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Stand structure and growth of *Robinia pseudoacacia* 'Jászkiséri' – 'Jászkiséri' black locust

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Abstract: Black locust (*Robinia pseudoacacia* L.) is one of the most widespread tree species introduced into Europe and also into Hungary. It covers 24% of the total Hungarian forest area, providing 25% of the annual timber output of the country. Due to the demands of consumers, new cultivars are to be produced by means of improvement techniques and are to be introduced into the practical forestry use. Mono- and multiclonal cultivars were developed, then variety comparison trials and cultivation tests were established. Based on preliminary yield tests the locust cultivar 'Jászkiséri' (*Robinia pseudoacacia* 'Jászkiséri') proved to be one of the best black locust cultivars. Consequently, a more precise investigation of the stand structure of this cultivar may also make a significant contribution to the improvement of the relevant cultivation technology. In this study, based on full inventories of 13 stands in 7 subcompartments, age of 5 to 35 years, relationships of mean tree volume to diameter (R^2 = 0.9797) and basal area (R^2 = 0.9781), furthermore the relationship between mean tree volume and diameter of the stands (R^2 = 0.9993) were examined. Besides that, the comparison of 15-year-old 'Jászkiséri' and common black locust (a case study) were presented in this paper, where 'Jászkiséri' proved to be better: significant differences (P < 0.05) were found in diameter, mean tree volume and stem form.

Keywords: fast growing tree species; cultivar; Hungary

Black locust is one of the most widespread broadleaved tree species in the world. It is native to North America and it was introduced into Europe in the early 17th century (Demené, Merzeau 2007). In Hungary, the first records of introducing black locust are from the early 1700s (Vadas 1911). Currently, this tree species is the most widespread in the country, it accounts for 24% of the total forested area (HCSO 2019). It has been closely connected with agriculture since its introduction into Hungary because it meets various needs (e.g., fuelwood, props, poles, honey production) of farmers (Keresztesi 1988; Rédei 2013). Black locust can also been considered as a suitable tree for fodder and for the reclamation of lands with unfavourable site conditions (Barrett et al. 1990; Enescu, Danescu 2013; Nicolescu et al. 2020). Despite its multipurpose utilization and many good qualities, it can have negative impacts on the ecosystem. Black locust is considered as an invasive tree species, by changing the chemical, physical and biological properties of soil and causing extinction of many endangered plant species (Boring, Swank 1984; Boer 2013; Vítková et al. 2015, 2017, 2018).

Black locust can be best promoted by its feature of improving the quality of forests and tree plan-

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tations. It is also necessary to use cultivars which have been bred with the end-user in mind.

According to the basic selection goal, cultivars can be classified into three groups:

(*i*) Main goal: production of logs suitable for sawmilling (target product: sawlogs). The best cultivars are: 'Nyírségi', 'Kiskunsági', 'Jászkiséri', 'Üllői', 'Appalachia', 'Pénzesdombi', 'Röjtökmuzsaji' and 'Góri'.

(*ii*) Main goal: production of poles and props (main products: pit props, vine and orchard props, fence poles, hop poles). Best cultivars: 'Zalai', 'Császártöltési', 'Szajki', 'HC-4146', 'Ricsikai' and 'Váti-46'.

(*iii*) Main goal: improvement of bee pastures and decorative planting. Best cultivars: 'Rózsaszín-AC', 'Debreceni-2', 'Halványrózsaszín', 'Debreceni 3-4', 'Mátyusi 1-3'.

Some cultivars are suitable for both forestry and honey production. Such double-use cultivars are 'Zalai', 'Kiskunsági', 'Császártöltési', 'Egylevelű' and 'Váti-46'.

With respect to the volume expected at felling age, the 'Jászkiséri', 'Kiskunsági', 'Nyírségi', 'Üllői' and 'Szajki' cultivars proved to be the best (Keresztesi 1988).

Besides Hungary (Rédei 2013; Rédei et al. 2008, 2013, 2017a, b), many European (e.g., Germany, Greece, Poland and Turkey) and Asian (e.g., China, India and South Korea) countries have also started their own black locust research programmes in the last decades. The main aims of the programmes are to help quality development of the black locust propagation material on one hand (Rédei et al. 2001, 2002); on the other hand, to complete the variety choice of particular regions producing new black locust cultivars that can be grown effectively under unfavourably changed ecological conditions (Dunlun et al. 1995; Dini-Papanastasi, Panetsos 2000; Liesebach et al. 2004; Sharma, Puneet 2006; Lee et al. 2007; Dengiz et al. 2010; Böhm et al. 2011; Kraszkiewicz 2013; Szyp-Borowska et al. 2016, 2020).

As mentioned above, more and more countries are interested in black locust improvement and management. Due to the negative effects of the climate change, its role in primary wood production is expected to be more and more significant over time.

The objectives of this paper are to present the stand structure and growth of the 'Jászkiséri' black locust and to give a review of this cultivar.

Provenance and tree features of 'Jászkiséri' locust. 'Jászkiséri' locust (*Robinia pseudoacacia* 'Jászkiséri') was improved by Béla Keresztesi and his co-workers Ferenc Kopecky, Hubert Pagony, Sándor Csányi at the Hungarian Forest Research Institute in the middle of the 20th century. The cultivar was registered in 1979 (Keresztesi 1988). The characteristics of 'Jászkiséri' locust are as follows (Figure 1): growth is vigorous, the stem is straight, and the foliage is dense. The crown is well developed, covering 1/3–1/2 of the tree height. Many branches grow at a narrow angle to the trunk. The bark of young trees is grey with darker stripes, veined like marble. The spines are relatively long (15 mm). The leaflets are elliptic, the tips truncate and not mucronate. Flowering is sparse. Flowers are moderately frequented by bees. From the apicultural evaluation of the so called sugar value it is apparent that 'Jászkiséri' proved to be an excellent sugar producing cultivar with its sugar yield of 1.48 mg·flowers^{-1}. 'Jászkiséri' locust is prone

Figure 1. 35-year-old 'Jászkiséri' black locust cultivars in subcompartment Gödöllö 5 G/1 (photo: Zsolt Keserü, 2015)

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to late and early frosts; therefore, this black locust cultivar is not suitable for sites in higher hilly zones and in areas where frost hollows occur. Its trunk is liable to fork (Keresztesi 1983, 1988).

According to Keresztesi (1988) and his co-workers the proportion of the first and second quality trees in the case of 'Jászkiséri' locust is about 54% higher while the final overall value of its wood is 47% higher than that of the control. It provides excellent raw material for sawmills. Its wood properties are different from those of the other tree species. Due to the lower density and lignin content, the highest total carbohydrate content, the favourable dry matter production, this cultivar may be of interest for the hemicellulose, particle board and fibreboard industries.

Rédei et al. (2017a) evaluated four 35-year-old black locust cultivars in Central Hungary under arid hydrological and brown forest soil conditions, where 'Jászkiséri' locust was found as one of the most promising cultivars for yield production.

MATERIAL AND METHODS

Site and stand parameters. In this study 13 experimental plots in 7 subcompartments were evaluated. These are located in different parts of Hungary (Figure 2). The experimental plots are found in either Turkey oak-sessile oak forest climate or forest-steppe climate (according to the Hungarian climate classification categories). The age of the 'Jászkiséri' black locust stands ranges from 5 to 35 years. During the full inventories, the key stand characteristics were measured, and then based on the data collected, the average height, diameter, volume, basal area and stem number given for total stands per hectare were calculated (Avery, Burkhart 1994; Van Laar, Akça 2007).

The stem volume was calculated using the following volume function based on the volume table for black locust (Sopp, Kolozs 2013):

$$v = 10^{-8} \times d^2 \times h \times \left(\frac{h}{h-1.3}\right)^2 \times \times \left(-0.6326 \times d \times h + 20.23 \times d + 3034\right) \quad (1)$$

where:
v – stem volume (m^3);
d – diameter at breast height (cm);
h – tree height (m).

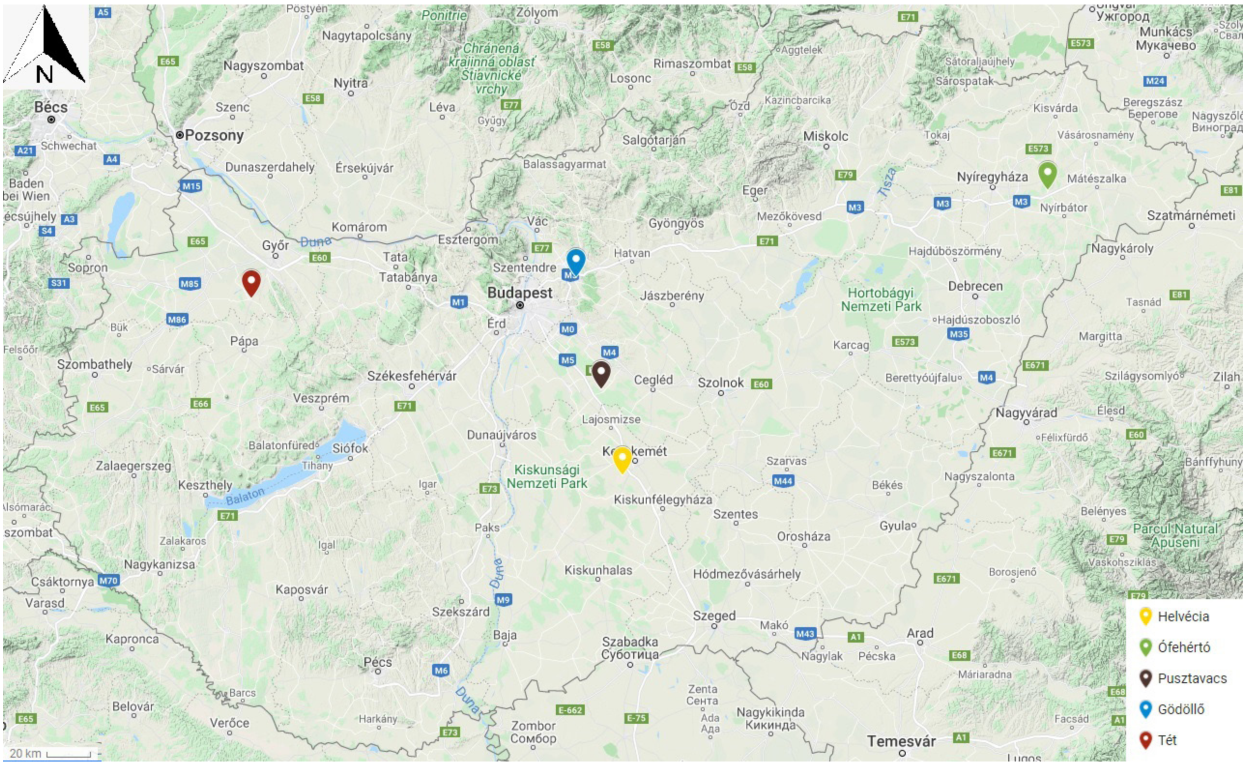

Figure 2. Locations of the experimental plots

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Table 1. Location, site type and stand characteristics of the 'Jászkiséri' black locust cultivar

Location, subcompartment	Climate	Hydrology	Genetic soil type	Depth of productive layer	Soil texture	Age (years)	*H* (m)	*DBH* (cm)	*DBH* × (*H* × 100)$^{-1}$ (%)	*V* (m^3·ha^{-1})	*N* (stems·ha^{-1})	*BA* (m^2·ha^{-1})	Mean tree volume (dm^3)	Yield class (Lessényi, Rédei 1986)
Helvécia 80 A	1	1	1	1	1	5	6.1	4.7	77.05	61.1	6 667	11.57	9.16	III.
Helvécia 80 A	1	1	1	1	1	7	8.8	6.2	70.45	90.2	4 484	13.54	20.12	II.
Gödöllő, Arboretum	2	1	3	3	1	10	12.1	9.1	75.21	72.89	1 711	11.06	42.6	III.
Helvécia 22 E/2	1	1	1	1	1	14	11.7	9.9	84.48	82.15	1 333	10.15	61.63	V.
Gödöllő, Arboretum	2	1	3	3	1	15	13.7	11.7	85.4	148.53	1 681	18.24	88.36	IV.
Ófehértó 13 F	2	1	1	2	1	19	20.1	18.5	92.04	298.6	1 067	28.7	279.85	II.
Gödöllő, Arboretum	2	1	3	3	1	20	18.6	15.9	85.48	203.65	1 052	21.08	193.58	II.
Tét 16 L	1	1	2	1	1	20	17	16.2	95	216.8	1 154	23.4	187.95	III.
Pusztavacs 161 A	1	1	1	2	1	22	15.2	13.4	75.57	138.82	1 000	14.05	138.82	III.
Pusztavacs 161 A	1	1	1	2	1	32	18.3	17.3	94.54	221.2	940	22.1	235.32	IV.
Gödöllő 5 G/1	2	1	3	3	1	35	23.8	26.7	112.18	228.3	342	19.1	667.54	II.
Gödöllő 5 G/2	2	1	3	3	1	35	23.4	26.8	114.53	309.85	466	26.4	664.91	II.
Gödöllő 5 G/3	2	1	3	3	1	35	23	26.9	116.96	391.4	590	33.7	663.39	II.

Climate: 1 – forest – steppe, 2 – Turkey oak – sessile oak; hydrology: 1 – free draining site, genetic soil type: 1 – humic sandy soil, 2 – lessivated brown forest soil, 3 – rusty brown forest soil; depth of productive layer: 1 – shallow, 2 medium deep, 3 – deep; soil texture: 1 – sand; *H* – mean height; *DBH* – diameter at breast height; *V* – mean volume; *N* – number of stems per ha; *BA* – mean basal area

Table 2. Parameters of 'Jászkiséri' cultivar and common black locust stands in subcompartment Helvécia 22 E/1 at the age of 15 years

	N (stems)	*DBH* (cm)	*H* (m)	*v* (m^3)	*SFV*
'Jászkiséri' cultivar	16	9.4	10.4	0.0546	1.75
Common black locust	30	7.6	9.8	0.0343	2.37

N – number of stems per ha; *DBH* – diameter at breast height; *H* – mean height; *v* – mean tree volume; *SFV* – stem form value

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The mean tree volume (v, m^3·tree^{-1}) was calculated using the means of stem volume for each of the experimental plots.

Table 1 shows the site description including location (subcompartments), site type (based on Járó and Lengyel 1988), and the most important dendrometric characteristics such as age, mean height (H), mean diameter at breast height (DBH), mean volume (V), number of stems per ha (N), mean basal area (BA) and mean tree volume (v). Some of the data (Helvécia 22 E/2, Pusztavacs 161 A) are from our full inventories, the rest are from Keresztesi (1988) and Rédei (2006, 2008).

Comparison of 'Jászkiséri' and common black locust. In subcompartment Helvécia 22 E/1, a comparison of 'Jászkiséri' and common black locust stands was performed. The 15-year-old stands are on slightly humic sandy soil, free draining site. In this area, the annual precipitation amounts to only 500 mm in some years, of which less than 300 mm falls in the dry summer period. It means that the water supply is a limiting factor. The trial at Helvécia is not one of the best sites available in Hungary but it can be considered as an average yield class site for black locust (Rédei, Gál 1984).

The following parameters were measured and calculated at the age of 15 years (Table 2): number of stems (N), tree height (h), diameter at breast height (DBH), mean tree volume of the stems (v) and stem form value (SFV). We used arithmetic mean in the case of tree height and DBH because it is more appropriate for certain types of experimental studies. Mean tree volume was calculated using Equation 1. For the evaluation of the stem form the following classification was used: 1 – straight, 2 – more or less straight, 3 – crooked, 4 – strongly crooked.

Statistical analysis. For statistical analysis of experimental results Microsoft Excel (2016) and IBM SPSS Statistics (Version 25, 2017) software packages were used. The comparison of the mean values ('Jászkiséri' and common black locust) was made by Student's t-test.

RESULTS AND DISCUSSION

Distribution of sample plots. Distribution of sample plots in the site index curves of the black locust yield table are presented in Figure 3. As the figure represents, most plantations belong to yield class I to III. This means the 'Jászkiséri' black locust can reach a relatively high volume under favourable site conditions where the objective is the production of sawlogs. A high proportion

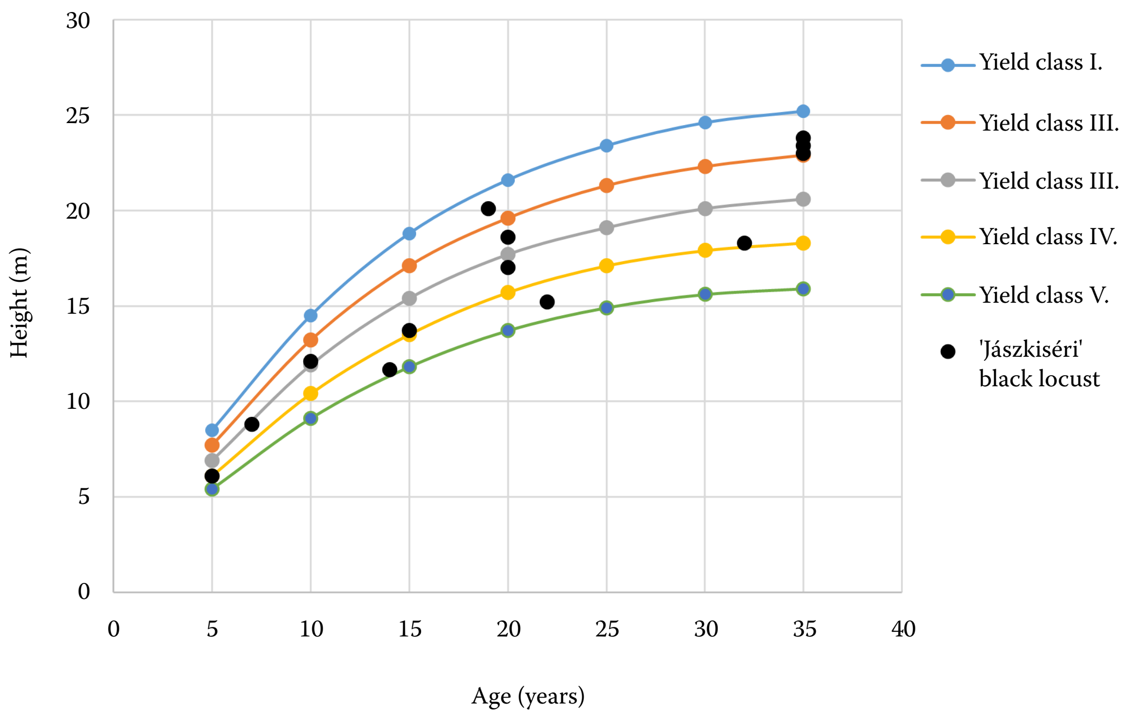

Figure 3. Experimental plots in the site index curves of the black locust yield table [based on Lessényi and Rédei (1986)]

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of poles and props can be expected from plantations of yield class IV.

Volume equations for 'Jászkiséri' black locust trees and plantations. Figures 4A and 4B show information about the relationships of mean tree volume and *DBH*, and the same relationship transformed to a straight line (basal area), based on the quantification of 23 'Jászkiséri' trees in Pusztavacs region. The tree volume equations are subsequently used to evaluate the mean tree volume in each diameter class.

$y = 0.001x^2 - 0.0038x$ ($R^2 = 0.9797$) (2)

$y = 10.508x - 0.0271$ ($R^2 = 0.9781$) (3)

Figure 5 provides information about the relationship of mean tree volume (v) and *DBH* based on the quantification of 13 'Jászkiséri' black locust plantations (see Table 1). The mean tree volume is multiplied by the number of trees per hectare (N) to give the total volume per hectare (V).

$y = 1.2275x^2 - 9.1376x + 27.97$ ($R^2 = 0.9993$) (4)

Results of the case study. Student's t-test for mean diameter at breast height (*DBH*), mean tree volume (v) and stem form value (*SFV*) at the end of the fifteenth growing season revealed statistically significant differences ($P < 0.05$) between the 'Jászkiséri' and common black locust under arid site conditions (Table 3).

The 'Jászkiséri' cultivar was 25% larger in diameter and 59% greater in mean tree volume than the common black locust (Table 4).

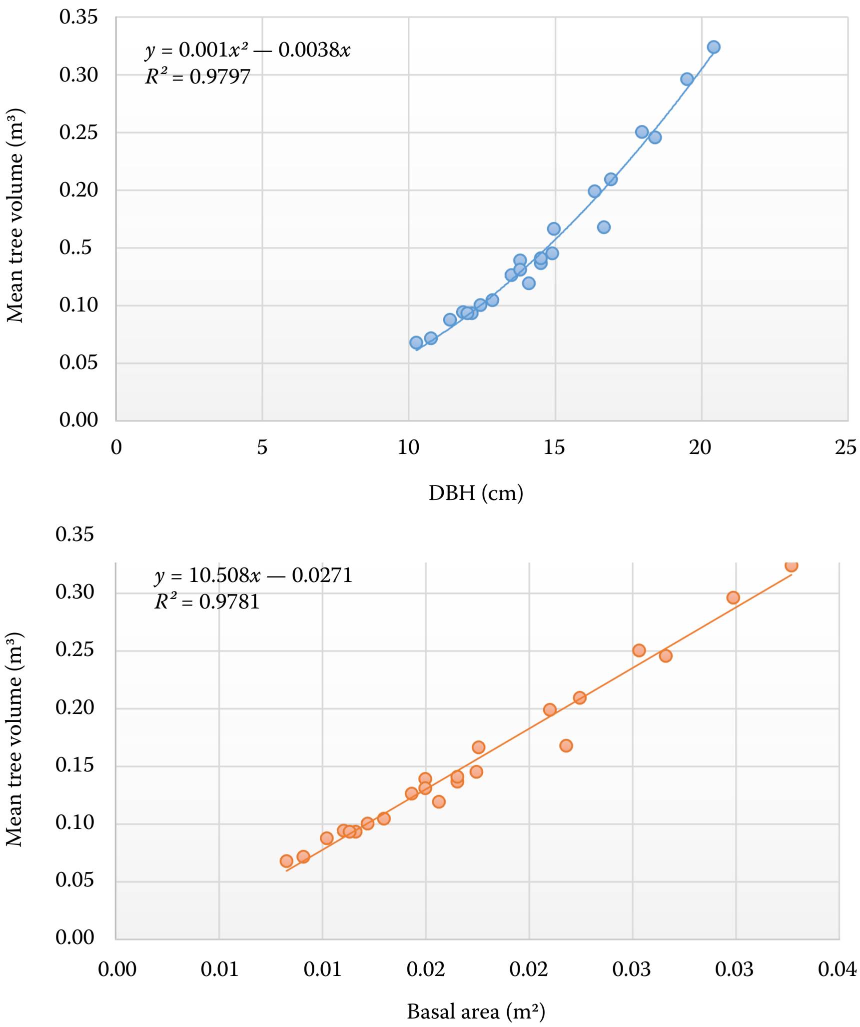

Figure 4. (A) Curvilinear relationship of mean tree volume (v) and diameter at breast height (*DBH*) (based on measurements of 22-years-old 'Jászkiséri' black locust trees in Pusztavacs 161 A); (B) Straight line relationship of mean tree volume (v) and basal area (*BA*) of single trees (based on measurements of 22-years-old 'Jászkiséri' black locust trees in Pusztavacs 161 A)

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CONCLUSION

For some decades, the importance of black locust has been increasing in several countries due to the harmful effects of climate change and the energy crisis, which has facilitated research on relatively fast-growing, nitrogen-fixing tree species such as black locust.

The conclusions of this study are as follows:

(*i*) the growth of 'Jászkiséri' black locust cultivar at the same age and under similar site conditions generally exceeds that of common black locust;

(*ii*) it can reach a relatively high volume under favourable site conditions where the objective is to produce sawlogs;

(*iii*) in view of its advantageous growth properties, the inclusion of 'Jászkiséri' black locust in wider cultivation is justified in any case;

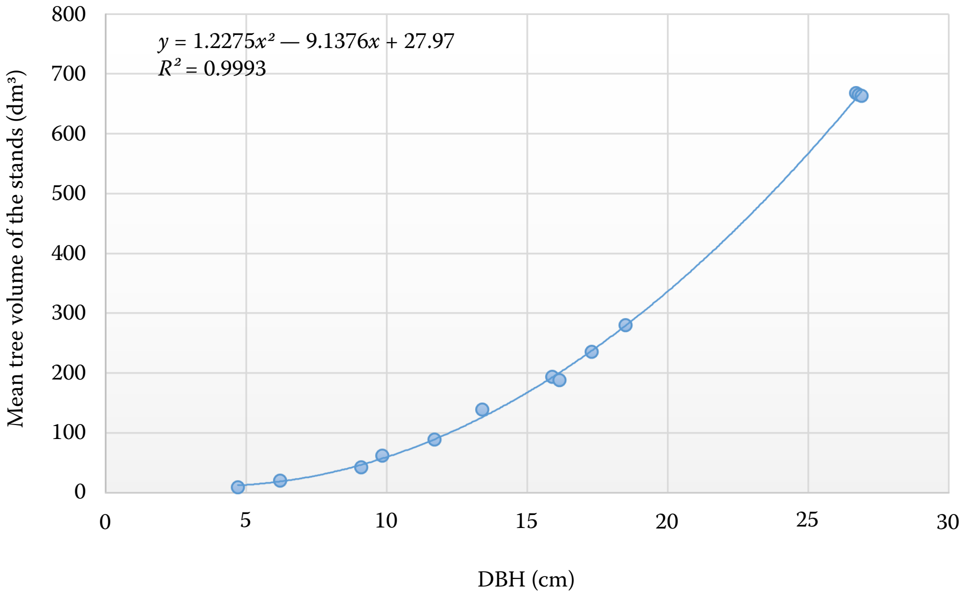

Figure 5. Curvilinear relationship of mean tree volume (v) and diameter at breast height (*DBH*) (based on measurements of 13 'Jászkiséri' black locust plantations)

Table 3. Results of Student's *t*-test

	t	*df*	Sig. (2-tailed)	Mean difference	95% confidence interval of the difference lower	upper
DBH	2.724	15	0.016*	1.86375	0.4052	3.3223
H	1.910	15	0.075	0.65188	–0.0757	1.3794
v	2.382	15	0.031*	0.02034	0.0021	0.0386
SFV	–3.630	15	0.002*	–0.62000	–0.9840	–0.2560

*significant difference ($P < 0.05$) between 'Jászkiséri' and common black locust; *DBH* – diameter at breast height; *H* – mean height; *v* – mean tree volume; *SFV* – stem form value; *t* – *t*-value; *df* – degrees of freedom; Sig. – significance

Table 4. Differences between 'Jászkiséri' cultivar and common black locust (control)

Cultivar	*H* mean (m)	(%)	DBH mean (cm)	(%)	*v* mean (m³)	(%)	*SFV* mean (1–4)
'Jászkiséri' cultivar	10.4	107	9.4	125	0.0546	159	1.75
Common black locust	9.8	100	7.6	100	0.0343	100	2.37

DBH – diameter at breast height; *H* – mean height; *v* – mean tree volume; *SFV* – stem form value

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(*iv*) the reported relationships between diameter at breast height, basal area and mean tree volume (Figures 4A and 4B) can also function as local (landscape) volume functions;

(*v*) the correlation between diameter at breast height and mean tree volume in relation to the stands, elaborated on the basis of 13 full inventories (Figure 5), makes it possible to approximate the volume per hectare when knowing the number of trees per hectare;

(*vi*) based on statistical analysis (Student's *t*-test) of this study, significant differences were observed in diameter, mean tree volume and stem form between the 'Jászkiséri' cultivar and common black locust on a marginal site (Table 3).

Even though the 'Jászkiséri' cultivar has better qualities than common black locust, this cultivar (along with the others) is not widespread in the Hungarian afforestation practice. The main reason is the higher cost of propagation material of this cultivar. Consequently, it is profitable for forest owners to use propagation material of common black locust instead of cultivars. Hopefully, EU subsidies and local/national funding for the forest sector can be useful in the promotion of cultivars in the long run.

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