Development of phytocoenoses and of above ground production of red oak (*Quercus rubra* L.) and black walnut (*Juglans nigra* L.) stands on the PRP series Ivanka pri Nitre

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Abstract

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There was studied the influence of moderate crown thinning on development of phytocoenoses and above ground dendromass production in pure and mixed stands of introduced species *Quercus rubra* L. and *Juglans nigra* L. Owing to succession process during more than 40 years the other 17 autochthonous tree species, 7 of them (41%) shrubs, have been penetrated in studied stands. The phytocoenoses contain 56 herb species including abundant indicators of the wetted edaphic-hydric order of geobiocoens manifesting that the water regime of soils has not been substantially disturbed by hydro-melioration of surrounding land and the Nitra riverbed regulation. Geobiocoenoses in which the series of permanent research plots has been established belong to the nitrophilous order of geobiocoens, group of forest types Ulmeto-Fraxinetum carpineum and forest type 954 Dry elm-ash forest with hornbeam. The highest reserve of above ground dendromass (686.81 m^3 ha^{-1}, 486.50 t ha^{-1}) and highest mean periodic annual increment (20.58 m^3 ha^{-1} $year^{-1}$, 14.18 t ha^{-1} $year^{-1}$) were found in the 48-year-old non-tended stand of red oak (80%) and black walnut (20%). The highest growth index of standing volume (414.30%) and the highest percentage of mean periodic annual increment (12.57%) were observed in the tended stand of black walnut (20%) and small-leaved linden (80%), while the highest growth index of dry weight reserve (526.85%) and highest mean periodic annual increment (17.07%) were found in the tended stand of black walnut (80%) and red oak (20%). The highest volume reserve of final-crop trees (299.57 m^3 ha^{-1}) was also found in the non-tended mixed stand of black walnut (80%) and red oak (20%), while the highest weight reserve (230.98 t ha^{-1}) and the highest mean periodic annual increment (11.27 m^3 ha^{-1} $year^{-1}$, 10.68 t ha^{-1} $year^{-1}$) were in the tended stand of red oak (80%) and black walnut (20%).

Key words

red oak, black walnut, crown thinning, soil properties, changes of phytocoenoses, development of dendroproduction

Introduction

Red oak (*Quercus rubra* L.) and black walnut (*Juglans nigra* L.) belong to the introduced tree species considerable distributed in Slovakia (Benčať, 1982). Their cultivation is well-founded with regard to high growth and yield ability (Réh J., 1967, 1989, 1995; Tokár 1979, 1987a, 1991a, b, 1996, 1998, 2000), resistance against airborne pollutants and tracheomycoses (Juhásová and Hrubík, 1984), as well as usability in orchard management, forest management and furniture industry (Réh R., 1992a, b, 1994, 1996).

In this work are evaluated geobiocoenological conditions and influence of moderate crown thinning with positive selection and interval of five years on course of successive processes and development of production of pure and mixed red oak and black walnut stands.

Materials and methods

The stands of the studied introduced species were established in years 1954–1956 in territory of the Forest District Nitra (Forest Enterprise Palárikovo). There had been bed out one-year-old plants of red oak and sowed the black walnut seeds (provenance Sereď) in triangular spacing. The territory is situated in the warm climatic region A with a mean annual temperature of 9.7 °C and mean annual precipitation of 580 mm (Petrovič a kol., 1968). The phytocoenoses were described and geobiocoenoses classified according to Zlatník (1976a, b) and Hančinský (1972). The plant taxa were determined and named according to Dostál (1989).

The series of six permanent research plots (PRP), each 50 × 50 m in area, was established in stands 131k (PRP I, II, III, VI), 131h (PRP IV) and 131d (PRP V) of introduced tree species in the year 1978. The trees on each PRP were marked with numbers. Since 1978, the PRP I to V were subjected to moderate crown thinning with positive selection and five-year interval, PRP VI has been left as control. The purpose of thinning is to regulate the development of the red oak – black walnut and black walnut – small-leaved linden mixed stands in such a way as to reach maximum in both wood mass and quality production. The used method is based on thinning of final-crop trees (Tokár, 1991a, b, 1992a, 1996, 1998, 2000), that means trees with appropriate qualitative (tree classes 1 and 2, stem and crown quality degrees 1 and 2) and quantitative parameters (thicker than the mean stand diameter $d_{1,3}$ and higher than mean stand height). The thinning schedule is in Table 1.

The stands on PRP were evaluated each 5 years (1978, 1983, 1988, 1993, 1998 and 2003) following the methods by Tokár (1982a, b, 1983, 1984, 1991a). The amount of above ground dendromass was determined with using the destructive method (Tokár, 1986a, b, 1987a, b, 1991b, 1992b). The necessary number of sample trees for analysis was determined based on stratified selection from the individual tree classes with an allowable error of 10% (Šmelko, 1963). In years 1978 and 1983 was selected 30 sample trees (owing to considerable variability of stem diameter $d_{1,3}$ in the tree classes), in years 1988, 1993, 1998 and 2003 only 15 sample trees. There was determined closeness of correlation between the dry weight dendromass determined at 105 °C and fresh leaf area on one side and the stem diameter $d_{1,3}$, tree height and crown length and width on the other. The closest relations were found to stem diameter $d_{1,3}$ and as most suitable function was second-degree parabola (Tokár, 1998). The dendromass stock was calculated from the smoothed values of dendromass and number of trees in the individual diameter classes. The area of three representative fresh leaf samples (3 × 100 leaves) taken from each tree species of stand was determined using a photo-planimeter EJKELKAMP. The leaf area of trees in diameter classes and stands was ascertained by means of conversion coefficient (kg m^{-2}) calculated from the average fresh leaves weight and area of sample trees.

The influence of thinning on development of standing volume and weight stock as well as on the total stand production (standing volume + thinning + mortality + other losses) was evaluated through growth index, periodic mean annual increment and total mean increment.

Table. 1. Thinning schedule realised on the PRP series Ivanka pri Nitre

PRP	Woody plant		Thinning				Age in		Thinning in	
			Intensity	Type	Method	Interval	1978	2003	1978	2003
	species	[%]					[years]		[chronology]	
I	Quercus rubra L.	20	Moderate	Crown	Positive selection	5-year	24	49	First	Sixth
	Juglans nigra L.	80					23	48		
II	Quercus rubra L.	100					24	49	First	Sixth
III	Quercus rubra L.	80					24	49	First	Sixth
	Juglans nigra L.	20					23	48		
IV	Juglans nigra L.	100					22	47	First	Sixth
V	Tilia cordata Mill.	80					17	42	First	Sixth
	Juglans nigra L.	20					21	46		
VI	Quercus rubra L.	80	Control plot				24	49	Without thinning	
	Juglans nigra L.	20					23	48		

Results

Geological and soil conditions

The series of permanent research plots is situated at an altitude of 150 m, on an alluvial floodplain of the Nitra river. In the lower part of the floodplain are late Tertiary gravel-sands covered in the Holocene by skeleton-less loamy flood sediments containing small amounts of carbonates.

The humus horizons are thick 6–8 cm, and they contain, in general 0.1–0.20%, very rarely even 0.45% of carbonates (PRP V). The content of carbonates in soils increases downwards on plots II, III and VI, while on plots I, IV and V it first moderately decreases up to the values of 0.05–0.10% (inside the layer 50–60 cm), and than it again increases in the lower layers of soil profile. The maximum amounts of carbonates (0.4–1.0%) were found at a depth of 100–110 cm (Bublinec, 2002; Bublinec and Janík, 1992).

The formed brown soils have features of both fluvisols and cambisols, and according to Collective (2000) they can be not unambiguously classified. The fact that their profile is dominated by browning horizons B containing small amounts of carbonates, allow us to classify them as Eutri-Cambic Fluvisols, on PRP V as Calcari-Cambic Fluvisols.

Actual reaction of fluvisols is ranging between 7.0 and 8.2. Neutral reaction was only found in the upper 0–60 cm layer of soils on PRP II and VI and in the 50–60 cm layer of soils on PRP III and V. The limit value of actual reaction 7.2 in the upper 0–5 cm soil layer differentiating the neutral and moderate alkaline soils and at the same time the heminitrophilous edaphic-trophic interorder (B/C) and calciphilous order (D) of geobiocoens (according to Kukla, 1993) was exceeded on PRP I, III, IV and V.

In the past, the soil surface on PRP was flooded episodically, these floods, however, were only short-lasting. The alluvial sediments show namely only very slightly signs of gleying, even at a depth of 100 cm. At present, these soils are not flooded any more or very rarely and for very short periods only. The ground water table is most part of year outside the main rhizosphere of forest stands. Its level depends on the water amount of the Nitra riverbed the flowage of which could be however partially changed owing to hydromelioration of the surrounding land and riverbed regulation. The extent to which these treatments have been reflected in changes of water regimen dynamics of PRP soils is not known, because the fluctuation of the Nitra river water level is not observed systematically.

The values of average moisture content in surface layer of these soils (up to a depth of 25 cm) range, according to Bublinec and Janík (1992) in the growing season from 18–20% without substantial differences between them. The highest soil water storage in the upper 25 cm soil layer was found on PRP V (496 m^3 ha^{-1}), the lowest on PRP I (457 m^3 ha^{-1}). The most favourable conditions for surface humus accumulation were found on control PRP VI (dry weight 15.7 t ha^{-1}), the lowest accumulation is on PRP V (dry weight 9.2 t ha^{-1}) where the dominant woody plant is small-leaved linden.

Phytocoenological and geobiocoenological conditions

Before the planting with the introduced tree species, the soil on PRP was tilled. Owing to succession processes that proceeded during their development have been formed the forest communities presented in Table 2.

After 42–49 years, the underwood in the stands of the introduced tree species was enriched with other 17 species, 7 of them (41%) shrubs, in a natural way. The most species – 15 (88%), have penetrated into the stand of red oak on PRP II and into the stand of black walnut and red oak on PRP I – 12 (71%), the least into the stand of black walnut and small-leaved linden on PRP V – 3 (18%), where the shadowing ability of small-leaved linden was markedly manifested. On PRP III were found 8 (47%) new woody plant species, on PRP IV there were 9 (53%) and on the control PRP VI the number of woody species was 10 (59%).

The black walnut regeneration was best on PRP I, III, IV and VI. Rarely it was found even on the most shadowed PRP V, together with sporadic present autochtonous species as *Acer campestre*, *Fraxinus excelsior*, *Tilia cordata* and *Tilia rubra*. Red oak begins with fructification in advanced age only, and at present, there is no regeneration of this tree species on the PRP series. From the autochthonous tree species, *Fraxinus angustifolia*, *subsp. danubialis* is abundantly present in undergrowth on almost all the studied plots (except PRP V), on the PRP I along with *Acer pseudoplatanus* and *Ulmus minor*, on the PRP II with *Acer pseudoplatanus, Tilia rubra* and *Acer campestre*, and on PRP III with *Acer pseudoplatanus* and *Tilia rubra*. From the shrubs are more abundant the species tolerating only short-term influence of floods, as *Sambucus nigra* (PRP I), *Swida sanquinea* (PRP I and IV) and *Euonymus europaeus* (PRP III). The abundance of the other shrub species is low.

The herb layer of the PRP stands comprises populations of 56 species, including 13 (23%) grasses and grass-like species. The most herb species were found on plots PRP IV – 36 (64%), the least on plots PRP V and VI – 18 (32%). The total number of species on PRP I was 33 (59%), on PRP II 9 (52%) and on PRP III 26 (46%). The highest proportion of grasses and grass-like species to the other herbs was found on PRP V (80%), substantially lower it was on control PRP VI (29%) and on PRP I (27%), and the lowest values were found on PRP IV (24%), PRP III (23%) and PRP II (21%).

Table 2. Geobiocoenological characteristics of the PRP series Ivanka pri Nitre

Permanent research plot		I	II	III	IV	V	VI
Silvicultural intervention		Moderate crown thinning with positive selection and 5-year interval					Control
Date of releve		10. 8. 2004					
Altitude [m]		150					
Inclination [°]		0					
Forest vegetation tier		2. beech-oak					
Edaphic-hydric order		wetted					
Edaphic-trophic order		heminitrophilous B/C					
Group of forest types		*Ulmi-fraxineta carpini superiora pannonica*					
Forest type		954 – Dry elm-ash stand with hornbeam; *Brachypodium sylvaticum*, *Rubus caesius, Convallaria majalis,* (*Dactylis glomerata subsp. polygama*)					
Parent rock		Alluvial sediments					
Soil	Variety	Eutri-				Calcari-	Eutri-
	Subtype	Cambic					
	Type	Fluvisol					
Stocking		$0.8^{0,6}$	0.7–0.9	0.8–0.9	0.6	0.9	$0.9^{0,8}$
Canopy [%]		80^{70}	80	80–90	70	90–100	90

Woody species complex						
Taxon	Cover [%]					
1 *Acer pseudoplatanus*	–	+				
Juglans nigra	60		40	90	60	40
Quercus rubra	20	70	20–30			30
2 *Juglans nigra*				10		
Quercus rubra	20–30	30	30–40			30
Tilia cordata					40	
4 *Acer campestre*		–	+	+		
Acer pseudoplatanus	+–5	–				
Fraxinus angustifolia	+–5	–		5–10		
Juglans nigra	+			5		
Quercus cerris				+		
Quercus rubra	10–20	+	5–10			10–20
Tilia cordata					+	
Ulmus minor	+–5	–		+		
Corylus avellana	+	+				+
Euonymus europaeus	+					
Prunus spinosa				+		
Sambucus nigra	$+–5^{30}$			+		
Staphylea pinnata		–				
Swida sanquinea	+			10–20		
5_{1a} *Acer campestre*	+	+ –5	+	+		+
Acer platanoides	+	+	+			
Acer pseudoplatanus	+	5–10	+–5			+
Cerasus avium						–
Fraxinus angustifolia	+	+–5		+		
Fraxinus excelsior	–	+				+

Table 2. Continued

Permanent research plot	I	II	III	IV	V	VI
Silvicultural intervention	Moderate crown thinning with positive selection and 5-year interval					Control
5_{1a} *Juglans nigra*	5–10^{30}	+	20–30	10–20	+	+
Quercus rubra	+	+	+–5			+
Tilia cordata					+	
Tilia rubra	+	+–5	+–5			+
Ulmus minor	+			+		
Corylus avellana	+					
Crataegus monogyna						–
Euonymus europaeus	+	+		+		
Prunus spinosa		+		+		
Sambucus nigra		–	+			
Swida sanquinea	+-5		-	+-5^{70}		
5_{1b} *Acer campestre*	+	+	+		+	+
Acer platanoides			+			
Acer pseudoplatanus		+	+			+
Cerasus avium						–
Fraxinus angustifolia		5–10	+–5		+	5–10$^{30–40}$
Juglans nigra	+–5	+–5	+–5	+–5	+	10–30
Quercus rubra	+–5	20	+			+
Quercus sp.	–			–		–
Tilia rubra	+	–	+		+	+
Ulmus minor		–				
Euonymus europaeus	+	+	+–5	+		+
Prunus spinosa		+				
Swida sanquinea		–		+^{10}		
5_2 *Tilia rubra*						+
Herbal complex						
Total cover [%]				80		
Grasses and grassy species [%]				+–5		
Other herb species [%]				75–80		
Taxon				Cover		
Brachypodium sylvaticum	–2$^{–3}$	+$^{+2}$	+	+$^{–3}$	+$^{–2}$	+ ÷1
Bromus benekenii		+1	–		+	
Bromus sterilis				0÷1$^{–3÷–4}$		
Carex acutiformis				+$^{+2}$		
Carex pilosa	0÷+$^{+2}$	0÷+3	0÷+3			+ ÷1$^{±2}$
Carex sylvatica	+	+	+	+	+ ÷1	+ ÷1$^{–2}$
Dactylis glomerata					+1	
Elymus caninus	+$^{+2}$	+		1÷–2^{+3}	+	
Melica uniflora					+$^{+2}$	
Milium effusum	+1			+^{1}	+ ÷1	
Poa nemoralis			+$^{–3}$	+$^{+2}$		
Vignea divulsa	+$^{+2}$		+			
Vignea muricata	+$^{–2}$				+	+
Ajuga reptans	–		+^{1}			
Alium scorodoprassum		–		+1 (dry)		

Table 2. Continued

Permanent research plot	I	II	III	IV	V	VI
Silvicultural intervention	Moderate crown thinning with positive selection and 5-year interval					Control
Alliaria petiolata	1	$+ \div 1^{-2}$	$+ \div 1^{+2}$	$+ \div 1^{-2}$		1^{+2}
Arctium sp.				+		
Campanula trachelium		–				
Chenopodium polyspermum				–		
Circaea lutetiana	–2	1÷–2	$1 \div -2^{+2}$	-2^{+3}		+ ÷1
Clematis vitalba	$+^{+3}$					
Convallaria majalis	$+^{+2}$	$1 \div -2^{-3}$	$+ \div 1^{+3}$		+–2	$+^{+2}$
Cucubalus baccifer	+			$+^{+2}$		
Epilobium montanum				–		
Fallopia dumetorum	+	+				
Galeopsis pubescens				–		
Galium aparine	$+ \div 1^{+2}$	1^{+2}		$\pm 2^{+3}$	$+^{1}$	
Geranium robertianum	±2			$1 \div -2^{+4}$		$1 \div +3^{+4}$
Geum urbanum				–		
Glechoma hederacea	$1 \div -2^{-3}$	$+ \div 1^{+2}$	$1 \div -2^{+3}$	$+ \div 1^{+2}$	+	$-2^{+3 \div +4}$
Hedera helix	$1 \div -2^{+4}$	$1 \div -2^{+3}$	$+^{+3}$		$+^{+4}$	$+^{+4}$
Heracleum sphondylium	–			+		
Humulus lupulus				+		
Impatiens parviflora	+	–	–			
Lactuca seriola				+		
Lamium maculatum	$\pm 2^{+3}$	±2	1÷–2	$+2^{+4}$	$1 \div -2^{-3}$	$1 \div -2^{+3}$
Lapsana communis	–			+		
Lysimachia nummularia		$+^{+2}$	$+^{+2}$			
Melandrium album	–					
Mercurialis perennis	$1 \div \pm 2^{+4}$	$1 \div +2^{+3}$	$1 \div \pm 2^{+3}$	$+2^{-5}$	$-2^{\pm 3}$	$1 \div -2^{\pm 3}$
Polygonatum latifolium			$+^{\pm 3}$			
Polygonatum multiflorum	+	+	+	$+^{-2}$	+	+
Pulmonaria obscura	1^{+2}	1	1	+ ÷1	$1 \div -2^{+2}$	$1 \div -2^{+2}$
Pulmonaria officinalis	1	+ ÷1	+	1^{-2}		
Rubus caesius	1^{+2}	+ ÷1	1÷–2	$1 \div -2^{+2}$		+ ÷1
Rubus idaeus				$+^{1}$		
Rumex sanquineus	+	+		–		
Solanum dulcamara		–				
Solanum nigrum				–		
Stachys sylvatica	$+ \div 1^{-2}$	$+^{-2} \div 1$	$+^{-2}$	1^{+3}		
Stellaria media	$+-^{3 \div +4}$					
Torilis japonica		–	+	$+ \div 1^{+2}$		
Urtica kioviensis	$-2^{-3 \div -4}$	$+^{+2}$	$+^{-2}$	$+^{+2}$		$+^{-2}$
Veronica chamaedrys						$+^{+2}$
Viola hirta	+	$+^{+2}$	+	+	+	$+^{-2}$
Viola reichenbachiana		+ ÷1	+ ÷1		$+^{1}$	

The basis of herb layer create abundant to dominant heminitrophilous to nitrophilous species as *Glechoma hederacea, Lamium maculatum, Mercurialis perennis* and, with exception of PRP V, also *Alliaria petiolata* and gradational *species Urtica kioviensis.* Additional species indicating increased amounts of plant accessible soil nitrogen is *Geranium robertianum* – the species abundant to dominant occurring on PRP I, IV and V, *Galium aparine* – abundant on PRP I, II, IV and *Elymus caninus* – sporadic to abundant present on PRP I, II, IV and V.

From mesotrophic species on PRP I, and II is abundant the lignifying liana *Hedera helix* and on PRP II and III *Convallaria majalis*. On the other plots, except of PRP IV, the gradation of these two species was observed. Sporadic to abundant is also the occurrence of mesotrophic to neutrophilous species *Brachypodium sylvaticum*, *Pulmonaria officinalis*, *Pulmonaria obscura* and *Rubus caesius*, as well as mesotrophic species *Circaea lutetiana*. The last two species and the sporadic to abundant occurring species *Elymus caninus, Milium effusum* and *Carex acutiformis* point out, at the same time, the moister soil environment, corresponding, sensu Zlatník et al. (1970) approximately to the 3th forest vegetation tier.

The above-discussed facts show evident that the water regime of PRP series was not substantially disturbed by hydromeliorative treatment of surrounding agricultural land and of the Nitra riverbed regulation, and the studied geobiocoenoses may be still regarded as component of the wetted edaphic-hydric order of geobiocoens. The strong dominance of heminitrophilous to nitrophilous species point out high content of for-plants-accessible nitrogen, presence of the nitrophilous edaphic-trophic order and, according to the more recent classification by Zlatník (1976a, b) also presence of group of types of geobiocoens Ulmi-fraxineta carpini superiora. Following Hančinský (1972), the geobiocoenoses in which the PRP series was established can be classified to the wet set and nitrophilous order of geobiocoens, group of forest types Ulmeto-Fraxinetum carpineum and forest type 954 – Dry elm-ash forest with hornbeam, with combination of the species *Brachypodium sylvaticum, Rubus caesius, Convallaria majalis, (Dactylis glomerata subsp. polygama)*.

Development of volume and weight stock of above ground dendromass of stands

In 2003, the highest volume stock of above ground dendromass (686.81 m^3 ha^{-1}) and the highest mean periodical volume increment (20.58 m^3 ha^{-1} year^{-1}) of stand, were reached on the control PRP VI. The highest growth index value (414.30%) was obtained in the tended mixed stand of black walnut and small-leaved linden. In this stand type, there was also found the highest increment percent (12.57%), which is by 5.36% higher compared to the control PRP VI (Table 3).

The highest weight stock of above ground dendromass (486.50 t ha^{-1}) and the highest mean periodical weight increment of stand (14.18 t ha^{-1} year^{-1}) was also found in the control PRP VI. The highest growth index of the weight stock (526.85%) was reached in the mixed stand of red oak (20%) and black walnut (80%) on PRP I. In this stand was also found the highest increment per-cent (17.07%), in comparison with PRP VI higher by 58.97% (Table 4).

Development of total volume and weight production of above ground dendromass of stands

In 2003, the highest total volume production (791.70 m^3 ha^{-1}) and the highest total periodical increment (16.29 m^3 ha^{-1} year^{-1}) were found on the control PRP VI (Table 3). The total volume production of the tended stands was lower from 11.08% (PRP III) to 21.67% (PRP I).

The highest total weight production of above ground dendromass (561.59 t ha^{-1}) and the highest total mean weight increment (11.54 t ha^{-1} year^{-1}) of stand were also reached on the control PRP VI (Table 4). The total weight production of tended stands was lower from 12.22% (PRP III) to 29.29% (PRP V).

Development of abundance and production of final-crop trees

In 2003, the highest number of final-crop trees was found on PRP V (823 pcs ha^{-1}, from which 470 pcs ha^{-1} was black walnut), the lowest on PRP I (200 pcs ha^{-1}, from which 160 pcs ha^{-1} was black walnut). The highest volume stock of final-crop trees was found on PRP VI (299.57 m^3 ha^{-1}), and the highest weight stock was on PRP I (230.98 t ha^{-1}). The mean periodical volume increment reached maximum on PRP III (11.27 m^3 ha^{-1} year^{-1}) and in comparison with control PRP VI was higher by 15.71% (Table 5). The highest mean periodical weight increment of above ground dendromass (10.68 t ha^{-1} year^{-1}) was found on PRP I, being by 39.79 % higher compared to the control.

The mean quality of final-crop tree stems of black walnut (1.14) in 2003 was higher in comparison with red oak (1.34). Owing to thinning the mean quality of red oak stems increased by 0.34 degree, and of black walnut stems by 0.28 degree. The values of leaf area index ranged between 0.30 ha a^{-1} (PRP IV) and 1.35 ha a^{-1} (PRP V).

Discussion

The forest stands composed of red oak and black walnut require an appropriate thinning schedule founded on relevant data on stand structure, development and quality, with the aim to control appropriately the

Table 3. Development of above ground volume production of different stand types on series of PRP Ivanka pri Nitre

Permanent research plot	Woody plant		Age in 1978	Stock in 1978 after thinning	Stock in 2003 before thinning	Growth index of stock	Mean periodical increment (MPI)		Growth index (MPI to PRP VI)	Age of woody species in 2003	Total volume production to Dec. 31, 2003	Total mean increment (TMI)	Growth index (TMI to PRP VI)
	species	[%]	[years]	[m^3 ha^{-1}]	[m^3 ha^{-1}]	[%]	[m^3 ha^{-1} $year^{-1}$]	[%]	[%]	[years]	[m^3 ha^{-1}]	[m^3 ha^{-1} $year^{-1}$]	[%]
I	*Quercus rubra* L.	20	24	20.14	32.40	160.87	0.49	2.43		49	61.21	1.25	
	Juglans nigra L.	80	23	89.97	401.84	446.64	12.47	13.86		48	552.30	11.51	
	Total	100		110.11	434.24	394.37	12.96	11.77	98.66		613.51	12.76	78.33
II	*Quercus rubra* L.	100	24	154.79	437.84	282.86	11.32	7.31	61.27	49	662.08	13.51	82.93
III	*Quercus rubra* L.	80	24	112.70	304.20	269.92	7.66	6.80		49	460.43	9.40	
	Juglans nigra L.	20	23	38.25	174.67	456.65	5.46	14.27		48	242.35	5.05	
	Total	100		150.95	478.87	317.24	13.12	8.69	72.84		702.78	14.45	88.92
IV	*Juglans nigra* L.	100	22	147.58	430.39	291.63	11.31	7.66	64.21	47	629.62	13.40	82.26
V	*Tilia cordata* Mill.	80	17	26.82	131.76	491.27	4.20	15.65		42	180.16	4.29	
	Juglans nigra L.	20	21	93.96	368.63	392.33	10.99	11.69		46	406.57	8.84	
	Total	100		120.78	500.39	414.30	15.19	12.57	105.36		586.73	13.13	80.60
VI (Control)	*Quercus rubra* L.	80	24	120.30	425.96	354.08	12.23	10.16		49	504.65	10.30	
	Juglans nigra L.	20	23	52.12	260.85	500.48	8.35	16.02		48	287.05	5.98	
	Total	100		172.42	686.81	398.33	20.58	11.93	100.00		791.70	16.29	100.00

Table 4. Development of above ground weight production of different stand types on series of PRP Ivanka pri Nitre

Permanent research plot	Woody plant		Age in 1978	Stock in		Growth index of stock	Mean periodical increment (MPI)		Growth index (MPI to PRP VI)	Age of woody species in 2003	Total weight production to Dec. 31, 2003	Total mean increment (TMI)	Growth index (TMI to PRP VI)
				1978 after thinning	2003 before thinning								
	species	[%]	[years]	[t ha^{-1}]		[%]	[t ha^{-1} year^{-1}]	[%]	[%]	[years]	[t ha^{-1}]	[t ha^{-1} year^{-1}]	[%]
I	*Quercus rubra* L.	20	24	15.17	24.39	160.78	0.35	2.31		49	47.56	0.87	
	Juglans nigra L.	80	23	54.52	342.77	628.70	11.53	21.15		48	421.00	8.77	
	Total	100		69.69	367.16	526.85	11.90	17.07	158.97		468.56	9.64	83.53
II	*Quercus rubra* L.	100	24	124.17	263.40	212.13	5.56	4.48	41.76	49	409.59	8.36	72.35
III	*Quercus rubra* L.	80	24	97.95	215.75	220.26	4.71	4.81		49	330.95	6.75	
	Juglans nigra L.	20	23	25.00	125.36	501.44	4.01	16.00		48	162.06	3.38	
	Total	100		122.95	341.11	277.44	8.72	7.09	66.04		493.01	10.13	87.78
IV	*Juglans nigra* L.	100	22	83.47	319.73	383.05	9.45	11.32	105.42	47	416.37	8.86	76.78
V	*Tilia cordata* Mill.	80	17	22.86	55.92	244.62	1.32	5.78		42	85.59	2.04	
	Juglans nigra L.	20	21	67.29	257.86	303.21	7.62	11.32		46	281.37	6.12	
	Total	100		90.15	313.78	348.06	8.94	9.92	92.36		366.96	8.16	70.71
VI (Control)	*Quercus rubra* L.	80	24	108.17	292.89	270.77	7.39	6.83		49	355.44	7.25	
	Juglans nigra L.	20	23	23.87	193.61	811.10	6.79	28.44		48	206.15	4.29	
	Total	100		132.04	486.50	368.45	14.18	10.74	100.00		561.59	11.54	100.00

Table 5. Development of above ground production of final-crop trees and index of leaf area in stand types on series of PRP Ivanka pri Nitre

Permanent research plot	Woody plant (stand type)	Number of final-crop trees in 2003	Stock in 1983 (after intervention)		Stock in 2003 (before intervention)		Mean periodical increment (PPP)		Growth index (PPP to TVP VI)		Index of leaf area in 2003
		[ps ha⁻¹]	[m³ ha⁻¹]	[t ha⁻¹]	[m³ ha⁻¹]	[t ha⁻¹]	[m³ ha⁻¹]	[t ha⁻¹]	[%]		[ha ha⁻¹]
	Quercus rubra L.	40	7.43	2.79	27.84	22.23	1.02	0.97			0.16
I	*Juglans nigra* L.	160	18.81	14.62	205.76	208.75	9.35	9.71			0.21
	Total	200	26.24	17.41	233.60	230.98	10.97	10.68	106.47	139.79	0.37
II	*Quercus rubra* L.	328	25.80	16.03	171.84	109.25	7.30	4.66	74.95	60.99	1.04
	Quercus rubra L.	260	24.11	19.99	154.53	107.22	6.52	4.36			0.91
III	*Juglans nigra* L.	120	23.81	18.67	118.87	54.11	4.75	1.77			0.13
	Total	380	47.93	38.66	273.40	161.33	11.27	6.13	115.71	80.23	1.04
IV	*Juglans nigra* L.	255	33.69	27.77	226.69	169.93	9.65	7.11	99.07	93.06	0.30
	Tilia cordata Mill.	353	19.04	13.17	41.96	25.76	1.15	0.63			0.87
V	*Juglans nigra* L.	470	79.84	52.34	185.88	131.04	5.30	3.93			0.48
	Total	823	98.92	65.51	227.84	156.80	6.45	4.56	66.22	59.68	1.35
VI	*Quercus rubra* L.	255	53.55	34.97	116.81	82.76	3.16	2.39			0.80
(Control)	*Juglans nigra* L.	191	51.07	35.52	182.76	140.64	6.58	5.25			0.23
	Total	446	104.62	70.49	299.57	223.40	9.74	7.64	100.00	100.00	1.03

relation between the dendromass production quantity and quality (Tokár, 1982a, b, 1991a, b, 1992a, b, 1993, 1996, 1998). For pure red oak stands, some authors (Réh, 1989, 1997; Štefančík, 1992) recommend strong thinning, because this method does not reduce the tree quality and it results in sooner reaching of the required assortment. According to Mittscherlich (1957) and Tokár (1991a, b, 1998) the first and second thinning should be moderate and the intensity of the following ones should be increased.

In conditions of floodplain forests, highly productive are also mixed stands of red oak and black walnut and mixed stands of black walnut and small-leaved linden (Fig 1). In these stands, the best growth, the highest production and the highest stem quality reaches the black walnut. For these stand types is recommended moderate crown thinning, with positive selection, repeated each five years, founded on selection and permanent marking of final-crop trees (Tokár, 1996, 1998). Final-crop trees are considered trees with bigger diameter and height than the stand mean diameter and height, having stem and crown quality corresponding to the first and the second quality degree. Their number should range between 250–300 pcs ha^{-1} (Tokár 1991a, b, 1992a, b, 1993, 1994a, b 1996, 1998).

Fig 1. Mixed stand of *Juglans nigra* L. and *Tilia cordata* Mill.

The obtained results show that the thinning most influenced growth characteristics of the mixed stand consisting of black walnut and small-leaved linden (PRP V) and the mixed stand consisting of black walnut and red oak in which the walnut representation was 80%. The highest weight stock of the above ground dendromass was reached in the tended mixed stand of black walnut (80%) and red oak (20%) on PRP I. Positive results were also reached in the pure black walnut stand on PRP IV (Fig 2). The volume stock of stands growing on the other PRP was lower compared with the control PRP, but the production quality was higher. The total volume and weight production of above ground dendromass in tended stands was also lower than on the control PRP VI.

Fig 2. Pure stand of *Juglans nigra* L.

The data on amount of chemical elements accumulated in soil and in above ground dendromass of various stand types of red oak and black walnut was processed by Tokár, (1992c, 1994c). The author identified certain relations between the content of elements in above ground dendromass and the stand type. The highest contents (kg ha^{-1}) of Mg (570), Ca (2,625) and K (1,053) were found in the above ground dendromass of the pure black walnut stand, of Na (543), Pb (1) and Fe (63) in the mixed stand of black walnut and small-leaved linden. The maximum content of Zn (52) was found in mixed stand of red oak and black walnut.

The amount of Ca, K, Mg, Na and Zn accumulated on PRP series Ivanka pri Nitre was higher, that of Pb and Fe lower compared with on PRP series Sikenica. The content of elements found in soils on PRP series Ivanka pri Nitre was also higher. On both PRP series, however, was rather high content of Ca found not only in dendromass but also in the soil. The reason of this phenomenon have not been recognised yet.

In orchard management the red oak and black walnut are utilised in park and street plantations. They have both high aesthetical qualities (leaf colour and shape, flowers and fruits) and phytoncide effects. Black walnut can be with success used also in planting of greenery around big fattening stations (stables).

Conclusions

In paper is evaluated the influence of moderate crown thinning on development of phytocoenoses and above ground dendromass of red oak (*Quercus rubra* L.) and black walnut (*Juglans nigra* L.) stands planted on the PRP series Ivanka pri Nitre.

At the stand age of 48 years, the highest stock of above ground dendromass was reached in the mixed stand of black walnut (20%) and small-leaved linden (80%) and in the mixed stand of black walnut (80%) and red oak (20%). Oak and linden create the medium and lower stand layer, which has favourable influence on stem quality and height growth of black walnut. Linden trees produce abundant litter that is rapidly decomposed and enriches the soil with nutrients profitable for the growth of black walnut.

In the stands of the introduced tree species naturally penetrated other 17 autochtonous species, 7 of them (41%) shrubs. In the herb layer consisting of 56 herb species, were present abundant indicators of the wetted edaphic-hydric order of geobiocoens, manifesting that the water regimen of the soils has not been disturbed substantially, either by hydromeliorative treatment of surrounding agricultural land or of the Nitra riverbed regulation.

The strong dominance of heminitrophilous to nitrophilous species indicates the presence of the nitrophilous edaphic-trophic order of geobiocoens, group of forest types Ulmeto-Fraxinetum carpineum (Ulmi-fraxineta carpini superiora) and forest type 954 Dry elm-ash forest with hornbeam.

The two introduced woody plants on the PRP series Ivanka pri Nitre fructify intensively. Their seeds can be used as in forest management as in planting of greenery of urban areas (street and park plantings) and farm buildings (stores, animal husbandry buildings) in warmer regions of South Slovakia.

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Vývoj fytocenóz a nadzemnej produkcie duba červeného (*Quercus rubra* L.) a orecha čierneho (*Juglans nigra* L.) na sérii TVP Ivanka pri Nitre

Súhrn

V práci sa hodnotí vplyv miernych úrovňových prebierok na vývoj fytocenóz a nadzemnej dendromasy porastov introdukovaných drevín *Quercus rubra* L. a *Juglans nigra* L. Za viac ako 40 rokov preniklo do pestovaných porastov 17 autochtónnych druhov drevín, z toho 7 (41 %) druhov krov. Vo fytocenózach tvorených 56 druhmi bylín sa hojne vyskytujú indikátori zamokreného edaficko-hydrického radu geobiocénov, ktoré dokazujú, že vodný režim pôd nebol hydromelioračnými úpravami pozemkov a toku rieky Nitra podstatne narušený. Geobiocenózy, v ktorých bola séria trvalých výskumných plôch založená, sú súčasťou nitrofilného radu, skupiny lesných typov Ulmeto-Fraxinetum carpineum a lesného typu 954 Suchá brestová jasenina s hrabom. Najvyššia zásoba nadzemnej dendromasy (686,81 $m^3 ha^{-1}$, 486,50 t ha^{-1}) a najvyšší priemerný periodický prírastok (20,58 $m^3 ha^{-1} rok^{-1}$, 14,18 t $ha^{-1} rok^{-1}$) sa dosiahol v 48 ročnom nevychovávanom poraste (orech čierny 80 %, dub červený 20 %), zatiaľ čo najvyšší index rastu objemovej zásoby (414,30 %) a najvyššie percento priemerného periodického prírastku (12,57 %) sa zistili vo vychovávanom poraste orecha čierneho (20 %) a lipy malolistej (80 %). Najvyšší index rastu hmotnostnej zásoby (526,85 %) a najvyššie prírastkové percento (17,07 %) sa zistilo v zmiešanom poraste orecha čierneho (80 %) a duba červeného (20 %). Najvyššia objemová zásoba nádejných stromov sa tiež zistila v nevychovávanom poraste (299,57 $m^3 ha^{-1}$), kým najvyšší priemerný periodický prírastok (11,27 $m^3 ha^{-1} rok^{-1}$) bol vo vychovávanom poraste duba červeného (80 %) a orecha čierneho (20 %). Najvyššia hmotnostná zásoba nádejných stromov (230,98 t ha^{-1}) a najvyšší hmotnostný priemerný periodický prírastok (10,68 t $ha^{-1} rok^{-1}$) boli zistené v zmiešanom poraste orecha čierneho (80 %) a duba červeného (20 %).

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