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EFFECTS OF THINNING ON GROWTH AND PRODUCTIVITY OF PURE AND MIXED EUROPEAN CHESTNUT STANDS

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Abstract:
The effects of stand types and different thinning options on productivity and bio-ecological indices have been analysed in both thinned and nonthinned plots of mixed and pure chestnut stands of seed origin at the age of 33 and 41 years respectively. Experimental plots were established in mixed (*Castanea sativa* with *Tilia cordata* and *C. sativa* with *Pinus sylvestris*) and pure stands at the Horné Lefantovce site; investigations were also carried out in pure chestnut stands under different thinning options at the Žirany site. Both sites are located in southwest of Slovakia. The highest productivity in the stands at Horné Lefantovce was shown by both nonthinned and thinned mixed *Castanea sativa* stands with *Tilia cordata* (volume 315,5 m^3 ha^{-1} and 265,7 m^3 ha^{-1} respectively and biomass 161,8 Mg ha^{-1} and 147,7 Mg ha^{-1} respectively) and the highest LAI was observed in mixed stands *Castanea sativa* and *Pinus sylvestris* (9,03 m^2 m^{-2} and 7,71 m^2 $m^{-2)}$. At the Žirany site, the best production characteristics (volume 618,0 m^3 ha^{-1} and biomass 342,6 Mg $ha^{-1)}$ were observed in a plot thinned with medium heavy intensity, 10 years frequency and the first intervention at age 18.

Key words: *Castanea sativa, chestnut forest,* pure stands, mixed stands, thinning, thinning options, productivity, leaf area index, Slovakia

VPLIV REDČENJ NA RAST IN PRODUKTIVNOST ČISTIH TER MEŠANIH SESTOJEV PRAVEGA KOSTANJA

Izvleček:
Na redčenih in neredčenih ploskvah smo proučevali vpliv sestojnega tipa in različnih načinov redčenja na produktivnost ter bioekološke značilnosti sestojev pravega kostanja, starih 33 oziroma 41 let. Poskusne ploskve so bile postavljene v mešanih (Castanea sativa in Tilia cordata oziroma Castanea sativa in Pinus sylvestris) ter čistih sestojih v kraju Horné Lefantovce; raziskave so potekale tudi v čistih sestojih kostanja v kraju Žirany, kjer se je izvajal drugačen način redčenja. Oba kraja ležita v jugozahodnem delu Slovaške. V sestojih na lokaciji Horné Lefantovce smo ugotovili največjo produktivnost v neredčenih (lesna zaloga: 315,5 m^3/ha; biomasa:161,8 Mg/ha) in redčenih (265,7 m^3/ha in 147,7 Mg/ha) mešanih sestojih kostanja in lipovca. Največji indeks listne površine smo izmerili v mešanih sestojih kostanja in rdečega bora (9,03 m^2/m^2 oziroma 7,71 m^2/m^2). V Žiranih smo najboljšo produktivnost (lesna zaloga: 618,0 m^3/ha; biomasa: 342,6 Mg/ha) ugotovili na ploskvi, kjer so bila opravljena srednje močna redčenja, in sicer prvič pri starosti sestoja 18 let ter s ponovitvami na vsakih 10 let.

Ključne besede: *Castanea sativa, kostanjev gozd, čisti sestoj, mešani sestoj, redčenje, način redčenja, produktivnost, indeks listne površine, Slovaška*

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VSEBINA

1 INTRODUCTION
UVOD

Slovakia represents the northernmost limit of chestnut distribution in central Europe. Chestnut grows mainly in the southern part of the country, in hilly regions with a more favourable and warmer climate. Based on accepted historical understanding, three main introductory waves of chestnut to Slovakia, in three distinct periods, have been assumed. They span from the period of the Roman invasion through introduction conducted in the 13th century until the period of Turkish invasions in the 16th and 17th centuries. Three introductions are in accord with three different regions/centers where at present old chestnut stands and/or orchards are in majority descendants of the originally introduced specimens. Cultivation of chestnut for fruit production prevails, but the total area of chestnut orchards, in majority composed of old trees of seed origin, is only about 130 ha including some 30 ha of relatively young chestnut plantations established 30 to 40 years ago. At that time, the more intensive exploitation of chestnut in forestry also begun by establishing plantations of different size (from 1 to 20 ha) situated within indigenous forest stands or in open land. Young chestnut stands, at ages up to 20 years, represent the largest proportion of chestnut forest area in our country (about 75% of total 1,400 ha). This increased interest in chestnut resulted from favourable ecological-production characteristics observed in this species in the area of its distribution in Slovakia (high growth increment, good wood properties, intensive decomposition of litter, favourable influence on accompanying tree species, good natural regeneration). Simultaneously with chestnut plantations for forest purposes, several experimental plots in pure and mixed chestnut stands were also established to study the effect of thinning and admixed woody species on stand characteristics and some bio-ecological indices. The first results indicated rather good growth and production characteristics of young pure and also mixed chestnut stands (TOKÁR 1985, 1990, 1992, 1994, 1999) although mixed chestnut stands are very rare and not of high production value in the main areas of chestnut distribution in Europe.

The main goal of this work is to deepen the present knowledge of the effect of crown thinning on growth, timber production and leaf area index in different stand types of European chestnut and, on the basis of this knowledge, to outline strategies for sustainable management of this species in Slovakia.

2 MATERIAL AND METHODS
MATERIAL IN METODE

The study was carried out in two experimental areas where both pure and mixed chestnut stands were artificially established by seedlings. Both areas belong to an oak forest vegetation belt of the forest type group *Carpineto-Quercetum.*

The first study area, called Castanetarium Lefantovce, is situated near the village Horne Lefantovce, about 20 km north of Nitra (48°27'N, 18°10'E) at the foothill of the Tríbeč mountains. It covers an area of 14,27 ha with a SW aspect and an altitude of 250 m a.s.l. The climate is warm continental; the average annual rainfall and temperature are 560 mm and 9,7°C. The soil is brown podzolic. During 1961 and 1962 one experimental plot with pure chestnut and three mixed plots with *Quercus petraea* (Mattusch.) Lieb., *Tilia cordata* Mill.. and *Pinus silvestris* L. were established by planting one-year-old seedlings of *Castanea sativa* Mill. and two-year-old seedlings of the other species. In mixed stands the chestnut alternated in rows with a spacing of 1 x 1 m. Since 1973, pure and mixed chestnut stands (at the age of 13 years), have been divided into two subplots, control and thinned, each of 0,06 ha in area. Crown thinnings of moderate intensity and a 5-year frequency were carried out to promote stems of best form and growth rate.

On all plots, dendrometrical parameters (number of stems living and dead, DBH, height) were surveyed before the thinning. The last measurement, processed for this work, was carried out at the age 35 years. Diameter at breast height (DBH) was measured on each tree using a metal calliper with an accuracy of 0,1 cm. According to the measured DBH values, the trees were classified into 4 classes: 1^{st} class – dominant trees, 2^{nd} class – co-dominant trees, 3^{rd} class – sub-dominant trees and the 4^{th} – class – suppressed trees. On each plot a transect was marked (5 rows of trees) where tree height was measured using a Blume-Leiss height-meter with accuracy of 0,5m. Based on the DBH values, the basal area of stands was calculated. Due to the absence of volume tables for chestnut, timber volume was calculated using the volume tables for oak (HALAJ 1963) with a subsequent conversion per one ha.

Aboveground biomass was determined using the destructive method of sampling trees. The total number of sample trees was separately determined for each tree species in each

type of stand according to ŠMELKO / WOLF (1977) with accuracy of 10%. Based on stratified selection, considering diameter variability in individual tree classes, approximately 15 trees were selected in the last inventory. The sample trees were distributed into diameter classes according to their percentage in diameter structure of the stand. In each sample, DBH, tree height, length and width of crown were measured. Stem, branches, annual-shoots, leaves (needles) were weighed separately on a KAMOR balance with a capacity of 50 kg and accuracy 0,01 kg. From each stand and each tree species, representative samples were taken from each crown third and annual shoots and leaves (needles) from each category of branch diameter. The samples were dried in the laboratory at 105°C and the dry mass of each sample was determined.

Leaf area index was calculated using direct measurements of leaf samples from the sample trees by EJKELKAMP photoplanimeter. During July and August from each tree species and each stand type, three representative samples (3 x 100 leaves) were collected and the transformation coefficient was calculated (weight of leaves in fresh state / leaf area in fresh state).

The second study area, Žirany, is situated at the foothill of the Tríbeč mountains at (48°25'N, 18°10'E) on a 5° slope with a southern aspect and an altitude of 200 m a.s.l. Climatic and soil characteristics are similar to those described in Horné Lefantovce. The stand (2,31 ha) was planted in the spring of 1956 with one-year-old chestnut seedlings of domestic provenience (Jelenec). Planting was in a triangular pattern with spacing of 1 x 1 m (between rows x within row). Before 1971, no silvicultural interventions were performed. In 1971, at the age of 13 years, seven plots were established in the stand to evaluate structure and productivity as well as to study the influence of crown thinning of various intensity and frequency on the quantitative and qualitative characteristics of the stand. In 1971 crown thinnings of two different intensities (moderate and medium-heavy) and different frequencies (5 and 10 years) were carried out, on five plots (I, II, III, IV, VII). On plot V, the first thinning with frequency 10 years was applied in 1976. During the last thinning, the basal area reduction was about 15% (moderate thinning) in two plots and 20% (slight-heavy thinning) in four plots. On all plots, dendrometrical, bio-ecological and structural surveys were undertaken similarly as in Horné Lefantovce at every five years from 18 to 41 years.

3 RESULTS
REZULTATI

3.1 PURE AND MIXED CHESTNUT STANDS IN HORNÉ LEFANTOVCE
ČISTI IN MEŠANI KOSTANJEVI SESTOJI NA LOKACIJI HORNÉ LEFANTOVCE

3.1.1 Stand characterisation
Značilnosti sestoja

In all pure and mixed stands, higher values of DBH and mean height were observed in thinned plots with the exception of the *C. sativa x T. cordata* mixed stand where mean height was higher than in the control plot (Table 1). On the other hand, basal area and volume were higher on control plots and the number of stems was lower on thinned plots. In the last thinning, in both pure and mixed stands, tree density was reduced by 17,9, 17,2 and 27,5%; in basal area by 11,6, 10,5 and 17,5%. However, in control pure and mixed stands, the number of stems was markedly reduced during the last five years by natural attrition (Figure 1). In pure chestnut stands, the mortality rate was 13,6% and in chestnut stands mixed with linden and pine, it was 17,8% and 24,1% respectively, not only because of the high natural attrition but also from damage caused by ink disease.

In mixed stands, the five-year increment of basal area and volume was higher in thinned than in control subplots but both indices were the highest in non-thinned pure stands (1,39 m^2 ha^{-1} yr^{-1} and 20,0 m^3 ha^{-1} yr^{-1}). The basal area removed in thinned plots after the last thinning had fully recovered during the previous five years and the value of basal area was slightly higher than five years ago. Among mixed plots, the highest volume increment was in a chestnut-linden mixture. However, the volume increment for linden was greater than the increment for chestnut, which was also true for pine mixed with chestnut. Regarding the social rank of trees, most chestnut trees belong to the co-dominant class. In mixed stands, pine trees mostly belong to the dominant class of trees and linden to the suppressed classed (control plot) or co-dominant trees (thinned plot).

Table 1: Stand characteristics and bio - ecological indices of control and thinned subplots in one pure and two mixed chestnut stands at 33 years in the Lefantovce experimental station. Mean annual increment (MAI) was calculated for last five years.

Preglednica 1: Lastnosti sestojev in bioekološki kazalniki na kontrolnih in redčenih ploskvah v čistem ter dveh mešanih kostanjevih sestojih (starost 33 let) na poskusni postaji Lefantovce; povprečni letni prirastek (MAI) je izračunan za obdobje zadnjih petih let.

Plot *Plo.*	Subplot *Delna ploskev*	Tree species *Drevesna vrsta*	Num. of Stems *Število dreves* N ha^{-1}	Mean DBH *Povprečni prsni premer* cm	Top height *Zgornja višina* m	Basal area *Temeljnica*		Volume *Lesna zaloga*		Biomass *Biomasa*		LAI	
						Total *Skupaj* m^2 ha^{-1}	MAI m^2 ha^{-1} per year	Total *Skupaj* m^3 ha^{-1}	MAI m^3 ha^{-1} per year	Total *Skupaj* t ha^{-1}	MAI t ha^{-1} per year	Total *Skupaj* ha ha^{-1}	MAI ha ha^{-1} per year
1	Control *Kontrola*	*C. sativa*	2.184	13,86	16,0	34,45	1,39	257,93	20,07	141,56	5,36	4,50	0,11
	Thinned *Redčeno*	*C. sativa*	1.684	14,76	16,9	29,6	0,83	217,19	5,02	121,37	1,02	3,87	0,23
2	Control *Kontrola*	*C. sativa*	1.290	14,05	17,7	21,11	0,46	163,65	9,13	87,50	1,91	2,80	0,03
		T. cordata	2.345	9,42	16,6	21,19	0,78	151,88	10,68	74,30	2,71	3,52	0,40
		Total / *Skupaj*	3.635	-	-	42,38	1,14	315,53	19,81	161,80	4,62	6,32	0,43
	Thinned *Redčeno*	*C. sativa*	975	16,84	15,8	22,94	0,80	145,56	2,86	99,70	2,31	2,96	0,10
		T. cordata	540	16,10	16,5	12,23	0,57	91,16	4,74	48,04	1,98	2,00	0,10
		Total / *Skupaj*	1.515	-	-	35,17	1,37	265,72	7,60	147,74	4,29	4,96	0,20
3	Control *Kontrola*	*C. sativa*	1.489	12,73	15,2	20,98	0,21	129,08	2,27	90,14	1,19	2,90	0,02
		P. sylvestris	588	18,62	16,6	16,93	0,83	124,88	7,60	78,16	6,65	6,13	0,40
		Total / *Skupaj*	2.077	-	-	37,91	1,04	253,96	9,87	168,30	7,84	9,03	0,42
	Thinned *Redčeno*	*C. sativa*	664	17,14	16,1	16	0,64	119,17	4,31	69,19	1,06	2,05	0,08
		P. sylvestris	423	21,28	16,7	15,48	0,94	115,55	7,80	70,04	3,89	5,66	0,35
		Total / *Skupaj*	1.087	-	-	31,48	1,58	234,72	12,11	139,23	4,95	7,71	0,43

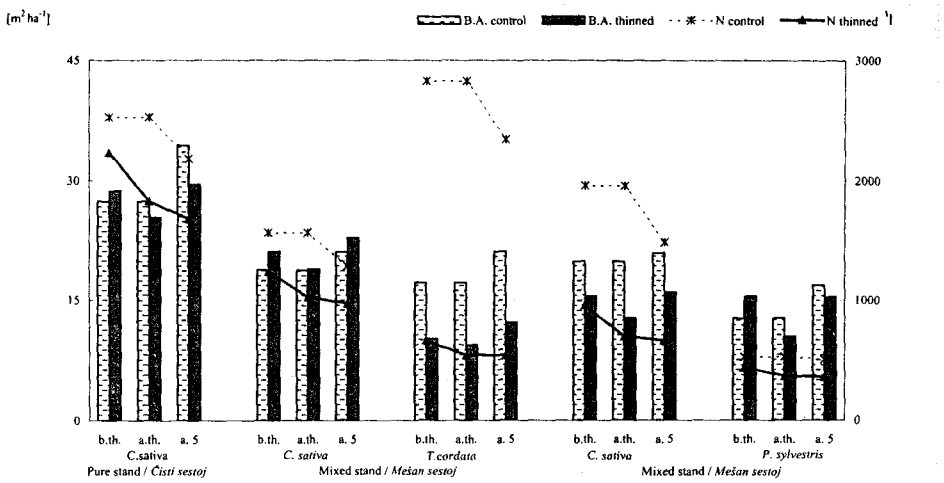

Figure1: Number of stems (N) and basal area (B.A.) on control and thinned plots before thinning (b.th.), after thinning (a.th.) and five years later (a.5), at age 33 years in pure and mixed chestnut stands.

Slika 1: Število dreves (N) in temeljnica (B.A.) na kontrolnih ter redčenih ploskvah pred redčenjem (b.th.), po redčenju (a.th.) in pet let kasneje (a.5); čisti in mešani kostanjevi sestoji; starost 33 let

3.1.2 Bio-ecological indices
Bioekološki indikatorji

In the mixed stands in both control (nonthinned) and thinned plots, the values of LAI as well as values of total aboveground tree biomass were higher than in pure chestnut stands (Table 1). The lowest LAI and the lowest amount of biomass (t ha $^{-1}$) were recorded in the thinned pure chestnut stand (3,87 ha ha $^{-1}$ and 121,37 t ha $^{-1}$) and the highest in the mixed control stand of chestnut and pine (9,03 ha ha $^{-1}$ and 168,30 t ha $^{-1}$). However, the 5-year increments of both biomass and LAI in the mixed stands were higher (Figure 2). The highest values were recorded in Scotch pine, both in control and in thinned plots, while the increments of little leaf linden were higher only in control plots due to a more consistent reduction of tree number during the last thinning of little leaf linden. The increment of LAI for chestnut grown in pure stands was higher than for chestnut in mixed stands. In mixed stands, the biomass increment for chestnut was highest in the mixture

with little leaf linden (2,71 t ha $^{-1}$ yr^{-1}) but among all plots, the highest biomass increment was in the control pure plot. Although in pure thinned plot the biomass increment was 5-times lower it has fully recovered the biomass which was removed in last thinning. This is true also for chestnut and mixed woody species in thinned mixed stands.

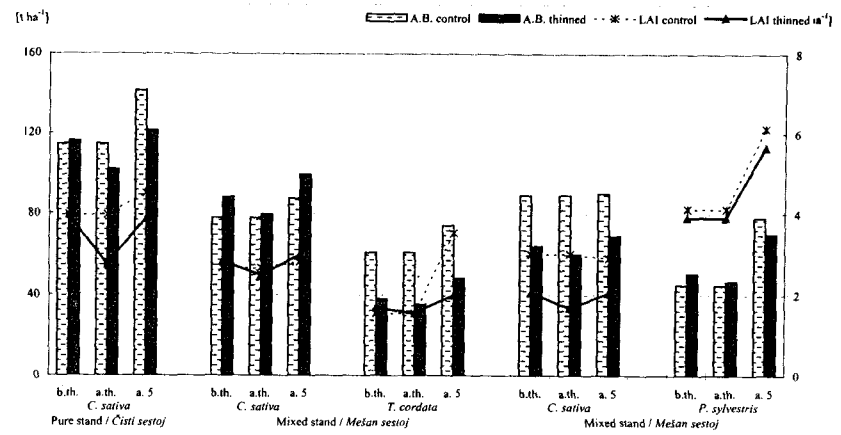

Figure 2: Aboveground biomass (A.B.) and leaf area index (LAI) on control and thinned plots before thinning (b.th.), after thinning (a.th.) and five years later (a.5), at age 33 in pure and mixed chestnut stands.

Slika 2: Nadzemna biomasa (A.B.) in indeks listne površine (LAI) na kontrolnih ter redčenih ploskvah pred redčenjem (b.th.), po redčenju (a.th.) in pet let kasneje (a.5); čisti in mešani kostanjevi sestoji; starost 33 let.

3.1.3 Pure chestnut stands under different thinning options in Žirany

Čisti kostanjevi sestoji z drugačnim načinom redčenja na lokaciji Žirany

Better growth and production characteristics were observed in the medium-heavy plots thinned with a frequency of 10 years and on control non-thinned plots than in plots moderately thinned with a frequency of 5 years (Table 2). However, mean annual increments of basal area, total volume and aboveground biomass were correlated with actual values of these characteristics on the studied plots. On plot V the actual values of all three characteristics as well as their increments were the highest among all seven plots. In this plot, only two interventions were undertaken before the last inventory while

three thinnings were carried out in plots II, IV and VII and five in plots I and II. Consequently, plot V showed the highest stem density among all tended plots. With decreasing stem density on tended plots, decreasing values of all three mentioned characteristics were observed. However, the untended control plot does not fit to this correlation, although with the highest stem density the values of basal area, volume and biomass levels are only the third compared with plot V. Hence, it was proved that the most suitable silvicultural treatment for pure chestnut stands in Slovakia is defined by medium-heavy thinning with a frequency of ten years and the first intervention at the age of about 18 years.

Table 2: Stand characteristics of pure chestnut stands at age 41 on the Žirany site on one control and six thinned plots subjected to different intensity and different frequency of thinning. Mean annual increment (MAI) calculated for last five years.

Preglednica 2: Lastnosti sestojev na kontrolni in šestih negovanih ploskvah, redčenih z različno pogostostjo in intenzivnostjo (čisti kostanjevi sestoji, starost 41 let, lokacija Žirany); povprečni letni prirastek (MAI) je izračunan za obdobje zadnjih petih let.

		Control plot *Kontrolna ploskev*	Thinned plots *Redčene ploskve*					
Thinning intensity *Intenzivnost redčenja*		-	Moderate / *Zmerno* (cca 10%)		Medium heavy / *Srednje-močno* (cca 20%)			
Thinning frequency (years) *Pogostost redčenja (let)*		-	5	10	5	10	10	10
Plot No. / *Št. ploskve*		VI	II	IV	I	III	V	VII
Number of stems (n ha^{-1}) *Število dreves (n ha^{-1})*		2.233	1.623	1.695	1.214	1.919	2.004	1.512
Mean DBH (cm) *Povprečni prsni premer (cm)*		17,04	18,0	19,0	20,8	19,6	18,9	20,0
Mean height (m) *Povprečna višina (m)*		19,3	18,6	18,7	19,0	19,2	20,1	19,9
Top height (m) *Zgornja višina (m)*		21,1	20,7	20,1	20,7	21,9	21,1	21,2
Basal area *Temeljnica*	Total / *Skupaj* m^2 ha^{-1}	56,07	45,32	50,15	42,72	62,90	64,84	49,20
	MAI m^2 ha^{-1}	1,65	3,24	2,55	3,04	2,78	4,69	1,39
Volume *Lesna zaloga*	Total / *Skupaj* m^2 ha^{-1}	551,8	432,9	485,0	424,4	618,0	658,1	495,8
	MAI m^2 ha^{-1}	16,86	35,08	29,23	26,22	31,20	42,03	21,95
Biomass *Biomasa*	Total / *Skupaj* m^2 ha^{-1}	305,6	236,6	272,0	239,9	342,6	358,7	269,9
	MAI m^2 ha^{-1}	11,13	18,56	16,69	16,9	17,5	28,88	10,82

4 DISCUSSION
RAZPRAVA

The results of the present work have proved that in Slovakia, European chestnut can be successfully grown for timber production not only in pure stands but also in mixed stands, especially with little leaf linden (*Tilia cordata*). Mean height and mean DBH in these mixed stands are in average higher than in pure chestnut stands. This is also true for other stand parameters (basal area, volume) and bio-ecological indices (biomass, leaf area index), which have reached higher values in both thinned and nonthinned mixed stands. However, if we want to preserve the original stand composition in mixed stands after full canopy cover development, the different competition behaviour between chestnut and other species requires promoting linden trees in chestnut stands mixed with linden; alternatively, in chestnut stands mixed with Scotch pine it is necessary to promote chestnut trees. While in mixed chestnut stands the most effective thinning resulted in being of moderate intensity and with a frequency of five years, in pure chestnut stands the best values of stand and production characteristics were observed in stands tended with medium heavy thinning (about 20% of basal area removed) with a frequency of ten years.

A comparison of our results with similar results reported elsewhere may be only relative because chestnut cultivation in artificially established plantations is rare in the optimal area of chestnut distribution in Europe. Most chestnut forests in this area are coppices where the traditional silvicultural system is characterised by a short rotation (11 to 18 yrs.). However, in recent decades, the prolongation of the rotations was promoted in order to produce high-quality timber by means of silvicultural treatment more suited to the new requirements of sustainability. This long rotation system (35 yrs. and more) is also applied in our chestnut plantations, However, in Italy, due to more favourable conditions for chestnut, growth is more vigorous and the stand characteristics of chestnut coppices show much higher and more uniform values than chestnut stands grown under similar characteristics in Slovakia. For instance, in thinned coppices in Monte Amiata (central Italy), at 35 years top height is about 21 m and mean DBH about 25 cm (AMORINI / BRUSCHINI / MANETTI 2000, CUTINI 2000). By comparison, in the Slovakian site thinned chestnut stands of similar age are characterised by a mean height of approximately 16 or 20 m and a DBH of 15 to 17 cm. As result, volume and biomass production in the assumed stands may vary from 217 m^3 ha^{-1} to 447 m^3 ha^{-1} and from 121

Mg ha^{-1} to 214 Mg ha^{-1}. The higher values of both parameters are similar to those reported for chestnut coppices of the same age grown in central Italy (volume 447 m^3 ha^{-1} and biomass 214 Mg ha^{-1}). In the best chestnut stands in Slovakia, the mean annual increments of volume and biomass are two to three times higher than in the previously mentioned Italian stands (CUTINI 2001). However, it must be considered that stem density in the Italian stands is two to three times lower than in Slovak stands.

On account of very good site conditions in chestnut coppices in south Europe (central Italy, northern Greece), heavy thinnings (removal of about one third of basal area) as early as the stand age of 11 to 13 years can be applied with good results on timber production as well as social structure and health condition of thinned stands (CUTINI 2000, ZAGAS 2000). However in aging chestnut coppices over 25 years old, situated in relatively dry sites in the south of the Alps (Ticino Canton), heavy thinning has not given positive results because stands were unable to replenish the loss of timber reserves by thinning (OTT / CONCEPRIO / PEDRINI 2000).

Similarly to volume stock and aboveground biomass, leaf area index (LAI) was also shown to be closely correlated with stem density. Both pure and mixed control stands (with little leaf linden and Scotch pine) at 33 years exhibited higher LAI than thinned plots, which had lower stem density. Higher LAI in control plots (5,3 m^2 m^{-2}) and lower LAI in thinned plots (4,7 m^2 m^{-2}) has been reported by CUTINI (2001) in chestnut coppices at 35 years. Although both LAI values are higher than respective ones observed in our experimental plots, the density of both control and thinned plots in central Italy was considerably lower (1.215 and 508 stems / ha, respectively) than in Slovak condition (2.184 and 1.684 stems / ha, respectively). Apparently, the good site conditions of central Italy chestnut show a better attitude to re-build homogenous canopy cover soon after a few years after heavy thinning (one third of basal area removal). Growth and increments in thinned plots were practically the same as in control plots: a consequence of consistently higher performances of released trees in thinned plots.

A close relation between LAI and stem density was also observed in the pure and mixed deciduous stands and/or coppices in central France (DUFRÊNE / BRÉDA 1995, LE DANTEC / DUFRÊNE / SAUGIER 2000). For instance the highest LAI (7,45 m^2 m^{-2}), based on direct estimates derived from litter collection, was observed in mixed stands of

Castanea sativa, Quercus petraea and *Tilia cordata* with a density 750 stems / ha and the lowest LAI (5,81 m^2 m^{-2}) in mixed stands of *Castanea sativa and Quercus petraea* with a density 395 stems / ha. However, young mixed chestnut coppices (24 years) with a density 2.856 stems/ha had a LAI of only 5,14 m^2 m^{-2}. Increasing LAI as well as production characteristics with age have also been observed in our experimental plots with chestnut. Ranking of the plots in LAI, volume and aboveground biomass observed during the inventory before the second thinning, was also maintained during the next inventories (TOKÁR 1998). In conditions of south Italy (Etna), it was also observed that aboveground biomass and all processes concerning productivity in chestnut coppices are closely related to the age and climatic conditions which differ according to the altitudinal location of the stands (LEONARDI *et al.* 1996).

5 POVZETEK

Na rast in proizvodne lastnosti kostanjevih sestojev (v starosti 33 oziroma 41 let), osnovanih s sadnjo sadik domačega porekla, sta vplivala tip sestoja in način redčenja. Indikatorji produktivnosti in rasti (zgornja višina, povprečen prsni premer, lesna zaloga) so bili največji v zmerno redčenih in neredčenih mešanih sestojih kostanja in lipovca. Povprečni temeljnični prirastek in lesna zaloga sta bila največja v neredčenih čistih kostanjevih sestojih, kar je najverjetneje rezultat velike gostote sestoja in velike stopnje smrtnosti (18 %); slednjo lahko upoštevamo kot nadomestilo za zmerno močno redčenje. V 41 let starih čistih sestojih, ki so bili podvrženi različnim načinom redčenja, sta bili najboljša rast in produktivnost ugotovljeni na ploskvah, kjer smo izvedli srednje-močno visoko redčenje, z začetkom pri starosti 18 let in ponovitvami na vsakih 10 let. V povprečju so imeli sestoji na lokaciji Žirany, ki rastejo v dobrih rastiščnih pogojih, boljšo produktivnost in rast kot sestoji na lokaciji Horné Lefantovce.

V mešanih sestojih, starih 33 let, smo tako na kontrolnih (neredčenih) kot na redčenih ploskvah ugotovili višje vrednosti indeksa listne površine in količine biomase kot v čistih kostanjevih sestojih. Najnižje vrednosti indeksa listne površine in količine biomase smo ugotovili v negovanih čistih kostanjevih sestojih, najvišje vrednosti pa na kontrolnih ploskvah v mešanih sestojih kostanja in rdečega bora. Medtem ko so primešane drevesne vrste v mešanih sestojih prispevale večji delež k indeksu listne površine, je delež teh vrst v količini biomase nižji ali enak, kot je delež kostanja (v redčenih mešanih sestojih kostanja

in rdečega bora). Rezultati kažejo na veliko rastno učinkovitost kostanja v mešanih sestojih.

6 REFERENCES
VIRI

AMORINI, E. / BRUSCHINI, S. / MANETTI, M. C., 2000. Alternative silvicultural systems in chestnut (*Chastanea sativa* Mill.) coppice: effects of silvicultural practices on stand structure and tree growth.- Ecol. Mediterran. 26, 1-2: 155-162.

CUTINI, A., 2000. Biomass, litterfall and productivity in chestnut coppices of various age at Monte Amiata (Central Italy).- Ecol. Mediterran. 26, 1-2: 33-41.

CUTINI, A., 2001. New management options in chestnut coppices: an evaluation on ecological bases.- Forest Ecol. Managem. 141: 165-174.

DUFRENE, E. / BRÉDA, N., 1995. Estimation of deciduous forest leaf area index using direct and indirect methods.- Oecologia 104: 156-162.

HALAJ, J., 1963. Tabuľky na určovanie hmoty a prírastku porastov.- Bratislava, SVPL, 37 s.

LE DANTEC, V. / DUFRÊNE, E. / SAUGIER, B., 2000. Inter-annual and spatial variation in maximum leaf area index of temperate deciduous stands.- Forest Ecol. Managem. 134: 71-81.

LEONARDI, S. / RAPP, M. / FAILLA, M. / GUARNACCIA, D., 1996. Biomasse, productivité et transferts de matiere organique dans une séquence altitudinale de peuplements de *Castanea sativa* Mill de l' Etna.- Ann. Sci. For. 53: 1031-1048.

OTT, E. / CONCEPRIO, F. / PEDRINI, A., 2000. Diradamenti di cedui castanili invecchiati – risultati di due parcelle sperimentali (1975-1997) a Novaggio, Ticino.- Schweiz. Z. Forstwes. 151: 43-56.

ŠMELKO, Š. / WOLF, J., 1977. Štatistické metódy v lesníctve.- Bratislava, Príroda, 330 s.

TOKÁR, F., 1985. Vplyv miernej úrovňovej prebierky na zmeny štruktúry, vývoja a kvality rôznych typov porastov gaštana jedlého (*Castanea sativa* MILL.).- Lesnictví 31, 8: 699-720.

TOKÁR, F., 1990. Vplyv úrovňovej prebierky na vývoj produkcie a kvality rovnorodých porastov gaštana jedlého (*Castanea sativa* MILL.).- Acta Fac. For. (Zvolen) 32: 85-101.

TOKÁR, F., 1992. Vlijanie rubok uchoda na produktivnosť nasaždenij kaštana sjedobnogo v usloviach Slovakii.- Lesovedenie 2: 48-52.

TOKÁR, F., 1994. Biomass production in relation to phytotechnique in various stand types of Spanish chestnut (*Castanea sativa* MILL.) in Slovakia.- Ecology (Bratislava) 13: 225-234.

TOKÁR, F., 1998. Fytotechnika a produkcia dendromasy porastov vybraných cudzokrajných drevín na Slovensku.- Acta Dendrobiologica, VEDA, Vyd. SAV, 157 s.

TOKÁR, F., 1999. Produkcia nadzemnej dendromasy a fytotechnika rovnorodých porastov gaštana jedlého (*Castanea sativa* MILL.) na Slovensku.- J. Forest Sci. 45, 12: 533-541.

ZAGAS, T., 2000. Untersuchung zur Behandlung von Kastanienniederwäldern in Nordgriechenland.- Schweiz. Z. Forstwes. 151: 57-61.