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The impact of pruning on tree development in poplar *Populus × canadensis* ‘I-214’ plantations

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The effect of pruning on tree development and the potential structure of wood assortments was investigated in the poplar *Populus × canadensis* clone ‘I-214’. The study was carried out in a permanent sample plot within a poplar plantation established in 2006, in the area of the “Vojvodinašume” Public Company, within the “Gornje Potamišje” Forest Management Unit (Republic of Serbia). Pruning was performed on a total of 325 trees at different stem heights and a total of 13,186 branches were pruned. The average number of pruned branches per tree at the stem height of 5 m was 36, while it was 40 at the stem height of 6 m and 46 at the stem height of 7 m. The average diameter of pruned branches was 1.7 cm. The results showed that there are no significant differences in diameters at breast height between pruned and unpruned trees after two different intensities of pruning. Our results showed that pruning do not impact the long-term growth performance in poplar clone ‘I-214’, while remarkably improving the quality and economic value of wood assortments obtained from pruned trees.

Keywords: Poplar, Pruning, Pruning Intensity, Pruning Height, Branch Diameter

Introduction

Pruning is an important silvicultural measure in poplar and pine plantations, which is often applied to increase the value of wood assortments (Montagu et al. 2003). In fact, the most common goal of pruning is to achieve a higher percentage of clear, knot free wood along the stem (Zobel 1992, Barbour et al. 2003).

Knots have a strong impact on the qualitative structure of wood assortments (Danilović 2000, 2006, Koman et al. 2013). Branch remains (knots) can represent a problem during mechanical wood processing, especially knots that fall out and rotten knots; therefore, a timely implementation of an adequate-intensity pruning in poplar plantations is often necessary. Pruning usually begins early and no later than the third growing season (Isebrands & Richardson 2014). Indeed, according to previous studies, pruning carried out in a three-year-old plantation favours the inclusion of small knots in the inner part of the trunk, therefore limiting their impact on the quality of wood assortments (Viquez & Perez 2005, Danilović 2006).

According to Desrochers et al. (2015) pruning intensity and season are the most important factors affecting the number and biomass of epicormic shoots, while the clonal material is not. Pruning of 1/3 of the crown length in summer reduced the emergence of epicormic shoots compared to pruning of 2/3 crown length, as well as spring or fall pruning. Field observations suggest that in this period trees are physiologically strong, sugar level in the tree is high and the callus can quickly be formed. The pruning of fast-growing species, such as poplar, can be performed in December and January, without major consequences on tree health and growth. The advantage of pruning during vegetation dormancy is the possibility of thoroughly observing the tree crown.

On the other hand, untimely pruning can cause a number of problems, especially in clonal plantations with intensive growth, including higher pruning costs, worse structure of wood assortments, physiological weakening of plants due to cutting thick branches, greater physical effort of workers who are carrying out pruning, etc. (Danilović & Dordević 2009).

The timing and intensity of this silvicultural operations can significantly affect its profitability, as well as the physiology and growth performance of trees. Pruning treatments to remove branches from the lower part of the crown are usually aimed at improving the shape of trees during the establishment period and/or to create knot-free wood, thus increasing the value of boles (Hubert & Courraud 1994).

The amount of leaves that is removed by pruning the bottom branches affects the development of the tree, and it is dependent on several factors, such as clone type, plantation density, plant vitality, soil type, pruning period, the period of time intervening between prunings, branch diameter, etc. (Danilović & Dordević 2009, Shock et al. 2007).

Recommendations for hybrid poplars in Canada suggest reaching a 6-7 m clear bole, in 3-5 lifts depending on tree growth, only removing one-third of the live crown at each lift (Boysen & Strobl 1991, Van Oosten 2006). Tools that are used for pruning include hand scissors and saws, various types of mechanized tools (scissors with a telescopic handle, pruning device equiped with a chain, etc.). In addition, there are specialized devices primarily used for pruning, such as tree Monkey, Tree shaver, etc. (Bajić & Danilović 2003).

An economic impact analysis of pruning in poplar plantations was already reported by several studies (Sekawin 1964, Knezević

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Tab. 1 - Average tree diameter (cm) and average height (m) of trees after pruning. Pruning intensity: (A) high, (B) low; (*): share of branch-free wood in total tree height.

Type	Variable	Sample plots						Control plot
Pruning type	Pruning intensity	A	B	A	B	A	B	-
	Pruning height (m)	5	5	6	6	7	7	-
After first pruning	Average diameter (cm)	10.45	10.5	10.41	10.38	10.56	10.46	10.97
	Average height (m)	4.78	4.74	4.78	4.76	4.99	4.81	5.16
	Stem* (%)	37	33	37	33	35	34	27
After second pruning	Average diameter (cm)	14.86	14.81	14.71	14.76	15.17	14.95	16.47
	Average height (m)	8.47	8.25	8.75	8.17	8.26	8.83	8.31
	Stem (%)	31	27	31	27	32	24	24
After third pruning	Average diameter (cm)	25.11	24.81	24.78	24.93	25.42	24.90	27.56
	Average height (m)	11.91	11.67	12.43	11.81	11.63	12.46	10.74
	Stem (%)	42	43	48	51	60	56	30

1966). The costs of poplar trees pruning depend on many factors (period of pruning, working tools, pruning method, etc.), but the increase in wood value achieved by applying this silvicultural measure significantly exceeds those pruning costs (Kirk & Parker 1996). In addition, pruning costs depend on type of tools and devices used for pruning, the pruning method, the period of pruning and the training of workers, etc. (Bajić & Danilović 2003).

The aim of this study is to examine the impact of pruning on the diameter increment of trees in a *Populus* × *canadensis* 'I-214' plantations. Our starting hypothesis was that pruning did not affect growth performances of poplar trees, while positively affecting the quality of wood assortments taken from them.

Material and methods

Study area

The research was carried out in the area of the "Banat" Pančevo Forest Estate, in a plantation of *Populus* × *canadensis* 'I-214' established in 2006 on haplic gleysol. During establishment, the planting material was arranged in a triangular form, with a distance of 6 m between cuttings, which implies that 320 cuttings were planted per hectare. The cuttings were placed at a depth of 80 cm. Before planting, complete terrain preparation had beed carried out by implementing adequate agro-technical and tending measures.

By the plantation age of nine years, the following tending measures had been carried out: (i) hoening around the trees and disc harrowing between the rows were carried out in the first year; (ii) disc harrowing between the rows was implemented in the second year; (iii) pruning and disc harrowing between the rows were carried out in the third year; (iv) disc harrowing between the rows was implemented in the fourth year; (v) pruning was carried out in the fifth year; (vi) none of the tending measures were implemented in the sixth year; (vii) pruning was carried out in the seventh year.

Methods

For the purpose of this study, a sample plot (1.12 ha) and a control plot (0.28 ha) were established. The control plot was established immediately next to the sample plot, so the climate, edaphic and orographic factors are expected to have equal effect on the growth of treated trees.

The experiment started in 2008 at the end of the second vegetation period of the plantation. The sample plot was subdivided in two equal parts. In one part, the pruning intensity was high (treatment A), and in the other part the pruning intensity was low (treatment B). Within both parts, pruning up to the 5, 6 and 7 m of stem height was carried out (treatments 5, 6 and 7, respectively).

The first pruning of high intensity (treatment A) consisted of the removal of branches of the first whorl (at pruned ring height of 22-24 cm) and the removal of thicker branches from the other parts of the crown. While the first pruning of low intensity (treatment B) included the removal of thicker branches in the crown.

The second pruning of high intensity (treatment A) included the removal of branches of the second whorl (at pruned ring height of 87-91 cm) and the removal of thicker branches in the crown, while the second pruning of low intensity (treatment B) included the removal of branches of the first whorl (at pruned ring height of 50-64 cm) and the removal of thicker branches in the crown.

Finally, the third pruning included the complete removal of branches up to 5, 6 and 7 m of stem height (treatments 5, 6 and 7, respectively).

The first pruning was carried out in late spring (May to June) in 2009. The second pruning was carried out in the same period in 2011, and the third pruning in 2013, also in the same period. This implies that pruning was carried out at the plantation age of three, five and seven.

Complete branch removal up to 5 m of stem height was performed on a total of 108 trees. Complete branch removal up to 6 m of stem height was performed on 113 trees and complete branch removal up to 7 m of stem height on 104 trees. Pruning was not performed in the control plot.

Measurements of diameter and heights of trees were carried out in the sample plots and in the control plot. The first measurement was carried out at the beginning of the experiment, in 2008. The second measurement was done a year after the first pruning, in 2010. The third measurement was conducted in 2012, a year after the second pruning. Measurement replications number 4, 5 and 6 were performed every following year (2013, 2014 and 2015).

Diameters of pruned branches were also measured to an accuracy of 1 mm.

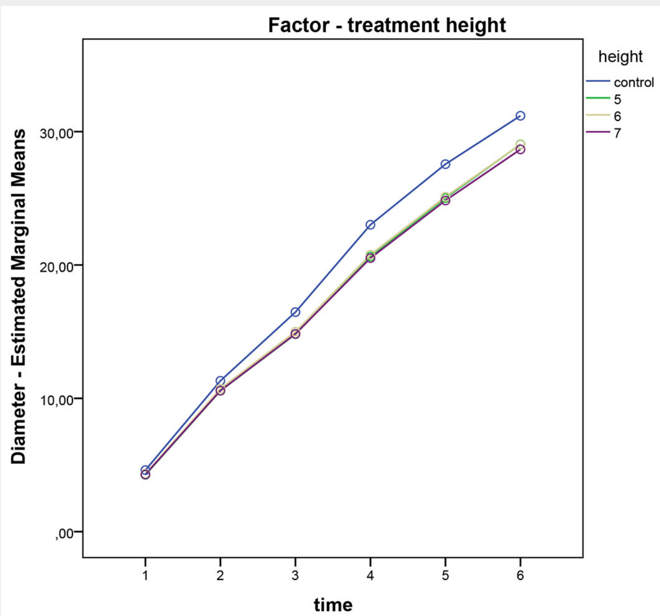

Fig. 1 - Impact of pruning height on diameter at breast height.

General Linear Model (GLM) repeated measures statistical technique was used for statistical analysis by the software SPSS® v. 28.0.1 (IBM, Armonk, NY, USA).

Results

The average diameter and average height of trees in the sample plots and control plot after the first, second and third pruning are shown in Tab. 1, while the total number of pruned branches and the average number of pruned branches per tree are shown in Fig. 1.

The total number of pruned branches increases with increasing the height up to which pruning was performed. In the case of pruning up to 5 m of stem height, the total number of pruned branches was 3891. In the case of pruning up to 7 m of stem height, the total number of pruned branches was 4754 (Tab. 2).

In the case of pruning up to 5 m of stem height, the average number of branches pruned per tree was 36. In the case of pruning up to 6 m of stem height, the average number of pruned branches per tree was 40 and in the case of pruning up to 7 m of stem height the average number of pruned branches per tree was 46. The total number of pruned branches over the three pruning carried out was 13,186, involving 325 trees overall (Tab. 2). The average diameter of pruned branches at high intensity pruning (treatment A) and low intensity pruning (treatment B) was 1.7 cm.

Six measurements of diameter were taken for within subject effects, and pruning height and intensity were taken for between subject effects (Tab. 3).

Two homogeneous subsets were detected by Tukey's HSD (Honestly Significant Difference) test; the first subset included the control plot, while the other included the treated plots for both pruning height and pruning intensity. There were very small differences between treated plots, and somewhat greater than the differences observed between treated plots and control plot (Fig. 1, Fig. 2). However, according to the results of GLM both treat-

Tab. 2 - Number of cut branches depending on pruning height (m from the ground).

Pruning height	Cut branches	
	Total	Average per tree
Up to 5 m	3891	36
Up to 6 m	4541	40
Up to 7 m	4754	46

Tab. 3 - Impact of pruning height (5, 6, and 7 m) and intensity (high: A, and low: B) on diameter at breast height. (CI): Confidence intervals.

Factor	Treat-ment	Repl.	Mean	Std. Error	95% CI	
					Lower Bound	Upper Bound
Control	0	1	4.617	0.093	4.433	4.800
		2	11.315	0.185	10.952	11.678
		3	16.466	0.233	16.007	16.925
		4	23.016	0.277	22.472	23.561
		5	27.561	0.302	26.967	28.154
		6	31.190	0.330	30.541	31.839
Height	5	1	4.264	0.081	4.105	4.423
		2	10.567	0.160	10.252	10.881
		3	14.812	0.202	14.415	15.210
		4	20.636	0.240	20.165	21.108
		5	25.021	0.261	24.507	25.535
		6	29.046	0.286	28.484	29.608
	6	1	4.341	0.079	4.185	4.496
		2	10.719	0.156	10.412	11.027
		3	14.990	0.198	14.602	15.379
		4	20.772	0.235	20.311	21.233
		5	25.113	0.256	24.610	25.616
		6	29.023	0.280	28.473	29.572
	7	1	4.290	0.082	4.129	4.452
		2	10.578	0.163	10.257	10.898
		3	14.832	0.206	14.427	15.238
		4	20.517	0.244	20.036	20.998
		5	24.837	0.267	24.313	25.361
		6	28.671	0.291	28.098	29.243
Intensity	A	1	4.309	0.066	4.179	4.440
		2	10.598	0.131	10.340	10.857
		3	14.793	0.166	14.467	15.120
		4	20.505	0.197	20.117	20.892
		5	24.897	0.215	24.474	25.319
		6	28.934	0.235	28.472	29.396
	B	1	4.288	0.065	4.159	4.416
		2	10.644	0.129	10.389	10.899
		3	14.963	0.164	14.642	15.285
		4	20.778	0.194	20.397	21.160
		5	25.083	0.212	24.667	25.500
		6	28.892	0.231	28.437	29.347

Tab. 4 - Impact of pruning height (5, 6, and 7 m) and intensity (high: A, and low: B) on diameter increment. (CI): Confidence intervals.

Factor	Treat-ment	Repl.	Mean	Std. Error	95% CI	
					Lower Bound	Upper Bound
Control	0	1	6.699	0.106	6.490	6.907
		2	5.151	0.064	5.026	5.276
		3	6.551	0.074	6.406	6.695
		4	4.544	0.060	4.427	4.662
		5	3.629	0.069	3.494	3.765
Height	5	1	6.303	0.092	6.122	6.484
		2	4.245	0.055	4.137	4.354
		3	5.824	0.064	5.699	5.949
		4	4.385	0.052	4.283	4.486
		5	4.025	0.060	3.908	4.143
	6	1	6.379	0.090	6.202	6.556
		2	4.271	0.054	4.165	4.377
		3	5.782	0.062	5.659	5.904
		4	4.341	0.051	4.242	4.440
		5	3.910	0.058	3.795	4.025
	7	1	6.287	0.094	6.103	6.471
		2	4.255	0.056	4.145	4.365
		3	5.684	0.065	5.557	5.812
		4	4.320	0.053	4.216	4.423
		5	3.834	0.061	3.714	3.954
Intensity	A	1	6.289	0.076	6.141	6.438
		2	4.195	0.045	4.106	4.284
		3	5.711	0.052	5.608	5.814
		4	4.392	0.042	4.308	4.475
		5	4.037	0.049	3.941	4.134
	B	1	6.356	0.074	6.210	6.503
		2	4.319	0.045	4.232	4.407
		3	5.815	0.052	5.714	5.917
		4	4.305	0.042	4.223	4.387
		5	3.809	0.048	3.714	3.904

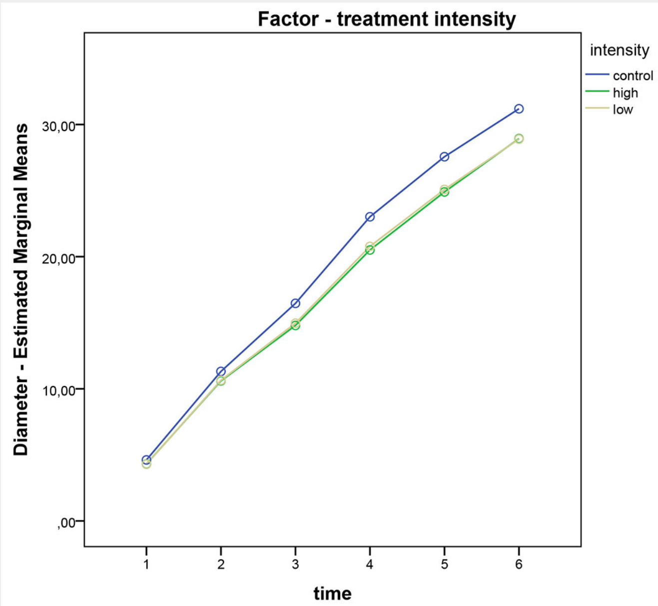

Fig. 2 - Impact of pruning intensity on diameter at breast height.

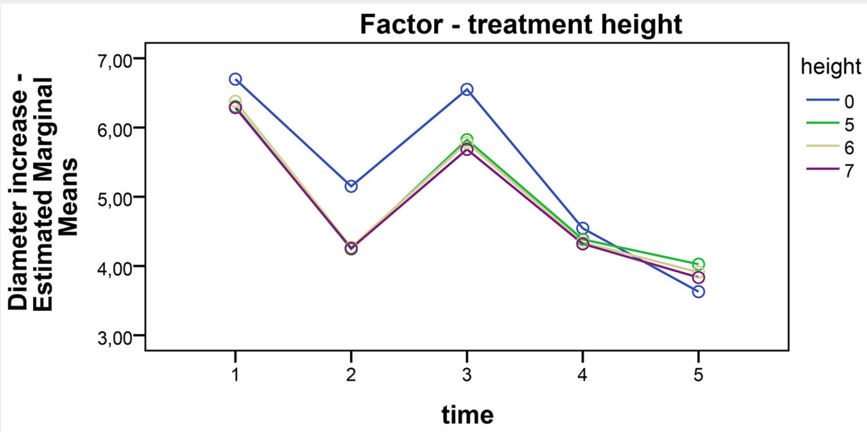

Fig. 3 - Impact of pruning height on diameter increment.

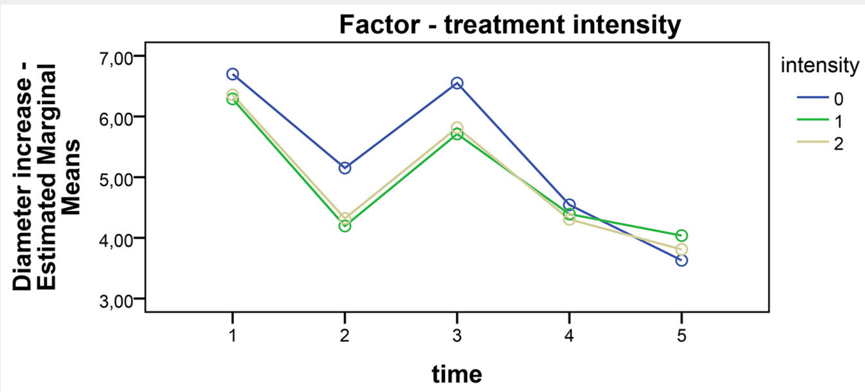

Fig. 4 - Impact of pruning intensity on diameter increment.

ment factors (*i.e.*, pruning height and pruning intensity) do not significantly impact on tree diameter.

The GLM repeated measures analysis was also conducted for diameter increment variable, taking the same between subject effects (Tab. 4). The results showed very small and non-significant differences between treated plots, while the difference was greater (though not significant) between treated and the control plot for both pruning height and pruning intensity. Diameter increment in the treated plots tends to equalize and overtake diameter increment of trees in the control plot (Fig. 3, Fig. 4).

Discussion

The results of this long-term study confirmed that pruning is necessary for the production of high quality wood assortments.

During the first few years after the establishment of the plantation, trees that were not pruned showed a better development due to the higher amount of leaf area and mass. Similar findings are reported by Viquez & Perez (2005) who conducted pruning up to 3, 4 and 5 m above the ground. According to Keller (1979), pruning of poplar clone 'I-214' at age of 7 did not affect height growth and reduced stem taper, but radial growth was decreased in the more severe tratments with branches pruned up to 60% of the tree height.

At the age of ten, the average diamater of pruned trees was similar to the average diameter of trees that were not pruned. However, the advantage of pruning is the higher value of the pruned trees. The most valuable wood assortments could be obtained from the bottom part of pruned trees, while the quality of wood assortments from the basal stem in the control area was lower.

The results reported by Danilović (2006) in a poplar plantation showed that the difference in value of assortments between the trees pruned up to 6 m of stem height and unpruned trees is about 9% (when the mean diameter at breast height is 35 cm). In addition, pruning costs are negligible compared to the increase of value of wood assortments thanks to pruning. When the average log volume is 0.7 m^3, the difference in the value of wood assortments is about 9.2 € per tree. In the first case, a log with a 35 cm mid-length diameter and a length of 7.2 m for sliced veneer (F class) is made. In the second case, two logs are made. The first one with a 37 cm mid-lenght diameter and a length of 3.7 m (F class) and the second one with a 34 cm mid-lenght diameter and the length of 3.5 m (class I).

Nonetheless, the height of pruning at up to 7 m of stem height can affect stem development. Hibbs (1996) observed a significant reduction in growth for trees pruned above 25% of their height. According to the Oregon State University Extension, pruning should not exceed the threshold of 50% of tree stem height.

According to Danilović & Dordević (2009), based on the daily cost using a HT 75® telescopic pole pruner (Stihl, Waiblingen, Germany), pruning costs amounted to 0.22 € per tree. Moreover, pruning costs increase with increasing the frequency of pruning. In addition, fuel and oil consumption depend on the average diameter of pruned branches, being apparently higher for large branches.

After the first pruning, the diameter increment of trees in the control plot was higher than that in the sample plot at the plantation age of ten years. At that age, any difference in diameter increment between sample plots and the control plot was detectable anymore. The reduction of the diameter increment in the control plot was caused by the natural dieback of lower branches.

Conclusions

The average diameter of pruned poplar trees (*Populus × canadensis* clone 'i-214') depends on the pruning intensity until the 10th year after plantation. At this age, the diameter increment of pruned trees matches that of unpruned control trees. We found no difference in diameter at breast height between trees pruned at high (treatment A) and low (treatment B) intensities. For the average mid-lengh log diameter of 35 cm, the value of wood assortments made from the bottom parts of trees that were pruned at up to 7 m of tree stem height is 9.2 € higher than the value of wood assortments made from unpruned trees. Finally, we found no statistically significant difference between the average diameter of branches pruned by applying pruning methods of diffenet intensity.

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