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The characteristics of diameter growth and increment of introduced North American ash species at the sites of common alder

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ABSTRACT: Research was conducted into diameter growth and increment of introduced American ash species at the sites of common alder (*Alnus glutinosa* [L.] Gaertn.) in three mixed stands of introduced ash and common alder in the lowland part of Croatia. About 10 samples of increment cores of each species were taken from trees in the diameter class of the mean basal area. In the process, an attempt was made to reach the centre of the trees with the purpose of getting an insight into the development of the trees over a long period, i.e. from the moment when the trees reached breast height. The increment cores were analysed by measuring the width of each individual ring to the tenth of the millimetre. Bark thickness was also measured. The results obtained from the analysis of the increment cores yielded trends of ring widths for individual trees as well as trends of the average ring widths for each species within a locality. On the basis of the increment core analysis, parts of the diameter growth curve of the mean stand tree were obtained. The increment curve of mean stand diameter was obtained by deriving the growth curve of mean stand diameter. Introduced ash was found to have average ring widths from 0.92 to 4.21 mm. The measured minimal and maximal values of ring widths in total were 0.2 and 6.5 mm, respectively. Consequently, introduced ash may have significantly large ring widths in conditions of prolonged flooding as well. Therefore, its pioneering role is not irrelevant at poor sites naturally inhabited by common alder. The average ring width of introduced ash is the highest up to the age of 30 years, after which it retains the value of 2 mm or less. In common alder, the average ring width in the studied stand ranged from 1.40 to 4.59 mm. The measured minimal and maximal values of ring widths in total were 0.4 and 7.0 mm, respectively. A comparison of average ring widths of introduced ash and common alder revealed that in Draganić locality common alder had a statistically significantly larger average ring width than introduced ash. In the localities Karlovac and Đurđevac the difference was not statistically significant.

Keywords: introduced American ash species; *Alnus glutinosa* (L.) Gaertn.; growth of mean stand diameter; radial increment

White ash (*Fraxinus americana* L.) and green ash (*F. pennsylvanica* Marshall) were introduced on a large scale into Croatian forests in the first half of the 20th century, as reported by Strepački (1931), Španović (1931, 1954), Fukarek (1956) and Dekanić (1974). More recently, the majority of authors (Rauš 1992, 1993; Rauš et al. 1985; Majer 1994) reported the presence of white ash in the area of Croatian lowland forests while Kremer (2001) and Kremer and Borzan (2001) primarily noted the presence of green ash. This is the reason why the term introduced ash is used in this paper. There was practically no record of the success or failure of establishing cultures of North American ash species in the area of Croatian lowland forests (Horvat 1940). It was only recently (Kremer 2001; Čavlović, Kremer 2002) that the first research into the growth and increment of introduced ash was started. Čavlović and Kremer (2002) studied the characteristics of radial growth and increment of narrow-leaved ash and introduced ash in the area of central Posavina. According to their findings, in

the first 15 years both species had equal growth, after which the radial development of introduced ash gradually lagged behind. At about 50 years of age trees of narrow-leaved ash clearly dominated over those of introduced ash in terms of diameter. More extensive research into the growth and increment of white ash (*F. americana* L.) in the area of the city forest of Pančevo was conducted by Panić (1957). Glavač (1962) studied the growth and increment of common alder (*Alnus glutinosa* [L.] Gaertn.) to the age of 20. He found that the average age increment for trees growing from seeds culminated at the age of 13, while for trees growing from stumps it culminated between the years 4 and 5.

Although introduced ash was primarily planted at the sites where narrow-leaved ash could not survive, attempts were made to plant it at the sites of common alder as well. Since introduced ash also grows at such sites, we thought it useful to study the basic properties of radial growth and increment of introduced ash at natural sites of common alder. Very few quality species tolerate waterlogging as does the common alder. For this reason, we believe that the pioneering role of other species, in this case North American ash species, is also important.

Study site

Research was conducted in three mixed stands of introduced ash and common alder in the lowland part of Croatia. One stand is located in the area along the Drava river (forest office of Đurđevac) and the two others between the rivers Sava and Kupa (forest offices of Draganić and Karlovac). The first stand (subcompartment 90j), aged 35 and covering an area of 13.30 ha is in the management unit "Draganički lugovi" of Draganić forest office, the second stand (subcompartment 33c) aged 125 and sized 5.32 ha is in the

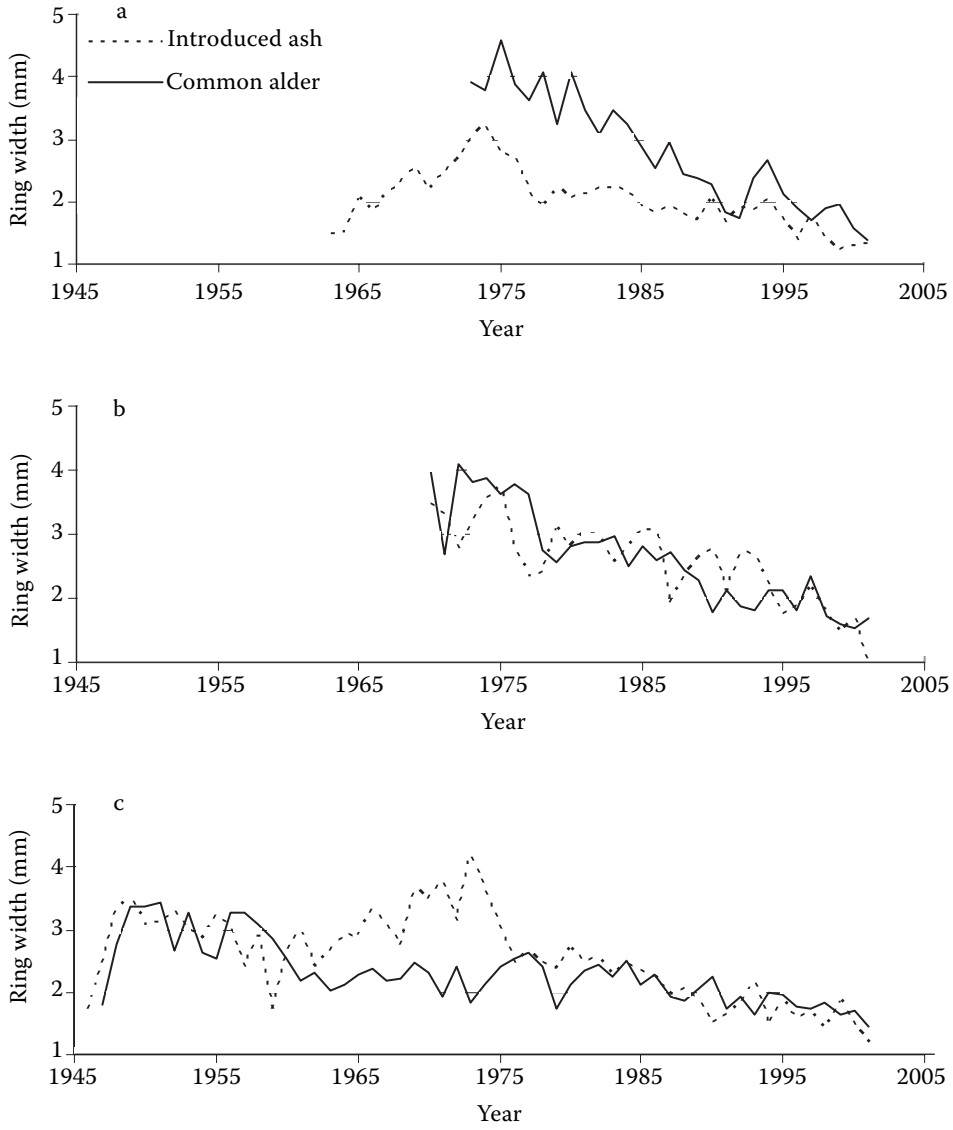

Fig. 1. Radial growth chronologies of mean stand trees: a – Draganić locality, b – Karlovac locality, c – Đurđevac locality

Table 1. Structure of the researched stands per ha

dbh (cm)	Introduced ash species		Common alder		Narrow-leaved ash		Other hardwoods		Total	
	N	G	N	G	N	G	N	G	N	G
Management unit "Draganički lugovi", subcompartment 90j										
12.5	374	4.60	26	0.32	1	0.01	1	0.01	402	4.94
17.5	233	5.61	58	1.40	1	0.02	1	0.02	293	7.05
22.5	115	4.58	45	1.79	–	–	–	–	160	6.37
27.5	43	2.55	19	1.13	–	–	–	–	62	3.68
32.5	3	0.25	–	–	3	0.25	–	–	6	0.50
37.5	2	0.22	–	–	–	–	–	–	2	0.22
Σ	770	17.81	148	4.64	5	0.28	2	0.03	925	22.76
Management unit "Rečički lugovi", subcompartment 33c										
12.5	156	1.92	44	0.51	–	–	6	0.07	206	2.50
17.5	106	2.55	88	2.12	–	–	6	0.14	200	4.81
22.5	81	3.22	113	4.50	–	–	13	0.52	207	8.24
27.5	31	1.84	–	0.36	–	–	–	–	37	2.20
32.5	–	–	–	–	–	–	–	–	–	0.00
37.5	–	–	–	–	–	–	31	3.42	31	3.42
42.5	6	0.85	–	–	–	–	–	–	6	0.85
Σ	380	10.38	251	7.49	–	–	56	4.15	687	22.02
Management unit "Đurđevačke nizinske šume", subcompartment 87a										
12.5	10	0.12	–	–	36	0.44	–	–	46	0.56
17.5	9	0.22	4	0.10	18	0.43	–	–	31	0.75
22.5	15	0.60	11	0.44	19	0.76	–	–	45	1.80
27.5	26	1.54	5	0.30	21	1.25	–	–	52	3.09
32.5	24	1.99	4	0.33	16	1.33	–	–	44	3.65
37.5	21	2.32	2	0.22	23	2.54	–	–	46	5.08
42.5	6	0.85	7	0.99	16	2.27	–	–	29	4.11
47.5	6	1.06	4	0.71	21	3.72	–	–	31	5.49
52.5	–	–	1	0.22	7	1.52	–	–	8	1.74
57.5	–	–	1	0.26	9	2.34	–	–	10	2.60
62.5	–	–	1	0.31	3	0.92	–	–	4	1.23
Σ	117	8.70	40	3.88	189	17.52	–	–	346	30.01

N – number of trees/ha, G – basal area/ha

management unit "Rečički lugovi" of Karlovac forest office, while the third stand (subcompartment 87a) aged 38 and sized 5.60 ha is in the management unit "Đurđevačke nizinske šume" of Đurđevac forest office.

Table 2. Results of Mann-Whitney *U*-test as regards on $p < 0.05$

Rank sum group 1	Rank sum group 2	Valid N group 1	Valid N group 2	*p*
Management unit "Draganički lugovi", subcompartment 90j				
168	142	10	10	0.003886*
Management unit "Rečički lugovi", subcompartment 33c				
118.50	112.50	11	10	0.863267
Management unit "Đurđevačke nizinske šume", subcompartment 87a				
122	68	10	9	0.078893

Group 1 = introduced ash species, group 2 = common alder

MATERIAL AND METHODS

Trees with breast-height diameters exceeding the taxation limit of 10 cm were measured dendrometrically and the structure of stands per hectare was calculated in the studied stands.

In the diameter class of mean stand trees ten increment cores were taken from introduced ashes and common alders. In the process, an attempt was made to reach the centre of the trees in order to obtain an insight into the tree diameter growth for the longest period possible. Using the tree-ring measuring device Digitalpositiometer SMIL3, bark thickness and each ring width were measured to the nearest 0.01 mm. The cores were analysed to obtain the annual growth increment for each tree from the year of measurement (2001) backwards. The ring widths were averaged for each individual year within each core sample of introduced ash and common alder. The diameter growth curve was obtained in the following way: the average ring widths were first doubled, and then five-year periods were determined from the year 2001 backwards, with the provision that the first period did not have to embrace a period of five years. This is how the mean tree diameter in the first period was obtained: double ring widths (1, 2, 3 or 4 rings) occurring before the year of the first full five-year period was complemented with the difference between the averages of breast-height diameters of the trees from which increment cores were taken, were reduced by the double average bark width and the total double ring width of the cores. Breast-height diameter at the end of the next five-year period was obtained as follows: the double average width of the next five rings was added to the diameter of the previous five-year period (Čavlović, Kremer 2002). Growth curves of breast-height diameters provided the curves of current annual diameter increments.

The values of the average ring width of introduced ash and common alder were compared in some stands. In order to accomplish the comparison, the ring widths for each of the analysed cores of one and the other species were added starting always from the same year (for example, from 1974 for Draganić locality), and divided by the number of rings (in our example with 27). The initial year was determined on the basis of the first year for which the ring width was measured in all trees of each species. By calculating the average ring width always from the same year, we wanted to avoid the impacts of different climatic conditions in individual years. In this way, the average ring widths for each individual tree (ten trees within each species within the locality) were obtained for each studied species. The frequency of distribution of average ring widths was investigated by Shapiro-Wilk *W*-test, which showed deviations from the normal distribution. For this reason, the ring widths of introduced ash and common alder were compared by non-parametric Mann-Whitney *U*-test, which was used instead of the *t*-test (Pranjić 1990).

RESULTS AND DISCUSSION

The structure of the first stand (compartment 90j) is shown in Table 1. The breast-height diameter of the mean stand tree of introduced ash is 17.16 cm and of common alder 19.98 cm. Fig. 1a shows the radial growth chronology of introduced ash over the last 38 years and of common alder over 28 years. A decreasing trend of the average ring width of the mean stand tree was noted in both species after they reached the highest values in their youth. The average ring width of introduced ash was the highest in the

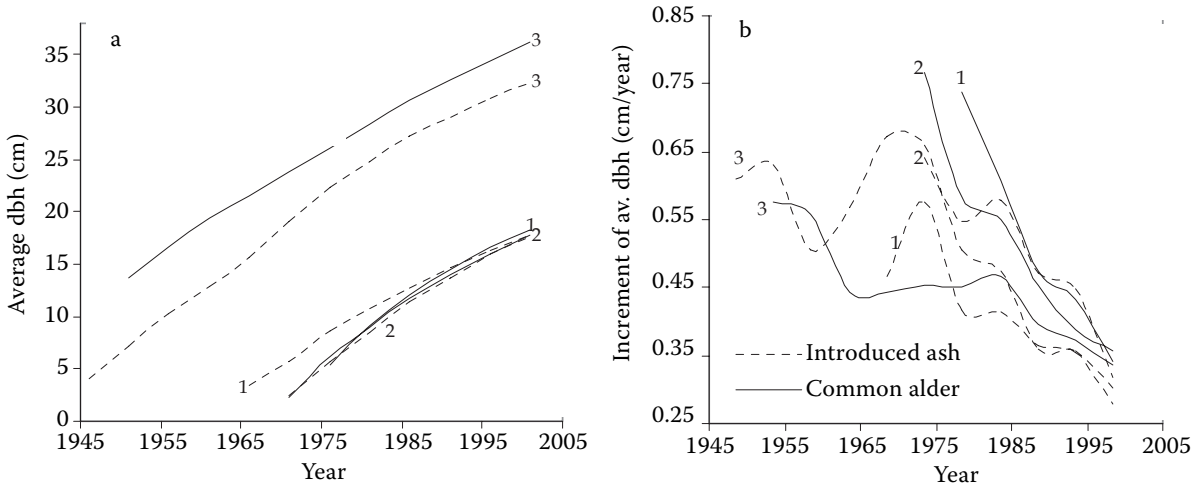

Fig. 2. a – growth curves of dbh, b – current annual increment curves of dbh. 1 – Draganić locality, 2 – Karlovac locality, 3 – Đurđevac locality

period from 1968 to 1976, reaching the highest value of 3.24 mm in 1974. In its youth common alder has a higher average ring width than introduced ash. The Mann-Whitney *U*-test (Table 2) showed that during the period from 1976 to 2001, 10 mean stand trees of common alder had a statistically significantly higher average ring width than 10 mean stand trees of introduced ash. In a way this is understandable, since trees of common alder are about ten years younger than trees of introduced ash and therefore have a higher average ring width. However, the higher average ring width in common alder can also be explained by the fact that common alder arrived at the site which was partially improved by introduced ash and its pioneering role. Fig. 2a shows growth curves of breast-height diameters of mean stand trees. It is clear that the breast-height diameter of common alder rises and gradually exceeds the breast-height diameter of introduced ash. The initial lagging behind of the breast-height diameter of common alder in relation to introduced ash is also the result of their different age. Common alder has a higher current radial increment than introduced ash, which is seen in the curves of current radial increment (Fig. 2b). The figure shows that introduced ash and common alder have the highest current radial increment in the early youth, after which it decreases. Thus, the culmination of current radial increment in introduced ash occurs at about 10 years of age. The time needed for the trees of introduced ash to reach breast height was not determined by detailed analysis of height growth, and the culmination of radial increment could not therefore be determined accurately.

Table 1 also shows the structure of the stand in subcompartment 33c. Breast-height diameter of the mean tree of introduced ash is 18.65 cm and of common alder 19.50. Fig. 1b shows trends of average ring widths of mean stand trees of introduced ash and common alder over the last 31 years. Both studied species display a decreasing trend of the average ring width (radial growth of the mean tree). In the first years of stand development, common alder had a higher average ring width, but this advantage was subsequently lost and alternated with shorter periods of one or the other species having a higher average ring width. Since 1995 the ring width has been equal in both species. It is therefore understandable that the results of Mann-Whitney *U*-test (Table 2) did not show any statistically significant differences in the average ring width of 11 mean trees of introduced ash and 10 mean trees of common alder for the period 1974–2001. Growth curves of breast-height diameters of mean stand trees show identical growth in the breast-height diameter in both species (Fig. 2a) as well as a similar current radial increment (Fig. 2b). The increment was slightly higher in common alder at the beginning of stand development, but after 1981 it was higher in introduced ash.

The structure of the third stand (subcompartment 87a) is also shown in Table 1. Breast-height diameter of the mean tree of introduced ash is 30.77 cm, and of common alder 35.15 cm. Fig. 1c shows trends of the average ring width of introduced ash over the last 55 years and of common alder over 54 years. What is immediately noticeable is that the radial growth of common alder during the observed period was uniform and that it gradually decreased. Introduced ash showed slightly larger oscillations that were the most prominent in the period from 1958 to 1976. Mann-Whitney *U*-test did not show any statistically significant differences between the average ring widths of 10 trees of introduced ash and 9 trees of common alder for the period from 1969 to 2001 (Table 2). According to Fig. 2a, common alder had a higher breast-height diameter than introduced ash over the whole observed period. Fig. 2b shows that introduced ash reached the highest current annual increment of mean diameter at about 22 years of age and common alder at about 6 years of age.

Although these stands are of different age, it is clear that in the youth the average ring widths of introduced ash were the highest in the stand in Đurđevac locality and the lowest in Draganić locality. Trends of average ring widths in the oldest stand (Đurđevac) clearly show that introduced ash has a higher average ring width in the first thirty years of life. After that the ring width increasingly falls and mostly remains below 2 mm in the last ten years of the stand life. In the localities Draganić and Karlovac the periods during which the average ring width has higher values are even shorter. The average ring width in introduced ash in Đurđevac locality ranged from 1.19 (2001) to 4.21 (1973), in Draganić locality from 1.22 (1999) to 3.24 (1974), and in Karlovac locality from 0.92 (2001) to 3.76 (1975). Panić (1957) found that in a 43-year-old stand in the area of Pančevo city forest (Serbia) the ring width over the last 10 years reached 0.58–1.50 mm. The age of Panić's stand is practically identical to the age of the stand in Draganić locality, in which the ring width of trees of introduced ash has ranged from 1.22 to 2.02 mm over the last 10 years.

Except the period of 3 years required for a tree to grow to breast height, it can be said that during the life of the observed stands, the ring width in all sampled trees of introduced ash ranged from 0.3 to 4.7 mm in Draganić locality, from 0.3 to 6.5 in Karlovac locality and from 0.2 to 6.3 mm in Đurđevac locality.

The mean trees of common alder in the investigated localities are also of different age. It is obvious that in the youth, the mean trees of common alder had the highest average ring width in Draganić locality and the lowest in Đurđevac locality. The average ring width of common alder in Đurđevac locality ranged from 1.46 (2001) to 3.42 mm (1951), in Đurđevac locality it was between 1.40 (1999) and 4.59 mm (1975), and in Karlovac locality it ranged from 1.54 (2000) to 4.08 mm (1972). According to Horvat (1940), the ring width of common alder in the area of Lipovljani was between 1.08 and 9.25 mm (2.75 mm on average).

In Draganić locality it was found that the ring width in all sampled trees of common alder during its life ranged from 0.4 to 9.87 mm, in Karlovac locality from 0.5 to 7.0 mm, and in Đurđevac locality from 0.4 to 6.3 mm.

CONCLUSIONS

Research confirmed that trees of introduced North American ash at the site of common alder have an average ring width from 0.92 to 4.21 mm, while the measured minimal and maximal values in total reached 0.2 or 6.5 mm. It is clear that even in conditions of long-lasting water stagnation, introduced ash may have a considerable ring width, which means that the pioneering role of introduced ash is not negligible even at heavy sites such as those inhabited naturally by common alder. The average ring width of introduced ash is the highest at the age of about 30 years, after which is decreases abruptly and retains the value of about 2 mm or declines even further.

In the studied stands of common alder the average ring width ranged from 1.40 to 4.59 mm. The measured minimal and maximal values of ring widths in total reached 0.4 and 7.00 mm.

A comparison between the average ring widths of introduced ash and common alder showed that in Draganić locality common alder had a statistically significantly higher average ring width than introduced ash, while in the localities Karlovac and Đurđevac the difference was not statistically significant.

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References

ČAVLOVIĆ J., KREMER D., 2002. The characteristics of diameter growth and increment of trees in the stands of narrow-leaved ash and introduced white ash in central Posavina. [In Croatian with English summary.] Šumarski list, *126*: 145–153.

DEKANIĆ I., 1974. Silvicultural characteristics in south-east Slavonia. [In Croatian.] In: VIDAKOVIĆ M., HORVATINOVIĆ S., ŠVAGELJ D. (eds.), Proceedings about hundredth anniversary forestry in south-east Slavonia. JAZU Centre for Scientific Work Vinkovci, Vinkovci – Slavonski Brod: 11–41.

FUKAREK P., 1956. Contributions about knowledge of forest communities where the narrow-leafed ash grow. [In Croatian.] Šumarski list, *80*: 30–40.

GLAVAČ V., 1962. The height growth rate of black alder up to its 20-year age. [In Croatian with English summary.] Šumarski list, *86*: 408–414.

HORVAT I., 1940. About technical properties of white ash (*Fraxinus americana* L., *F. alba* Marshall). [In Croatian with French summary.] Šumarski list, *64*: 217–230.

HORVAT I., 1960. The physical and mechanical properties of common alder-wood (*Alnus glutinosa* Gaertn.). [In Croatian with English summary.] Šumarski list, *84*: 217–230.

KREMER D., 2001. Representation of white ash (*Fraxinus americana* L.) and green ash (*Fraxinus pennsylvanica* Marshall) in Kupa river basin, Sava river basin and Danube basin. [In Croatian with English summary.] [Master Thesis.] Zagreb, Faculty of Forestry: 227.

KREMER D., BORZAN Ž., 2001. Presence and range of white ash (*Fraxinus americana* L.) and green ash (*Fraxinus pennsylvanica* Marshall) in Kupa river basin, Sava river basin and Danube basin. [In Croatian with English summary.] In: MATIĆ S., KRPAN A.P.B., GRAČAN J. (eds.), Science in sustainable management of Croatian forests. Faculty of Forestry, Forestry Institute Jastrebarsko and "Croatian forest" Zagreb. Zagreb: 87–93.

MAJER Ž., 1994. Flood plain forests of the Danube basin and their natural regeneration. [In Croatian with English summary.] Glasnik za šumske pokuse, *31*: 391–434.

PANIĆ Đ., 1957. Observations Concerning the Form, Volume and Increment of the White Ash. Šumarstvo, Belgrade, *10*: 37–62.

PRANJIĆ A., 1990. Forestry biometrics. Zagreb, Zagreb University, Faculty of Forestry: 204.

RAUŠ Đ., 1992. Vegetation of marshlands forests along the river Drava between Varaždin and Osijek with particular attention paid to the Varaždin forests along the river Drava. Glasnik za šumske pokuse, *28*: 245–256.

RAUŠ Đ., 1993. Phytocoenology and vegetation map of central Croatia flatland forests. [In Croatian with English summary.] Glasnik za šumske pokuse, *29*: 335–364.

RAUŠ Đ., ŠEGULJA N., TOPIĆ J., 1985. Vegetation of north-eastern Croatia. [In Croatian with English summary.] Glasnik za šumske pokuse, *23*: 223–355.

STREPAČKI V., 1931. About profitability of draining swamp in Slavonian forests. [In Croatian with French summary.] Šumarski list, *55*: 308–311.

ŠPANOVIĆ T., 1931. Softwood or marshlands forests in the Danube basin. [In Croatian with French summary.] Šumarski list, *76*: 157–178.

ŠPANOVIĆ T., 1954. Willows of our Danube's basin marshlands. [In Croatian.] Šumarski list, *78*: 506–521.

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Charakteristiky tloušťkového růstu a přírůstu u introdukovaných druhů severoamerických jasanů na stanovištích olše lepkavé

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ABSTRAKT: V nížinné oblasti Chorvatska jsme ve třech smíšených porostech introdukovaného jasanu a olše lepkavé prováděli výzkum tloušťkového růstu a přírůstu u introdukovaných druhů amerických jasanů na stanovištích olše lepkavé (*Alnus glutinosa* [L.] Gaertn.). Ze stromů patřících do tloušťkové třídy střední výčetní plochy jsme u každého druhu odebrali zhruba 10 vzorků vývrtů. Při tomto postupu jsme se snažili dosáhnout středu stromů, abychom získali pohled do vývoje stromů během dlouhého období, tzn. od okamžiku, kdy stromy dosáhly výčetní výšky. Vývrty jsme analyzovali tak, že jsme změřili šířku každého jednotlivého letokruhu s přesností na jednu desetinu milimetru. Rovněž jsme měřili tloušťku kůry. Výsledky analýzy vývrtů ukázaly trendy šířek letokruhů u jednotlivých stromů i trendy šířek letokruhů u každého druhu v rámci lokality. Na základě analýzy vývrtů jsme získali části křivky tloušťkového růstu středního stromu porostu. Křivku přírůstů střední porostní tloušťky jsme sestrojili odvozením růstové křivky střední porostní tloušťky. U introdukovaného jasanu jsme zjistili průměrnou šířku letokruhů v rozmezí od 0,92 do 4,21 mm. Naměřené minimální a maximální hodnoty celkem činily 0,2 mm, resp. 6,5 mm; proto může mít introdukovaný jasan v podmínkách dlouhotrvajícího zaplavení významně větší šířku letokruhů. Jeho úloha jako pionýrské dřeviny na chudých stanovištích osídlených olší lepkavou není tedy bezvýznamná. Průměrná šířka letokruhů u introdukovaného jasanu je největší do věku 30 let, pak zůstává na hodnotě 2 mm nebo méně. U olše lepkavé se průměrná šířka letokruhů ve sledovaném porostu pohybovala od 1,40 do 4,59 mm. Naměřené minimální a maximální hodnoty šířky letokruhů celkem dosahovaly 0,4 mm, resp. 7,0 mm. Srovnání průměrné šířky letokruhů u introdukovaného jasanu a olše lepkavé ukázalo, že na lokalitě Draganić měla olše lepkavá statisticky významně větší průměrnou šířku letokruhů než introdukovaný jasan. Tento rozdíl na lokalitách Karlovac a Đurđevac nebyl statisticky významný.

Klíčová slova: introdukované druhy amerického jasanu; *Alnus glutinosa* (L.) Gaertn.; růst střední porostní tloušťky; tloušťkový přírůst

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