

## Comparison of the growth pattern of black walnut (*Juglans nigra* L.) in two riparian forests in the region of South Moravia, Czech Republic

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**ABSTRACT:** The black walnut (*Juglans nigra* L.), an introduced species into the Czech Republic, is planted for its production of valuable timber. A systematic study of the black walnut growth rate at different localities and consequently the creation of standard volume tables under Central European conditions therefore appear to be of high relevance. The aim of our study was to reveal the black walnut growth pattern in its pure stands in two riparian forests along the Morava and Svatka River (Strážnice locality and Židlochovice locality, respectively). To describe and to compare relationships among diameter at breast height (dbh), tree height and age, we used a forest management plan and measured 573 and 670 trees in pure sample stands at Strážnice and Židlochovice, respectively. We found out that the measured mean DBH and mean height were consistently higher in Strážnice, however the relationships of DBH to height, age to DBH, and age to height showed the same pattern at both localities. The mean heights of trees were 16.3, 24.1, 28.7, 31.9, and 34.5 m in 20, 40, 60, 80, and 100 year age classes and were consistently taller in comparison with other, mainly European, regions. Therefore our results suggest the high potential of black walnut in timber production in riparian forests in the Czech Republic, mainly in the South Moravian region.

**Keywords:** growth; *Juglans nigra*; riparian forest; South Moravia

The black walnut (*Juglans nigra* L.) represents one of the introduced tree species into the Czech Republic. Originally from North America its native distribution ranges from the Great Lakes in the north to the northern part of Florida in the south and from coastal areas of the Atlantic Ocean to the Great Plains in the west. Although in its native area black walnut is found on a variety of sites, it grows best in coves and well-drained bottoms in the Appalachians and in the Midwest (BURNS et al. 1990; PONDER 2004). The black walnut is highly valued for lumber and veneers (SHIFLEY 2004) and belongs to the most valuable hardwood tree species in North America (PONDER 2004). This fact, coupled with the walnut's relative rarity has resulted in an ongoing interest in inventory data detailing location, volume, size and quality of black walnut trees (SHIFLEY 2004).

In Europe the first records of introducing the black walnut are from the beginning of the 17<sup>th</sup> century, when it was planted in parks for amenity purposes. In the 19<sup>th</sup> century, the black walnut was introduced into forests for its valuable timber, relatively high resistance to harmful factors, and fast growth rate (MEZERA 1956). The black walnut is more resistant to harmful factors such as ice floe rubbing the tree bark away during floods or to occasional droughts (MEZERA 1956). POKORNÝ (1952) also claimed that in comparison with other tree species only a few species of flora and fauna could damage the black walnut in the given region (Czech Republic) more seriously (rodents, May beetles).

In comparison with the common walnut (*Juglans regia* L.), the black walnut is planted only occasionally in Europe (HEMERY et al. 2010). Despite that rarity, the area of black walnut stands is not negli-

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gible in certain countries. For instance, in Croatia the black walnut stands take up 826.8 ha of pure black walnut stands and 3 162.3 ha of black walnut plantations (KREMER et al. 2008). In Romania all black walnut plantations cover the area of 2,100 ha and in Hungary 3,400 ha (NICOLESCU 1998).

In the Czech Republic, the oldest stands of black walnut were established in the Ždánický les locality in 1823 (POKORNÝ 1952). Its distribution has gradually been enlarged and as it requires deep rich well-drained loamy soils, the black walnut is nowadays planted mainly in riparian forests in Natural Forest Area (NFA) No. 35 – Jihomoravské úvaly (in South Moravia). According to the status in 2000, the reduced area of black walnut in NFA No. 35 is 492.8 ha, which represents 93.7% of the total reduced area in the Czech Republic (2005).

Although the black walnut in the Czech Republic is planted for its production of valuable timber, the standard volume tables are still missing and its stand volume is calculated according to the tables for domestic oaks (*Quercus* sp.) (ÚHUL 1990; PRUDIČ 1991; HRIB et al. 2003). Since the necessity of intensive management, namely thinnings, for increasing the black walnut growth rate and production quality was confirmed (TOKÁR, KREKULOVÁ 2005), the creation of standard volume tables under Central European conditions appears to be of high relevance. To attain this, a systematic study of the black walnut growth rate at different localities is necessary. Therefore the aim of our study was to reveal the black walnut growth pattern in its pure stands and to compare its growth at the two most important areas where the black walnut is planted in the Czech Republic, namely in the areas along the Svratka and Morava River, respectively. We hypothesize that the growth pattern does not differ between the two localities.

## MATERIALS AND METHODS

### Study area

The study was conducted at two localities of riparian forests in southern Moravia, both belonging to Natural Forest Area (NFA) No. 35 – Jihomoravské úvaly. The forests provide the same ecological conditions, although two main geological systems meet there: Hercynian and Carpathian (MEZERA 1956). The first locality called “Strážnice” is situated along the Morava River between the towns of Uherské Hradiště (coordinates 49°04'07.03"N; 17°27'39.07"E) and Strážnice (48°53'56.99"N; 17°18'57.62"E). The

average annual precipitation is 495 mm and the mean annual temperature is 9.0°C (ÚHUL 1999). The soil types are mainly Fluvisols and rarely Gleysols in land depressions.

The second locality “Židlochovice” is situated along the Svratka River between the town of Židlochovice (49°02'15,39"N; 16°37'06,93"E) and the northern bank of Nové Mlýny Water Reservoirs (48°54'31,54"N; 16°36'24,50"E). The average annual precipitation is 585 mm and the mean annual temperature is 9.5°C (ÚHUL 1999). The soil types are mainly Fluvisols and rarely Gleysols in land depressions.

While the main forest habitat type at both localities is defined as an alluvial site in lowlands (L1), the localities differ in individual habitat types on which black walnut stands are found (Table 1).

### Data collection and analyses

Two sets of data for both localities were obtained from two sources. The first source was data from forest management plans (FMP) – mean dbh and mean height per stand. The FMP of Židlochovice locality 2000 was created for the decade 2000–2009 and the FMP of Strážnice locality (ÚHUL 1997) for the decade 1997–2006. For the analyses, we selected stands consisting of 60% of black walnut at minimum. We used FMP data on diameter at breast height (dbh = 1.3 m), tree height and tree age [Strážnice: *N* (number of selected stands) = 131, Židlochovice: *N* = 294].

The second data set was collected on sample plots in the study areas in 2008. At the Strážnice locality, 31 circular plots of 300 m<sup>2</sup> in size (radius of 9.77 m) were established in pure (100%) black walnut stands and at the locality Židlochovice 32 plots of the same area using the LaserVertex with a transponder and monopod staff. Thus the experimental design is stratified according to the black walnut composition, the pure stands were selected.

On each plot, all trees were recorded and diameters at breast height (dbh) (1.3 m) and heights were measured using an electronic calliper (65 cm Caliper Haglöf Mantax Digitech) and land laser hypsometer (LaserVertex, Haglöf, Sweden). A total of 573 and 670 trees were measured at Strážnice and Židlochovice, respectively.

The age of sampled stands was taken from FMP and verified by summarizing the tree rings in increment cores collected at random using a Pressler increment borer. To attribute the age to sampled

Table 1. Area of forest habitat types in riparian forests on which black walnut stands are found

Locality	Forest habitat type		Area (ha)	% from locality Strážnice or Židlochovice	% from both localities together
	code	name			
Strážnice	1L0	transition from oak-ashwood to poplar-elmwood	74.60	52.50	20.70
Strážnice	1L2	elm alluvial forest with <i>Brachypodium</i>	60.30	42.50	16.70
Strážnice	1L9	oak-ashwood with <i>Rubus caesius</i> and <i>Iris pseudacorus</i> on heavy gley soils	7.06	5.00	2.00
Židlochovice	1L1	elm alluvial forests with <i>Rubus caesius</i> on heavy alluvial soils	23.00	10.50	6.40
Židlochovice	1L2	elm alluvial forest with <i>Brachypodium</i>	103.10	47.20	28.50
Židlochovice	1L4	elm alluvial forest with <i>Brachypodium</i> on light fluvisol	57.20	26.20	15.90
Židlochovice	1L6	elm alluvial forest with <i>Lamium maculatum</i> on elevated places	5.78	2.60	1.60
Židlochovice	1L7	elm alluvial forest on gravel on river Dyje's terraces	2.54	1.20	0.70
Židlochovice	1L8	elm alluvial forest with <i>Brachypodium</i> on fluvisol	5.34	2.40	1.50
Židlochovice	1L9	oak-ashwood with <i>Rubus caesius</i> and <i>Iris pseudacorus</i> on heavy gley soils	21.74	9.90	6.00

plots the mean dbh and mean height (MH) were calculated. The mean dbh was considered as the dbh corresponding to the average basal area on the plot. The MH was derived from the logarithmic relation between dbh and height on each plot according to the respective regression formula, in particular for age classes of 20, 40, 60, 80, and 100 years.

We analyzed the data from FMP and from sample plots separately. Mean dbh, mean height and mean age from FMP were calculated as arithmetical average of particular stands. To evaluate the black walnut growth pattern, three relations (between age and dbh, age and height, and dbh and height) were determined using logarithmic regression (VEBLEN 1992; ŠMELKO 2000). To determine the difference in growth pattern between the two localities, we used the comparison of correlation coefficients. In addition, for data from sampled plots we tested separately the differences in height and dbh between the two localities using ANCOVA with 'locality' as a categorical predictor and dbh and

height as covariates. All the analyses were performed in the STATISTICA software.

## RESULTS

### Black walnut growth indices from the forest management plan

According to the FMP, the mean age of black walnut stands was 42.2 years ( $\pm 1.7$  SE) and 50.8 years ( $\pm 1.3$  SE) in Strážnice and Židlochovice areas, respectively. In Strážnice mean dbh was 23.8 cm ( $\pm 0.8$  SE) and mean height 22.2 m ( $\pm 0.6$  SE) and in Židlochovice dbh was 25.9 ( $\pm 0.6$  SE) and mean height 22.3 m ( $\pm 0.4$  SE). dbh and tree height were highly correlated with the age at both sites, however this correlation was significantly closer in Strážnice than in Židlochovice area (Figs. 1a and 1b; Table 2). On the other hand, dbh and tree height were highly correlated; however these correlations did not differ between both areas (Fig. 1c; Table 2).

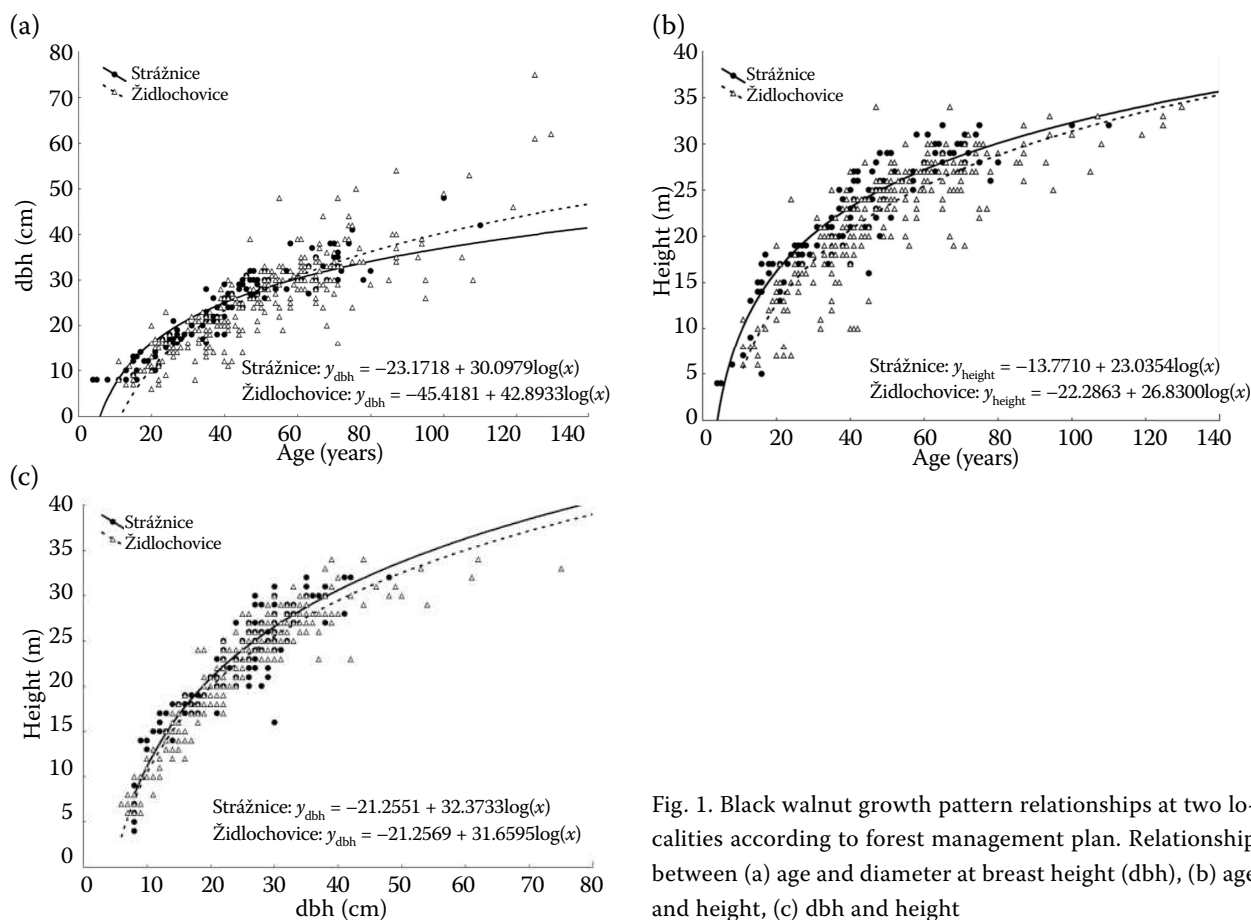


Fig. 1. Black walnut growth pattern relationships at two localities according to forest management plan. Relationship between (a) age and diameter at breast height (dbh), (b) age and height, (c) dbh and height

**Black walnut growth indices measured in pure stands**

In Strážnice the measured mean dbh was 23.0 cm ( $\pm 0.5$  SE) and the measured mean height was

22.4 m ( $\pm 0.3$  SE) and in Židlochovice the measured mean dbh was 20.9 cm ( $\pm 0.4$  SE) and the measured mean height was 21.8 m ( $\pm 0.2$  SE). The differences in mean dbh and mean height between the two localities were statistically significant

Table 2. Comparison of the black walnut (*Juglans nigra*) growth pattern at two investigated areas

Source of data	Locality	Relation	Correlation coefficient	P-value	P-value of comparison of correlation coefficients
FMP	Strážnice	height/age	0.882	< 0.001	0.013
	Židlochovice	height/age	0.808	< 0.001	–
	Strážnice	dbh/age	0.931	< 0.001	< 0.001
	Židlochovice	dbh/age	0.862	< 0.001	–
	Strážnice	height/dbh	0.901	< 0.001	0.356
	Židlochovice	height/dbh	0.881	< 0.001	–
Sample plots	Strážnice	height/age	0.915	< 0.001	0.878
	Židlochovice	height/age	0.908	< 0.001	–
	Strážnice	dbh/age	0.923	< 0.001	0.363
	Židlochovice	dbh/age	0.951	< 0.001	–
	Strážnice	height/dbh	0.902	< 0.001	0.332
	Židlochovice	height/dbh	0.911	< 0.001	–

FMP – forest management plans, dbh – diameter at breast height

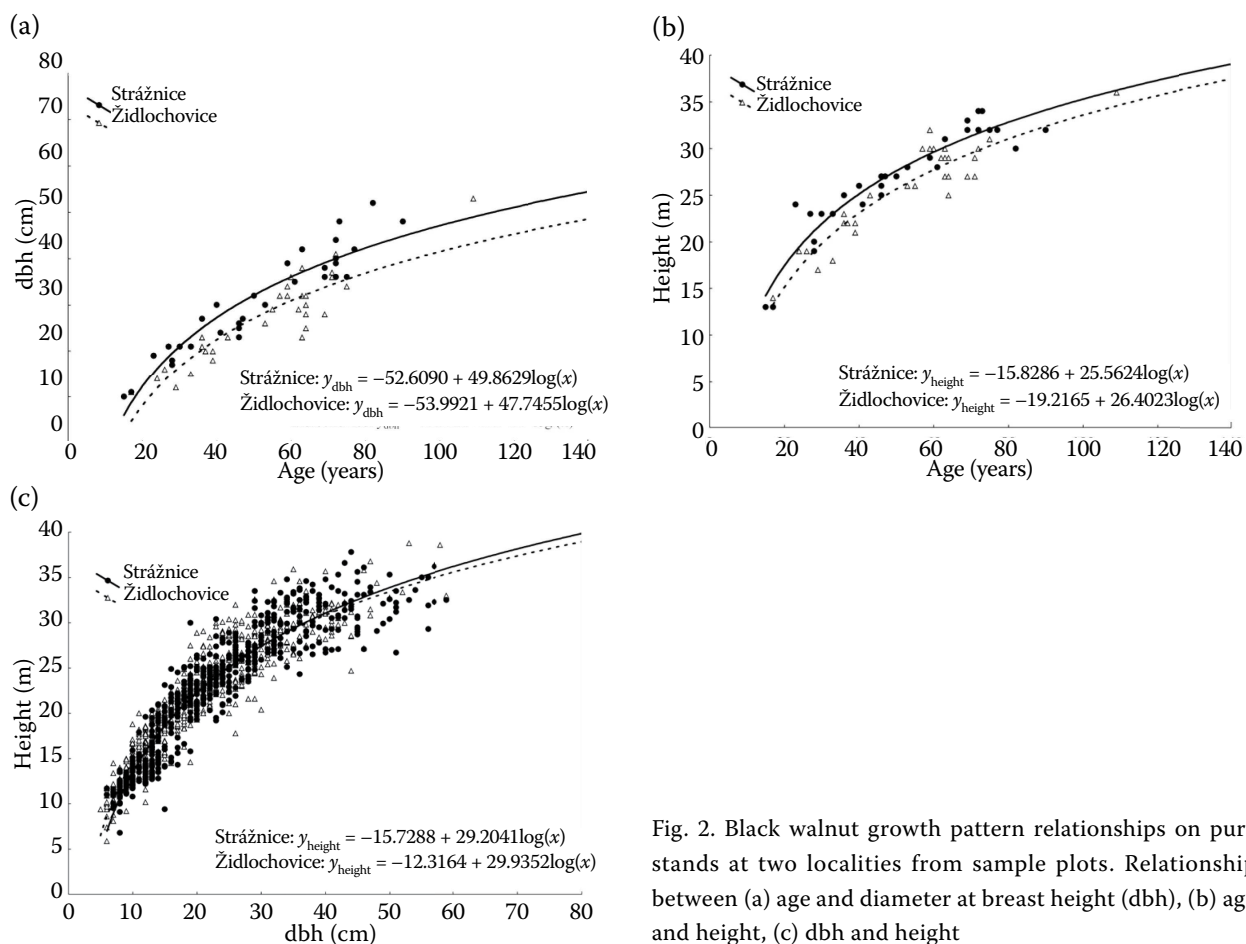


Fig. 2. Black walnut growth pattern relationships on pure stands at two localities from sample plots. Relationship between (a) age and diameter at breast height (dbh), (b) age and height, (c) dbh and height

(ANCOVA for dbh:  $F_{(1, 1,240)} = 26.70, P < 0.001$ ; ANCOVA for height:  $F_{(1, 1,240)} = 16.32, P < 0.001$ ). The relationships between dbh and tree height were very close and did not differ between the two localities (Fig. 2c; Table 2). The mean age of sample plots was 52 years ( $\pm 3.8$  SE,  $N = 31$ ) in Strážnice and 54.4 years ( $\pm 3.3$  SE,  $N = 32$ ) in Židlochovice. In Strážnice the calculated mean dbh was 30.9 cm ( $\pm 2$  SE) and the calculated mean height was 27 m ( $\pm 1$  SE). In Židlochovice the calculated mean dbh was 27.4 cm ( $\pm 1.6$  SE) and the calculated mean height was 25.8 m ( $\pm 0.9$  SE). The relationships between age and calculated mean dbh and calculated mean height were also very close and did not differ between the two localities (Figs. 2a and 2b; Table 2). Relating the black walnut to the age classes, the mean height was consistently higher in Strážnice than in Židlochovice (Table 3).

## DISCUSSION

The growth pattern relationships at the two compared localities obtained from the FMP and sample plots were not fully consistent. The FMP showed differences in the relation of height and dbh to the

age, while the sample data showed no difference. The discrepancy is probably caused by a difference in the method of calculating the mean height and mean dbh on sample plots and within the FMP. The mean values on sample plots were calculated directly from measured data whereas the mean values presented in FMP are based on the visual estimation of mean dbh and mean height of the respective forest stands. Therefore we consider the results from sample plots more relevant for an assessment of the black walnut growth pattern.

The results showed that the black walnuts grow similarly in both areas and we can use the complete data for another evaluation, for instance for the creation of volume tables. On the other hand, we recorded that the black walnut trees growing in Strážnice were thicker and higher than those in Židlochovice. This dissimilarity may be caused by different forest habitat types at both localities which are conditioned mainly by soil subtypes (ÚHUL 1999).

The black walnut mean height (MH) in 20-year age classes indicates the fast growth of black walnut in riparian forests along the Morava and Svatka Rivers (Table 3; HRIB et al. 2003). For instance, in the Strážnice area, comparing three different habitat types, the best growth was recorded indeed

Table 3. The comparison of tree growth using the mean height (MH) or site index (SI) in different age classes of the black walnut (*Juglans nigra*), Narrow-leaved Ash (*Fraxinus angustifolia*), and Pedunculate oak (*Quercus robur*)

	20 years	40 years	60 years	80 years	100 years
Black walnut MH: Strážnice, own data	17.4	25.1	29.6	32.8	35.3
Black walnut MH: Židlochovice, own data	15.1	23.1	27.7	31.0	33.6
Black walnut MH: average MH from the both localities	16.3	24.1	28.7	31.9	34.5
Black walnut MH in riparian forest (PRUDIČ 1991)	14.0	22.0	26.0	29.0	–
Black walnut MH (POKORNÝ 1952)	12.5	21.2	25.3	–	–
Black walnut MH after thinning (TOKÁR, KREKULOVÁ 2005)	–	17.4 (39 years)	28.6 (64 years)	–	–
Black walnut MH (HRIB et al. 2003)	–	–	–	–	35.9 (107 years)
Black walnut MH (PEDLAR et al. 2007)	11.7	16.3 (30 years)	–	–	–
Black walnut on the best site SI (ARES, BRAUER 2004)	22.0	26.0	–	–	–
Black walnut on the best site SI (NICOLESCU 1998)	13.5	21.0	25.5	–	–
Ash on site class +1 MH (Lesprojekt 1981)	12.0	22.0	27.0	30.0	31.0
Oak on site class +1 MH (ČERNÝ et al. 1996)	13.0	21.0	26.0	30.0	32.0

in the riparian forest (PRUDIČ 1991). In southern Moravia, the MH was also taller in comparison with other regions (TOKÁR, KREKULOVÁ 2005; PEDLAR et al. 2007). TOKÁR and KREKULOVÁ (2005) pointed out that heavy crown thinning affected stem and crown characteristics and enhanced the growth rate. Furthermore, the black walnut reaches even taller MH than other European native dominant tree species growing in riparian forests such as pedunculate oak (*Quercus robur* L.) (POKORNÝ 1952; ČERNÝ et al. 1996) or narrow-leaved ash (*Fraxinus angustifolia* Vahl.) (Lesprojekt 1981; POKORNÝ 1952). The tree growth in relation to the age of trees can also be evaluated using a site index (SI) in terms of mean dominant height (MDH) for a given age class (STURTEVANT, SEAGLE 2004; GUO, WANG 2006). However, MDH cannot be equal to MH because it is calculated as the average height of 30% of the tallest trees in the stand (ARES, BRAUER 2004) while the MH is calculated from the whole spectrum of tree heights in a stand or on sample plots (ŠMELKO 2000). Implicitly, the MDH and hence SI is always higher than MH of the stand. For that reason, together with considering the native range of the black walnut in North America, ARES, BRAUER (2004) investigating the black walnut growth on plantations, found out higher growth rates in particular age classes. On the other hand, NIKOLESCU (1998) recorded lower values despite the use of the SI (Table 3). This suggests that in the conditions of riparian forests of Central Europe the black walnut

reaches large height increment, even in comparison with its native area.

## CONCLUSION

The black walnut growth pattern in its pure stands did not differ between the Strážnice locality along the Morava River and the Židlochovice locality along the Svratka River. The black walnut growing in riparian forests in the region of South Moravia (Czech Republic) was found to reach higher growth rate in comparison with other regions as well as in comparison with other tree species in the area. Therefore our results suggest the high potential of black walnut in timber production in riparian forests in the Czech Republic, mainly in the South Moravian region.

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