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ECOLOGY, PHYTOTECHNICS AND PRODUCTION OF BLACK WALNUT (*Juglans nigra* L.) PLANTATIONS

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Abstract

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Impact of ecological conditions and different phytotechnics (moderate crown thinning – PRP III, and heavy crown thinning – PRP IV, with positive selection and interval of 10 years) on growth and aboveground dendromass production of black walnut plantations on the series of permanent research plots Sikenica (Forest Enterprise Levice, Forest District Levice) was evaluated over the period 1978–2003. The walnut forests of seed origin were established in the segment of the forest type 954 Dry elm-ash forest with hornbeam belonging to heminitrophilous group of forest types *Ulmeto-Fraxinetum carpineum*. The Eutri-Fluvic Cambisol was formed from brown Holocene alluvial sediments. The black walnut (*Juglans nigra* L.) aged 64 years had the following values of parameters: basal area 31.03 $m^2.ha^{-1}$, aboveground dendromass 463.88 $m^3.ha^{-1}$ (194.98 $t.ha^{-1}$). The mean annual periodical increment in basal area was 0.51 $m^2.ha^{-1}$, in aboveground dendromass 11.48 $m^3.ha^{-1}$ (5.39 $t.ha^{-1}$). Development of the average stem, basal area and aboveground dendromass was more influenced by heavy crown thinning.

Key words: Eutri-Fluvic Cambisol, *Ulmeto-Fraxinetum carpineum*, black walnut, crown thinning, periodical increment, growing stock

Introduction

The growth and development of introduced tree species stands in Slovakia has not been systematically evaluated yet, consequently, there is lacking sufficient amount of conclusive data about their species composition and spatial arrangement. The problem of these stands tending, mainly in connection with different ways of their establishment, species composition and development is therefore one of very high importance (Tokár, 1998a, 2000).

Experiences obtained in Central Europe show that the black walnut (*Juglans nigra* L.) belong to commercially important tree species because of very valuable wood (Beran,

Šindelář, 1996; Réh, 1994, 1996; Šindelářová, 1973), fruits (Šika, 1957), fast growth and high productivity in convenient sites (Beran, Šindelář, 1996; Holubčík, 1968; Hríb et al., 2003; Prudič, 1991; Tokár, 1995, 1996a, b, 1998a, b, 2000; Tokár, Krekulová, 2005), and also resistance against biotic and abiotic injurious agents (Juhásová, Hrubík, 1984).

This paper is focused on evaluation of side-ecological and phytocenological conditions and impact of various phytotechnics (thinning) on trends in growth and aboveground dendromass production of black walnut stands on the series of permanent research plots (PRP) Sikenica over the period 1978–2003.

Material and methods

The stand of black walnut of Slovak origin was sown in a triangular spacing of 2x2 m in 1939, in territory of the Forest District Levice (Forest Enterprise Levice). There followed two cleanings, three clearings and in 1979 a somewhat delayed more intensive thinning. The series of three permanent research plots Sikenica (PRP III, IV and V – control), each with dimensions 50x50 m, was established in 1978 in the stand 9 b with the current age of 39 years. The stand is situated in the alluvium of the Hron river, at of 150 m a.s.l, in the locality Hrable-bažantnica, near the village of Želiezovce. The territory belongs to the warm climatic zone A.

The soil and phytocoenological characteristics have been described in July 2005. The soils were classified according to Collective (2000), geobiocoenoses according to Zlatník (1959, 1976a, b) and Hančinský (1972). The names of plant taxa are given according to Dostál (1989). The air-dried soil samples were passed through a sieve with a mesh size of 2x2 mm and used for determination of following soil parameters:

– particle-size distribution using a laser analyser (Fritsch analysette 22)
– values of active and exchange soil reaction using a digital pH-meter, type 08 211/1, Radelkis (ratio of fine earth to water or 1 M KCl solution 1:2.5)
– soil carbon content oxidimetrically, according to Ťurin.

On each partial PRP was determined the volume production of black walnut stand according to Halaj (1963), and the oven-dry weight (at 105 °C) of aboveground dendromass by method of the sample trees. This method was also used in case of other woody species (*Castanea sativa* M i l l., *Quercus rubra* L., *Pinus nigra* A r n o l d). The number of sample trees was determined with using stratified sampling according to the distribution of basal area in the tree classes with required standard error (Šmelko, Wolf, 1977). The point field of dry weight values of stems, branches, annual shoots, leaves and leaf area index in fresh state of sample trees was fitted with a parabola of the second degree. The fitted dry weight values of sample trees components were used for calculation of dendromass stock in the diameter classes per 1 ha of stand. The scale for the tree quality assessment is in Table 1.

PRP III was subjected to moderate and PRP IV to heavy crown thinning with positive selection repeated at 10-year intervals. The purpose was to control the development of black walnut stands in such a way as to reach maximum production and quality. The used thinning method is based on tending of final-crop trees selected

T a b l e 1. Scale used at stem and crown quality evaluation according to tree classes.

Evaluation degree	Tree class	Stem quality	Crown quality		
			Size	Density	Type
1	dominant	high	average	average	regular
2	co-dominant	medium	long	very dense	fork-shaped
3	intermediate	low	small	open	bouquet
4	suppressed	very low	very small	very open	irregular (deformed)

from the 1st and 2nd tree classes, with diameter bigger than the mean breast-height diameter of stand and higher as the mean stand height. Apart from the dimensional criteria, there are also concerned qualitative indicators (1st and 2nd degree of stem and crown quality) and spacing between the future crop trees. The growth of basal area, volume and dry weight of aboveground dendromass were evaluated by means of growth index, mean periodical increment and in case of total production (growing stock + thinnings + necromass + other losses) also based on the total mean increment. The data obtained from the PRP influenced by thinning were compared with data found on the control PRP V.

The leaf area index (LAI) of sample trees was determined using a photoplanimeter EJKELKAMP (3x100 leaves) and conversion coefficient (weight of fresh leaves in kg/area of fresh leaves in m^2).

Results

Geological and soil conditions

The PRP Sikenica are situated on a floodplain of the Hron river, formed from Neogene gravel sands buried with skeleton-less non-carbonate brown alluvial loam. The ground water level is during year mostly outside the main rhizosphere of forest stands. It depends on amount of water in bed of river Hron and close to the soil surface ascends only in periods of more lasting and intensive precipitation, usually in spring and autumn. In the past was the soil surface probably episodically flooded, but duration of these floods was not long ones. It is evident from the fact that alluvium sediments show any hydromorphic sign even at a depth of 80 cm. Owing to land drainage, at present, the soils are not already flooded or only seldom and shortly. Macro-morphological properties of soils were described on the PRP III. situated in the middle of black walnut stand:

L +, dry herbs, mainly of *Galium apparine* species

Aop 0–7 cm, brown-black, clay loam, with medium crumbs, loose, moist to wet, with medium dense roots, without skeleton

Bv_1 7–25 cm, dark-brown, clay loam, lumped, medium compacted, fresh moist, with weakly to medium dense roots, without skeleton

Bv_2 25–80 cm, brown, loam to clay-loam, lumpy, compacted, fresh moist, with weakly dense roots, without skeleton.

In soils on the PRP are dominant brown-coloured B-horizons. The upper 40-50 cm soil layer is loamy or clay-loam, lower layers are sandy-loam (by Novák 1952, in Šály 1991). According to the textural triangle (Collective, 2000), the soil is clay or silt-clay, in their lower part silty-loam or loamy (at a sandy fraction content of 46%). The maximum of physical and coarse clay is in a depth of 20 cm, of the coarse dust in 30–60 cm layer (Table 2).

The topsoil is medium or strong humous, the lower layers are moderately humous. Even in a depth of 70–80 cm is almost 2% of humus. In 2005, the soil was neutral (in surface horizons) to mildly acid (in a depth below 30–40 cm). From the viewpoint of edaphic-trophic conditions, the neutral soil reaction indicates (according to Kukla, 1993) the occurrence of heminitrophilous order of geobiocoens with equilibrium limit values of pH_{H2O} 6.0–7.2.

Phytocoenological and geobiocoenological conditions

Before plantation of the introduced black walnut, the plots had been ploughed. The succession processes running in monoculture have resulted in forest communities with the species composition described in Table 3.

At present, the phytocoenosis comprises 34 plant species, from which there are 6 (18%) woody species, 7 (20%) grass species and 21 (62%) forbs. From autochthonous woody species characteristic for floodplain forests, in lower layers of woody complex occur *Fraxinus angustifolia,* subsp. *danubialis* and shrubs indicating none or only short-term floods. Another spontaneously spreading introduced woody plant (apart from black walnut) is *Negundo aceroides*, significantly present in the lower storey (30–40%).

The occurrence of grasses as *Brachypodium sylvaticum, Dactylis glomerata* and *Poa nemoralis* was found very irregular (cover 10–30%), depending on amount of light penetrating through forest canopy to soil surface. On the other hand, the presence of species as *Aethusa cynapium*, subsp. *cynapioides, Arum alpinum, Carduus crispus, Circaea lutetiana, Elymus caninus, Lyzimachia nummularia, Milium effusum, Solidago giganthea* and *Stachys sylvatica* was connected with more favourable moisture regimen of soils. In phytocoenosis were dominant mesotrophic plant species as *Ajuga reptans, Clematis vitalba, Dryopteris filix-mas, Geum urbanum, Lapsana communis, Stellaria media, Viola hirta, Xanthoxalis dillenii* and others, together with heminitrophilous and nitrophilous species as *Galium apparine, Geranium robertianum, Glechoma hederacea, Urtica kioviensis* and an invasive alien species *Chelidonium majus.*

T a b l e 2. Some properties of Eutri-Fluvic Cambisol (PRP III).

Layer		Fine earth fraction [mm]									pH		Ekv. $CaCO_3$	Cox	Humus
		clay		silt		sand									
		phys.		coarse		fine		coarse	total						
		< 0.002	< 0.01	0.01-0.05	0.01-0.063	0.05-0.1	0.063-0.1	0.1-2.0	0.05-2.0	0.063-2.0					
hor.	[cm]	[%]									H_2O	KCl	[%]		
Aop	0-5	11.42	42.90	39.65	41.11	3.22	1.76	14.22	17.44	15.98	7.27	7.12	0.07	7.44	12.83
Bv_1	10-20	13.74	46.21	37.64	38.24	1.40	0.79	14.75	16.15	15.54	6.84	6.44	0.00	4.03	6.95
	30-40	12.93	42.12	41.85	43.02	3.02	1.84	12.98	16.00	14.82	6.50	5.75	0.00	1.89	3.26
Bv_2	50-60	8.82	28.67	39.59	43.41	13.45	9.64	18.13	31.58	27.77	6.02	5.24	0.00	1.21	2.09
	70-80	7.00	22.45	31.03	34.10	11.43	8.37	34.94	46.37	43.31	5.82	5.17	0.00	1.15	1.99

T a b l e 3. Base characteristics of black walnut geobiocoenosis.

Locality		Sikenica	
Permanent research plot		III	
Altitude [m]		130	
Slope [°]		0	
Parent rock		alluvial clays	
Soil subtype		Eutri-Fluvic Cambisol	
Edaphic-hydric order of geobiocoens		changeably wetted and dried	
Edaphic-trophic order of geobiocoens		heminitrophilous	
Group of forest types		*Ulmeto-Fraxinetum carpineum* (UFrc)	
Forest type		954 Dry elm-ash forest with hornbeam	
Type of natural (potential) phytocoenosis		*Brachypodium sylvaticum, Rubus caesius, Convallaria majalis* – (*Dactylis glomerata* subsp. *polygama*)	
Tree species complex			
Stocking	0,7-0,8	*Dactylis glomerata*	+ ÷-2^{+2}
Canopy [%]	70-80	*Elymus caninus*	+[1]
Taxon	cover [%]	*Milium effusum*	+
1. Juglans nigra	100	*Poa nemoralis*	+ ÷1^{-3}
4. Juglans nigra	5	*Aethusa cynapium,* subsp. *cynapioides*	1÷ +2^{+3}
Negundo aceroides	30	*Ajuga reptans*	+ ÷1^{+2}
Fraxinus angustifolia, subsp. *danubialis*	+-5	*Aristolochia clematitis*	+$^{-2}$
Euonymus europaeus	+	*Arum alpinum*	+ ÷1
Ligustrum vulgare	+-5	*Carduus crispus*	+ ÷1
Sambucus nigra	+	*Chelidonium majus*	+$^{-2}$
5_{1a} *Juglans nigra*	+	*Circaea lutetiana*	+$^{-3}$
Negundo aceroides	+	*Carduus* sp.	-
Fraxinus angustifolia, subsp. *danubialis*	+-5	*Clematis vitalba*	1÷ +2^{+4+5}
Euonymus europaeus	+	*Dryopteris filix-mas*	+
Ligustrum vulgare	+-5	*Galium apparine* (dead)	1÷-2
Sambucus nigra	+	*Geranium robertianum*	+ ÷ +2^{+4}
5_{1b} *Juglans nigra*	5	*Geum urbanum*	+ ÷1^{-2}
Fraxinus angustifolia, subsp. *danubialis*	+-5	*Glechoma hederacea*	1÷ +2^{-3}
Euonymus europaeus	+	*Lapsana communis*	+ ÷1
Herb layer		*Lyzimachia nummularia*	+$^{+4}$
total cover [%]	$50\text{-}70^{100}$	*Solidago giganthea*	+ ÷1^{-2}
therefrom grasses and sedge [%]	$20\text{-}30^{70}$	*Stachys sylvatica*	1÷-2^{+2}
Taxon	Cover	*Stellaria media*	+[1]
Brachypodium sylvaticum	1÷+$2^{+3÷+4}$	*Urtica kioviensis*	+ ÷1^{+2}
Calamagrostis epigeios	+$^{+2}$	*Viola hirta*	+[3]
Carex sylvatica	+	*Xanthoxalis dillenii*	+

According to Hančinský (1972) the black walnut geobiocoenosis can be included into wet heminitophilous group of forest types *Ulmeto-Fraxinetum carpineum* and the forest type 954 Dry elm-ash forest with hornbeam – autochthonous phytocoenosis *Brachypodium sylvaticum, Rubus caesius, Convallaria majalis*, (*Dactylis glomerata* subsp. *polygama*). According to newer classification of Zlatník (1976a, b) the permanent ecological conditions have character of wetted edaphic-hydric order of geobiocoens, heminitrophilous edaphic-trophic interorder of geobiocoens and group of types of geobiocoens Ulmi-fraxineta carpini superiora.

The herb layer cover and floristic composition on plot IV (light thinning) was similar to plot III, the only exception was presence of *Aristolochia clematitis* species. Substantially lower cover was only found on plot V (control, without thinning), where the herb species were sporadic (*Pulmonaria officinalis* +, *Chelidonium majus* +, *Viola reichenbaciana* +), if we neglect occurrence of dead aboveground parts of the species *Galium apparine* (cover $\pm 2^{-4}$).

Stand structure, bio-sociological status of trees and stand quality

At the experiment launching in 1978 (Fig. 1), the most frequent were trees belonging to the 2nd tree class – from 61.8% (PRP IV) to 70.6% (PRP III). The percentage of trees with very high quality of stems fluctuated between 51.9% (PRP III) and 66.8% (PRP V), with medium-size crown between 50.0% (PRP III) and 63.2% (PRP V), average crown density between 61.2% (PRP III) and 89.6% (PRP V) and regular crown

Fig. 1. Pure stand of black walnut (*Juglans nigra* L.) in 1978 on the locality Sikenica.

Fig. 2. Potential final crop tree of black walnut (*Juglans nigra* L.) on PRP IV Sikenica in 2003.

form between 55.6% (PRP III) and 70.5% (PRP V). Rather high was already proportion of trees with forked crowns – from 28.5% (PRP V) to 42.5% (PRP III).

Owing to dynamic changes in 1979–2003 (Fig. 2) the proportion of trees belonging to the 2nd tree class was increased and reached from 74.4% (PRP V) to 94.6% (PRP III). The proportion of trees with very high quality of stems created from 60.3% (PRP III) to 86.7% (PRP V), with medium-size crown from 66.4% (PRP III) to 82.6% (PRP V), average crown density from 76.3% (PRP III) to 94.8% (PRP V) and regular crown form from 33.6% (PRP III) to 66.4% (PRP V). The amount of trees with forked crowns reached from 32.7% (PRP V) to 66.4% (PRP III).

Development of average stem variables

During 25 years the heavy crown thinning (TVP IV) mostly influenced development of mensurational variables of average stem (Table 4). Index of increment percent (p) compared to the control PRP reached in case of breast-height diameter ($d_{1,3}$) 75.11% and in volume yield 80.70%.

Development of basal area, growing stock and stock of aboveground biomass

The basal area of black walnut stands at the current age of 64 years (Table 5) ranged between 27.93 $m^2.ha^{-1}$ (PRP III) and 33.95 $m^2.ha^{-1}$ (PRP V), the growing stock from 381.12 $m^3.ha^{-1}$

T a b l e 4. Mean values of stem parameters in black walnut (*Juglans nigra* L.) monocultures.

PRP Sikenica	Variable	Stand age		Growth index	Periodic (mean) annual increment (p)		Index p (%) in relation to PRP V
		39 years (in 1978 after intervention)	64 years (in 2003 before thinning)				
				[%]	[abs.]	[%]	[%]
III	d.b.h. (cm)	16.610	28.200	169.78	0.460	2.77	139.19
	height (m)	18.500	26.300	142.16	0.310	1.67	99.40
	volume (m^3)	0.285	0.874	306.67	0.023	8.07	143.85
	weight (kg)	68.340	398.200	582.67	13.190	19.30	116.05
IV	d.b.h. (cm)	16.050	29.100	181.31	0.520	3.24	162.81
	height (m)	17.400	28.600	164.37	0.490	2.82	167.86
	volume (m^3)	0.260	1.044	400.00	0.031	11.92	212.48
	weight (kg)	66.820	439.140	657.20	14.890	22.28	133.97
V (control)	d.b.h. (cm)	16.610	24.820	149.43	0.330	1.99	100.00
	height (m)	17.800	25.300	142.13	0.300	1.68	100.00
	volume (m^3)	0.285	0.692	242.81	0.016	5.61	100.00
	weight (kg)	61.330	316.400	515.90	10.200	16.63	100.00

T a b l e 5. Values of some variables in black walnut (*Juglans nigra* L.) monocultures.

PRP Sikenica	Variable	Stand age		Growth index	Periodic (mean) annual increment (p.a.i.), decrement (p.a.d.)		Index p. (%) in relation to PRP V
		39 years (in 1978 after intervention)	64 years (in 2003 before intervention)				
				[%]	[abs.]	[%]	
III	N (trees.ha^{-1})	892.00	436.00	-	-	-	-
	G ($m^2.ha^{-1}$)	18.58	27.93	150.32	0.37	1.99	94.31
	V ($m^3.ha^{-1}$)	183.98	381.12	207.15	7.88	4.28	86.29
	M ($t.ha^{-1}$)	60.96	173.61	284.79	4.51	7.40	83.15
IV	N (trees.ha^{-1})	902.00	444.00	-	-	-	-
	G ($m^2.ha^{-1}$)	18.36	31.03	169.01	0.51	2.78	131.75
	V ($m^3.ha^{-1}$)	176.97	463.88	262.12	11.48	6.49	130.85
	M ($t.ha^{-1}$)	60.09	194.98	324.48	5.39	8.97	100.79
V (control)	N (trees.ha^{-1})	1050.00	656.00	-	-	-	-
	G ($m^2.ha^{-1}$)	22.22	33.95	152.79	0.47	2.11	100.00
	V ($m^3.ha^{-1}$)	202.80	454.32	224.02	10.06	4.96	100.00
	M ($t.ha^{-1}$)	64.40	207.56	322.30	5.73	8.90	100.00

Note: G – basal area; V – volume stock; M – stock of aboveground dendromass (dry matter)

(PRP III) to 463.88 $m^3.ha^{-1}$ (PRP IV). The highest values of growth index (169.01 % in case of basal area, 262.12% in case of growing stock), mean periodical increment (11.48 $m^3.ha^{-1}$. $year^{-1}$) and increment percent (6.49%) were found on PRP IV subjected to heavy

T a b l e 6. Total values of some variables in black walnut (*Juglans nigra* L.) monocultures.

PRP Sikenica	Variable	Stock in 2003	Tending losses in 1978-1998	Other losses	Stock plus losses till 31.12. 2003	Total mean increment (TMI)	Index TMI (% of PRP V)
III	N (trees.ha^{-1})	436.00	515.00	29.00	980.00	-	-
	G (m^2.ha^{-1})	27.93	9.54	0.52	37.99	0.59	109.26
	V (m^3.ha^{-1})	381.12	80.98	5.96	468.06	7.31	101.25
	M (t.ha^{-1})	173.61	38.85	2.87	215.33	3.36	101.51
IV	N (trees.ha^{-1})	444.00	554.00	19.00	1017.00	-	-
	G (m^2.ha^{-1})	31.03	11.42	0.47	42.92	0.67	124.07
	V (m^3.ha^{-1})	463.88	103.67	5.22	572.77	8.95	123.96
	M (t.ha^{-1})	194.98	48.36	2.70	246.04	3.84	116.01
V (control)	N (trees.ha^{-1})	656.00	0.00	238.00	894.00	-	-
	G (m^2.ha^{-1})	33.95	0.00	0.76	34.71	0.54	100.00
	V (m^3.ha^{-1})	454.32	0.00	8.06	462.38	7.22	100.00
	M (t.ha^{-1})	207.56	0.00	4.15	211.71	3.31	100.00

Note: G – total basal area; V – total volume stock; M – total stock of aboveground dendromass (dry matter).

crown thinning. The stand on this PRP also reached the highest index of increment percent (30.85% in comparison with control plot).

The stock of aboveground biomass at the stand age of 64 years ranged between 173.61 t.ha^{-1} (PRP III) and 207.56 t.ha^{-1} of dry matter (control PRP V). The highest growth index (324.48%), increment percent (8.97%) and its index to the control PRP V (0.79%) were found on PRP IV (heavy crown thinning).

Development of total basal area, total volume production and total aboveground dendromass

The total basal area of the 64-year old homogeneous stands of black walnut (Table 6) ranges from 34.71 m^2.ha^{-1} (PRP V) to 42.92 m^2.ha^{-1} (PRP IV) and their total mean increment from 0.54 (PRP V) to 0.67 m^2.ha^{-1}.year^{-1} (PRP IV). The index of the total mean increment (TMI) to the control PRP V ranges for the tended stands from 9.26% (PRP III) to 24.07% (PRP IV).

The total volume production of the 64-year old tended stands ranged from 468.06 m^3.ha^{-1} (PRP III) to 572.77 m^3.ha^{-1} (PRP IV) and their total mean increment from 7.31 m^3.ha^{-1}.year^{-1} (PRP III) to 8.95 m^3.ha^{-1}.year^{-1} (PRP IV), that means by 1.25% (PRP III) to 23.96% (PRP IV) more than on the control plot (growing stock 462.38 m^3.ha^{-1} and total mean increment 7.22 m^3.ha^{-1}.year^{-1}). The total aboveground dendromass in these stands ranged from 215.33 t.ha^{-1} (PRP III) to 246.04 t.ha^{-1} (PRP IV) and their total mean increment from 3.36 t.ha^{-1}.year^{-1} (PRP III) to 3.84 t.ha^{-1}.year^{-1} (PRP IV), what is by 1.51% (PRP III) to 16.01% (PRP IV) more than on the control plot.

T a b l e 7. Growing stock of final-crop trees in black walnut (*Juglans nigra* L.) monocultures.

PRP Sikenica	Variable	Stock		Growth index	Periodic (mean) annual increment (p.a.i.)		Index p (% of PRP V)
		in 1978	in 2003	[%]	[abs.]	[%]	
III	N (trees.ha^{-1})	148.00	132.00		–	–	–
	G (m^2.ha^{-1})	3.08	10.16	329.87	0.28	9.09	95.58
	V (m^3.ha^{-1})	43.22	142.44	329.56	3.97	9.18	79.00
	M (t.ha^{-1})	14.3	64.03	447.76	1.99	13.92	78.33
IV	N (trees.ha^{-1})	172.00	160.00		–	–-	–
	G (m^2.ha^{-1})	3.64	14.70	403.85	0.44	12.08	127.02
	V (m^3.ha^{-1})	49.19	229.04	465.62	7.19	14.62	125.82
	M (t.ha^{-1})	16.67	94.32	565.81	3.11	18.66	105.01
V (control)	N (trees.ha^{-1})	164.00	140.00		–	–	–
	G (m^2.ha^{-1})	3.47	11.78	339.48	0.33	9.51	100.00
	V (m^3.ha^{-1})	43.30	169.00	390.30	5.03	11.62	100.00
	M (t.ha^{-1})	13.73	74.64	543.63	2.44	17.77	100.00

Note: G – basal area; V – volume stock; M – stock of aboveground dendromass (dry matter).

From these results we can see that the homogeneous black walnut stands tended by means of heavy crown thinning have higher aboveground biomass production than non-tended stands (control). The production of the stands subjected to moderate thinning was found without significant differences compared to the control.

Leaf area index (LAI)

The leaf area index in 1978, at the age of black walnut stands of 39 years was 4.60 ha.ha^{-1} (PRP III) and 4.70 ha.ha^{-1} (PRP IV and V). In 2003, at the stand age of 64 years it was 6.54 ha.ha^{-1} (PRP III), 7.24 ha.ha^{-1} (PRP IV) and 7.82 ha.ha^{-1} (PRP V).

Aboveground dendromass stock and leaf area index in final-crop trees

In 1978 the final-crop trees (from 148 to 172) was selected and permanently labelled on separate plots (Table 7). The basal area of these trees ranged from 3.08 m^2.ha^{-1} (PRP III) to 3.64 m^2.ha^{-1} (PRP IV), volume stock from 43.22 m^3.ha^{-1} (PRP III) to 49.19 m^3.ha^{-1} and aboveground dendromass from 13.73 t.ha^{-1} (PRP V) to 16.67 t.ha^{-1} (PRP IV).

In 2003 the number of final-crop trees ranged between 132 trees.ha^{-1} (PRP III) and 160 trees.ha^{-1} (PRP IV, Fig. 2). The basal area of these trees reached 10.16 m^2.ha^{-1} (PRP III) to 14.70 m^2.ha^{-1} (PRP IV), volume stock 142.44 m^3.ha^{-1} (PRP III) to 229.04 m^3.ha^{-1} (PRP IV) and aboveground dendromass production 64.03 t.ha^{-1}.year^{-1} (PRP III) to 94.32 t.ha^{-1} (PRP IV).

The highest growth index in all the mensurational variables was found in final-crop trees on plot PRP IV (heavy crown thinning), what is also evident on the higher values of the increment percent index compared to the control plot (by 5.01 % to 27.02 %).

The values of leaf area index of 64 year-old final-crop trees reached 2.39 $ha.ha^{-1}$ (PRP III), 2.78 $ha.ha^{-1}$ (PRP V) and 3.47 $ha.ha^{-1}$ (PRP IV).

Discussion

The development of structure and production of black walnut stands in Slovakia tended by thinning was discussed in previous works of Tokár (1991a, b, 1992, 1995, 1996a, b, 1998a, b, 2000), Tokár, Krekulová (2005) and Tokár, Kukla (2008). For tending black walnut monocultures is recommend heavy crown thinning with positive selection repeated at intervals of 10 years. For mixed walnut stands with red oak and small-leaved linden is recommended moderate crown thinning with positive selection, repeated after five years.

The thinning is based on selection and permanent labelling of final-crop trees and corresponding silvicultural measures. The selected final-crop trees correspond to quantitative and qualitative criteria. There are thicker and higher than the average stand diameter and height and belong to the first and second class of the stem and crown quality. The number of final-crop trees should be 250–300 $trees.ha^{-1}$.

The growth, production and growing possibilities of black walnut in area of the South Moravia (Forest Enterprises Strážnice and Židlochovice) have been summarised and evaluated by Prudič (1991) and Hríb et al. (2003). Also other authors (Beran, Šindelář, 1996; Frýdl, Šindelář, 2004) recommend growing this woody plant in forest management in the Czech Republic, on the background of hitherto positive experience and knowledge about its growing in ecological conditions of floodplain forests.

The growth, production and silviculture of black walnut stands is also connected with damage by fungi and animal pests. According to Juhásová, Hrubík (1984), this woody plant has a high resistance against both biotic and abiotic noxious agents. Tokár, Kukla (2008) found local occurrence of eggs of *Lymantria dispar* L. and rust fungi in the locality Ivanka pri Nitre in 2003. We also found the occurrence of *Lymantira dispar* species on several black walnut stems in the Sikenica locality.

Conclusion

This work evaluates the ecological condition and 25 years lasting impact of thinning on development of phytocenoses, as well as growth and production of homogeneous stands of black walnut (*Juglans nigra* L.) in the locality Sikenica (Forest Enterprise Levice, Forest District Levice).

The black walnut forests of seed origin were established in the segment of the forest type 954 Dry elm-ash forest with hornbeam belonging to heminitrophilous group of forest types *Ulmeto-Fraxinetum carpineum*. In herb layer dominate the species as *Brachypodium sylvaticum, Aethusa cynapium,* subsp. *cynapioides*, *Clematis vitalba*, *Geranium robertianum*, and *Glechoma hederacea*, frequent are also *Dactylis glomerata* and *Stachys sylvatica*. The Eutri-Fluvic Cambisol was formed from brown Holocene alluvial sediments.

The growth and production of black walnut stands were more influenced by heavy crown thinning. In 2003, at the age of 64 years, the stand had the following parameters: basal area 31.03 $m^2.ha^{-1}$, growing stock 463.88 $m^3.ha^{-1}$ and 194.98 $t.ha^{-1}$, mean periodical increment 0.51 $m^2.ha^{-1}.year^{-1}$, 11.48 $m^3.ha^{-1}.year^{-1}$ and 5.39 $t.ha^{-1}.year^{-1}$, total production 42.92 $m^2.ha^{-1}$, 572.77 $m^3.ha^{-1}$ and 246.04 $t.ha^{-1}$, total mean increment 0.67 $m^2.ha^{-1}.year^{-1}$, 8.95 $m^3.ha^{-1}.year^{-1}$ and 3.84 $t.ha^{-1}.year^{-1}$. The growth index of increment percent in comparison to control is in case of total basal area +24.07%, total volume production +23.96% and total weight production +16.01%.

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