107	0.16	133
	R.p. 'Váti-46'	23	10	15.5	18.7	115	0.22	183
	R.p. 'PV 201 E 2/3'	21	10	16.6	18.1	111	0.21	175
Isaszeg 8/E	*R.p. 'PV 201 E 2/3'*	22	10	12.9	16.3	100	0.14	117

The comparing revealed that only cultivars from the two Isaszeg subcompartments showed greater values than the common black locust in the same area. There weren't any clones that would fit the criteria of greater volume and 2 days more of average and intensive blooming period length. These results show that the area of Kecskemét-Méheslapos and Debrecen aren't and won't be valuable for black locust cultivars to plant. Regarding the two still valuable plots, *R. p. 'Oszlopos', R. p. 'PV-BORZ, R. p. 'Váti-46'* and *R. p. 'PV 201 E 2/3'* is better for both wood harvesting and beekeeping reasons. These clones can also be the so-called correlation breakers. As the results show, there is no trade-off phenomenon between the intensive flowering capacity and the height growth of black locust when it's not on the dry edge of its distribution, so our hypothesis is true. The correlation between height (m), volume (m^3), length of average flowering and blooming period (day) weren't strong to begin with, but in the drier ends of the areas (Debrecen and Kecskemét) and correlation was even smaller or slightly negative (Table 2). We can assume that this is because of the trade-off examined in other plants between growth and sexual production.

Table 2: Correlation between height, volume and flowering period lengths

p values	Kecskemét	Debrecen	Isaszeg 8/C	Isaszeg 8/E
Volume - Average flowering period	*0.22707*	*0.23085*	*0.34986*	*0.28350*
Height - Average flowering period	*0.23134*	*-0.09791*	*0.32140*	*0.38735*
Volume - Intensive flowering period	*0.64479*	*-0.01117*	*0.15220*	*0.35298*
Height - Intensive flowering period	*0.56200*	*0.07032*	*0.28363*	*0.18355*

The Kecskemét-Méheslapos subcompartment has a strong correlation between volume, height and intensive flowering period length but this occurs because all the numbers were lower regarding these qualities.

CONCLUSIONS

Several factors influence the quality of flowering and stem characteristics. Climate factors influence blossoming the most. The length of the flowering also depends on stand structure, stand age, the number and direction of the gaps and lanes, and the altitude of the population (Fritsch 2012). According to Guoqing L. et al. (2014) and Valeriu-Norocel N. et al. (2020) and an EUSTAT map (2024), it will no longer find its optimum in the southern east planes of Hungary and as our results show this is already happening. Instead, in the next 20-50 years it will spread to our northwest regions where our hills and mountains are. We can predict that since the average temperature will be higher but also the number of days with average temperature below zero will increase, the flowering period will start earlier and will be shorter than nowadays. This will have a devastating effect on our beekeeping industry. While the criteria of the site optimum of different poplar clones and cultivars have been made, no such assessment was made for black locust clones. Although the propagules are vegetatively made (via micropropagation or using root suckers), the generative reproductive capacity of the species may be an indication in future decision-making to maintain allelic diversity and adaptability (which will play a huge role in the face of climate change). We need to work on a cheaper and more effective method of growing black locust and select clones that can tolerate the effects of an even drier but more volatile climate if we want to maintain our beekeeping sector's income and microprogataion may help us in this task.

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