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"Agrosym 2018"
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CHARACTERISTICS OF THE INCREMENTS OF SPRUCE TREES IN THE PERIOD FROM 32 TO 50 YEARS AFTER THE APPLICATION OF TWO HEAVY SELECTIVE THINNINGS

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Abstract

The paper presents the characteristics of the increment of tree growth elements (height, diameter, basal area and volume) in the monoculture of the spruce (*Picea abies* Karst.) in the period of 33-40 and 41-50 years, after the application of heavy selective thinnings. In both periods, the trees with larger dimensions, i.e., breast height diameter, had greater increments of growth elements compared to the smaller trees. By grouping trees in the group of 200 trees per hectare sorted by their diameters showed that after the first thinning the 600 thickest trees per hectare had uniform increments of diameter at breast height, basal area and volume being significantly larger than the next group of thinner trees. In the period after the second thinning, the groups of the 200 thickest trees per hectare had significantly higher increments of diameter, basal area and volume in relation to the next groups of 201 to 600 thickest trees that had a uniform and significantly greater increments from the following groups of the thinner trees. The results indicate that in the studied spruce plantation only 600 thickest trees per hectare singled out according to the size of the increment in the period after the first thinning. In the period after the second thinning, only the 200 thickest trees were singled out according to the size of the increment in diameter at breast height, basal area and volume, which indicates to intensive differentiation of trees according to the increment potential under the influence of heavy selective thinning.

Key words: *Picea abies* Karst., increment of growth elements, differentiation of trees, increment potential.

Introduction

In Serbia excluding Kosovo, Norway spruce cultures cover an area of 32,400 ha (Banković et al, 2009). A large number of these cultures typically had a spontaneous development in the first decades after the establishment. The first thinnings were usually carried out at the age when economically viable assortments were most likely to be obtained. Such a trend has also been a characteristic of other conifer cultures throughout Europe because late crown thinnings provide higher and more valuable cutting yields (Slodičak et al, 2005).

The results of long-term research of the effects of thinnings in spruce cultures generally indicate that the stands have a positive reaction to the thinnings, regardless of the age when commercial thinnings are performed (Mäkinen and Isomäki 2004a, 2004b). Based on the results of the research on the application of two heavy selective thinnings on a permanent experimental plot in Serbia, a positive reaction of the tree for tending, *i.e*. the future trees, was determined at the age from 32 to 50 years (Bobinac et al., 2017). However, under conditions of ice and snow breaks to which the researched stand was exposed, a permanent selection of trees for tending based on the approach introduced by Schedelin (1934) was applied, and the reaction of trees depending on their dimensions was not clearly defined.

The aim of the paper is to point out to the characteristics of the increment of the growth elements (height, diameter, basal area and volume) of trees under the influence of two heavy selective thinnings depending on their dimensions, *i.e.* their breast height diameters, and to

define groups or the number of trees in certain stages of development with a similar reaction of the increment of growth elements to thinnings.

Materials and methods

The research was conducted in a Norway spruce culture on Velika Brezovica of the Kučaj mountain range in northeastern Serbia (MU Bogovina I, compartment 87a) which was established by afforestation of pasture with dense planting (2×1 *m*), and according to the available data from the management records it had not been thinned before the age of 32 years. A permanent experimental plot was established in the culture in 1994 when it was at the age of 32 years and in which strong heavy selective thinning was carried out. The second thinning, which was also a heavy selective thinning, was carried out when the culture was 40 years old. In the first thinning 1,378 trees were cut per hectare (35.2%), with a volume of 115.1 $m^3 \cdot ha^{-1}$, while in the second thinning 911 trees per hectare (46.1%) were felled down with the volume of 142.3 $m^3 \cdot ha^{-1}$ (33.7%) (Bobinac *et al*, 2017). All trees on the experimental plot were numbered and at the age of 32, 40 and 50 years two cross diameters at breast height, with an accuracy of 1 mm, were measured. For the construction of the height curve, the heights of the trees are measured with a Vertex III type hypsometer.

The influence of the thinnings on the current (average periodic) height increment (i_h), diameter increment (i_d), basal area increment (i_g) and volume increment (i_v) was analyzed with an identical group of trees that grew after the thinning in the period from 33 to 40 years and in the period from 41 to 50 years.

Testing the differences between mean increments of growth elements among the observed two periods was done with a t-test. The ANOVA and least significant difference ($LSD_{0.05}$) tests were used for testing differences between the average size of the increment of growth elements of trees grouped by the size of their breast height diameters in groups of 200 trees per hectare.

Results and discussion

The mean value of the current height increment of 52 $cm \cdot year^{-1}$ was significantly higher in the period from 33 to 40 years, compared to 42 $cm \cdot year^{-1}$ in the period from 41 to 50 years. However, the mean value of diameter increment (5.1 $mm \cdot year^{-1}$), as well as basal area (18.98 $cm^2 \cdot year^{-1}$) and volume increment (24.12 $dm^3 \cdot year^{-1}$) per tree, was significantly higher in the period from 41 to 50 years in relation to the mean value of diameter (3.1 $mm \cdot year^{-1}$), as well as basal area (8.92 $cm^2 \cdot year^{-1}$) and the volume increments (11.23 $dm^3 \cdot year^{-1}$) per tree in the period from 33 to 40 years (Figure 1).

Increments of growth elements grouped by the size of their breast height diameters into groups of 200 trees per hectare significantly differ in all increments and in both researched periods (Table 1).

The mean values of current height increments by groups of 200 trees per hectare, sorted by its diameters, show that the thickest trees have the highest current height increments in both periods and that increments are decreased in the thinner trees. The height increments of 600 thickest trees per hectare are uniform in both periods, and there are no significant differences between them. The mean values of current diameter increments, as well as basal area and volume increments per tree, are the highest in the thickest trees and are reduced in the thinner trees in both researched periods after the implementation of a heavy thinning. However, in the period after the first thinning a group of 600 thickest trees per hectare had a uniform diameter increment of 4.9-5.2 $mm \cdot year^{-1}$, a basal area of 15.5-17.4 $cm^2 \cdot year^{-1}$ and a volume of 18.5-23.4 $dm^3 \cdot year^{-1}$, as opposed to the period after second thinning, in which a group of 200 thickest trees per hectare with a current diameter increment of 7.5 $mm \cdot year^{-1}$, a basal area of 33.5 $cm^2 \cdot year^{-1}$ and a volume of 44.3 $dm^3 \cdot year^{-1}$, are separated. A group of 201-600 trees per hectare, sorted by their diameters, has significantly less current increment compared to the

group of 200 thickest trees per hectare, but also significantly higher than the next groups of thinner trees (Figure 2).

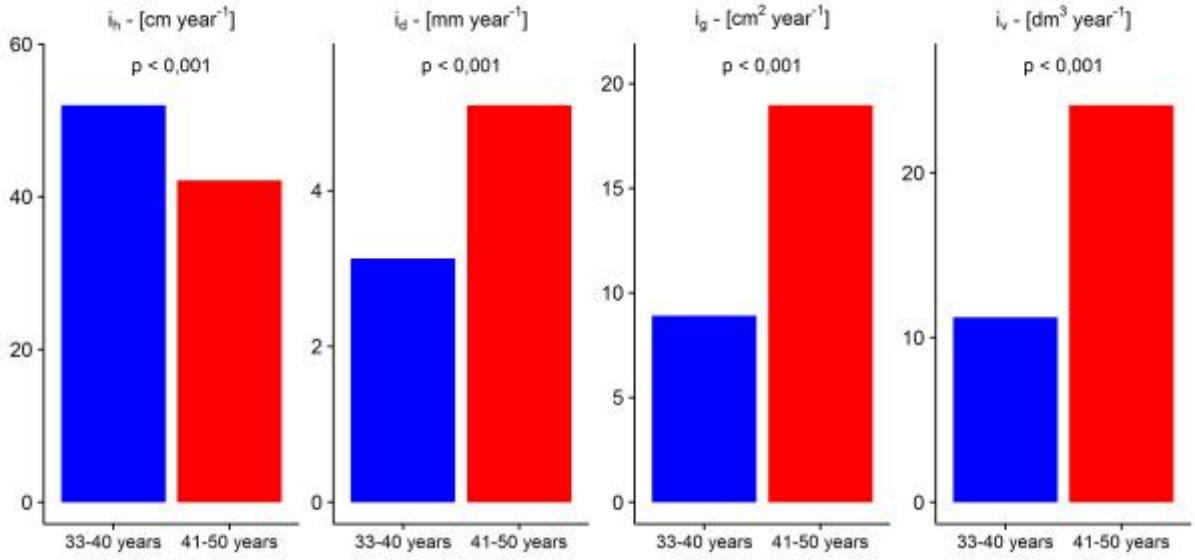

Figure 1. Average values of current increments of height, diameter, basal area and volume per tree in periods 33-40 and 41-50 years.

Table 1. Results of the ANOVA test (F coefficient) of the comparison of height, diameter, basal area and volume per tree of different breast height diameters by groups of 200 trees per hectare.

Period	Current increment of the growth elements			
	i_h	i_d	i_g	i_v
33-40 god.	595.68***	217.16***	294.58***	413.20***
41-50 god.	88.35***	108.30***	148.57***	164.22***

The thinning made in 32 years was the first intervention in the researched stand and was carried out in a period that does not significantly differ from the period when the first commercial thinnings in Europe were performed (Slodičak, Novak, 2003). Based on the characteristics of increments of the diameter and height of the dominant trees, the thinning is characterized as a delayed tending measure (Bobinac, 2004). However, the dominant trees, in particular 400 thickest trees per hectare, were in the phase of significant height increments at the time of the thinning, which conditioned the maintenance of high height increments in the period from 33 to 40 years. The mean height increment of 0.5 m·year^{-1} is in agreement with the growth characteristics of spruce trees at a similar age when the thinnings begin (Stojanović and Krstić, 1984, Orlić, 1991). However, the current height increment of the mean tree in the researched culture is higher compared to the height increment of the trees after the application of different thinnings on several series of experimental trials in the Czech Republic at a similar age (Slodičak, Novak, 2003). Makinen and Isomaki (2004a) state that the height increment does not depend on the intensity of the thinning and decreases with the age of trees, which is in line with our results.

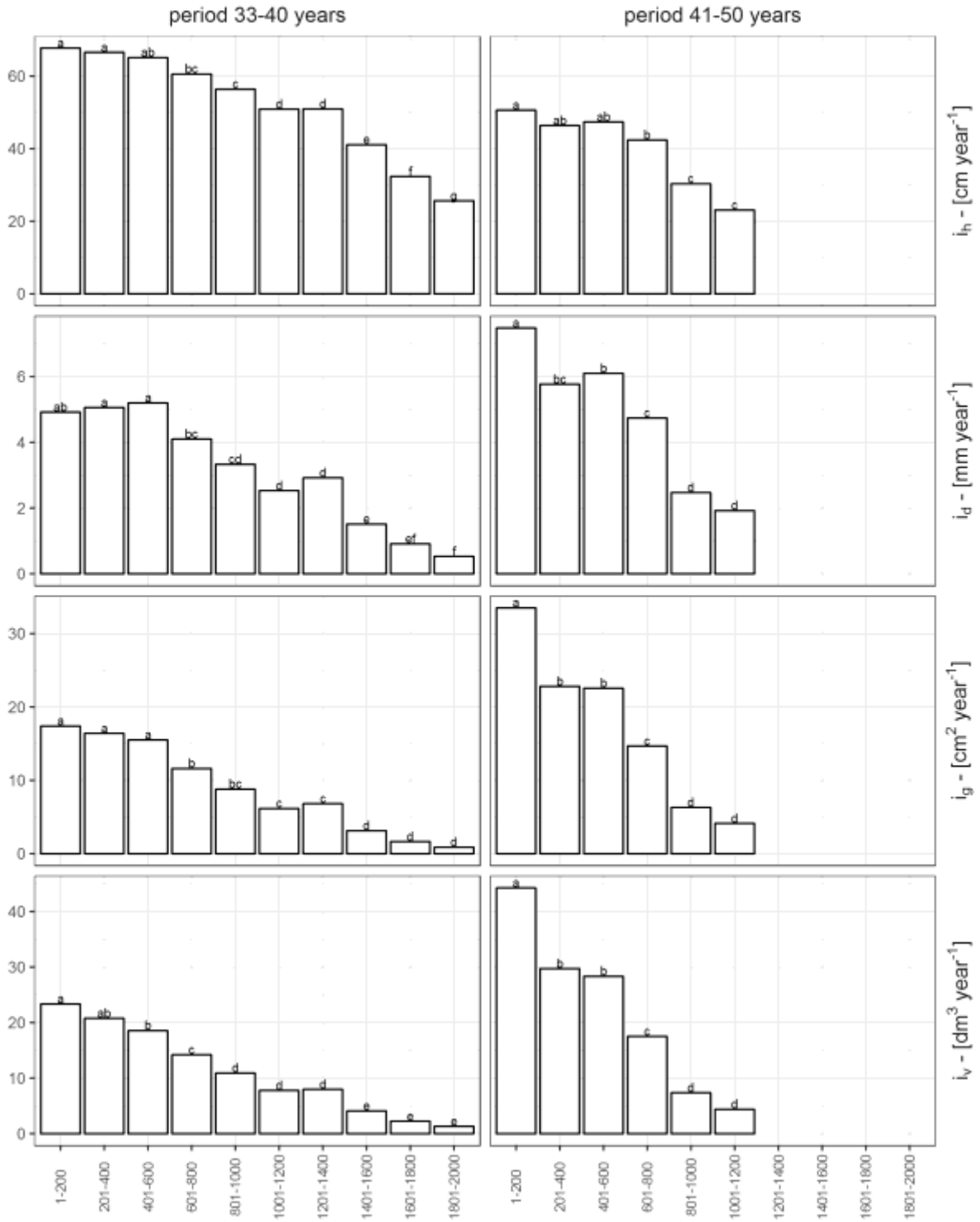

Figure 2. Current increments of height, diameter, basal area and volume of trees grouped according to the size of their breast height diameters in groups of 200 trees per hectare in the periods 33-40 and 41-50 of culture age.

During the period from 33 to 40 years, there was noted a weak reaction of diameter increment on the remaining trees, which is a consequence of a large number of trees, i.e., the absence of thinnings in the previous period. The current diameter increment of the remaining trees after thinning in the researched culture (0.31 cm·year^{-1}), compared with the results of Stojanović and Krstić (1984), is similar to the diameter increment on the control plot in two five-year

periods (0.34 cm·year^{-1}) with a 30% higher number of trees per hectare in the period from 32 to 42 years.
The second thinning at the age of 40 years caused a significantly higher diameter increment, i.e. a better reaction of diameter increment on the remaining trees compared to the thinning in the age of 32 years. The difference in the diameter increments between the two observed periods in the examined stand agrees with the results of other authors that spruce trees in the stands at favorable habitats and with a number of trees that are not too large for the appropriate age positively respond to thinnings and in the later period (Mäkinen and Isomäki, 2004a; 2004b; Preuhsler and Schmidt, 1989).
The increments of different elements of tree growth (height, diameter, basal area and volume) are reduced with decreasing breast height diameter of trees that are in line with previous research (Mäkinen & Isomäki, 2004b). This means that the effects of the thinnings are greatest in the trees of larger dimensions in the stand, that is, smaller trees are not able to react to the increasing space for growth as strongly as the larger trees can do.
The diameter increments of 200 and 400 of the thickest trees in the examined stand from 4.9 to 5.2 mm·year^{-1} in the period after the first thinning are somewhat higher (5-20 %) than the increment of the same group of trees in several series of experimental plots with a heavy crown thinnings in Sweden (Karlsson, 2006). Compared to the above results, *i.e.* diameter increments of the same collective of trees after the application of heavy low thinnings, the diameter increments at the experimental plot after the first thinning are smaller by 50% and are in the range with the obtained diameter increments at the control plots. Also, the diameter increments of 200 and 400 thickest trees per hectare in the period after the second thinning on the series of experimental plots where low thinnings were performed, as well as on the control plots, are smaller than in the period after the first thinning, and are larger only on the experimental plots with a heavy crown thinning, which is in line with our research.
Diameter increment of the 600 thickest trees per hectare in the examined culture in the period of 33-40 years was significantly smaller than the increment of the similar number of future trees per hectare when the first thinning is carried out at the age of 20 years (Štefančik, 2012). However, the diameter increment of 200 thickest trees per hectare of 7.5 mm·year^{-1} on our examined plot in the period after the second thinning is in agreement with the results stated by Štefančik (2012).
Basal area increment per tree of the 600 thickest trees in the stand after the thinning in the year of 32, from 15.5 to 17.4 cm^2·year^{-1}, is in the ranking with the increment of the basal area of the 300 thickest trees per hectare in the spruce stands in Finland in which heavy low thinnings were carried out in the early period of development, *i.e.*, they are in the ranks with increments of the 100-150 thickest trees when heavy low thinnings performed in the later period (Mäkinen and Isomäki, 2004b).

Conclusions

The results of the study show that the characteristics of increments of the growth elements (height, diameter, basal area and volume) of the spruce trees vary depending on the condition and intensity of the thinnings. In the period after the first thinning in the age of 32 years compared to the period after the second thinning in the age of 40 years, it is a significantly higher increment of height, which is a consequence of high height increments after culmination. In contrast, diameter increment, as well as basal area and volume increments, are significantly smaller, which is a consequence of a large number of trees and the absence of thinnings in the earlier period.
By grouping the trees into groups of 200 trees per hectare sorted by their breast height diameter after the first thinning was shown that the 600 thickest trees per hectare have a uniform reaction of diameter, basal area and volume increments, that is, those trees that had

the greatest increment potential. The second thinning allowed a more intense reaction of all the remaining trees, but the highest diameter, basal area and volume increment had only the 200 thickest trees per hectares. This indicates to intensive tree differentiation according to the increment potential under the influence of heavy selective thinning and that the increment potential of the tree is related to their dimensions.

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