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# DEVELOPMENT OF BEECH TREES IN MIXED FORESTS OF SPRUCE, FIR AND BEECH (*PICEETO-ABIETI-FAGETUM*) ON MT. LJUBIŠNJA
# RAZVOJ STABALA BUKVE U MJEŠOVITIM ŠUMAMA SMRČE, JELE I BUKVE (*PICEETO-ABIETI-FAGETUM*) NA LJUBIŠNJI

**Abstract**

In order to analyse the developmental characteristics of beech in tri-dominant mixed forests of beech, fir and spruce (Piceeto-Abieti-Fagetum s. lat.) on Mt. Ljubišnja, one dominant beech tree has been felled at each of the eight experimental plots. By studying the pattern in development of those trees, it was established that the slow growth (so-called vegetative time) period lasted longer in trees from the Vukodol site, on the limestone soils.

**Key words:** beech, stem analysis, increment, Ljubišnja

**Izvod**

U cilju analize razvojnih karakteristika bukve, u trodominantnim šumama bukve, jele i smrče (*Piceeto-Abieti-Fagetum* s. lat.) na Ljubišnji oboreno je po jedno srednje dominantno stablo svake zastupljene vrste na osam oglednih parcela. Proučavanjem zakonomjernosti u razvoju stabala, utvrđeno je da je vrijeme usporenog rasta (tzv. vrijeme vegetiranja) trajalo duže kod stabala sa lokaliteta Vukodol na krečnjačkoj podlozi.

**Ključne riječi:** bukva, analiza stabla, prirast, Ljubišnja

## INTRODUCTION

Forest eco-systems of Mt. Ljubišnja are typical representatives of massifs rich in high mountainous, mixed deciduous-coniferous forests (Čurović et al. 2011). Tri-dominant forests of beech, fir and spruce (Piceeto-Abieti-Fagetum s. lat.) are of great significance for science, as well as for practice. These are high production class forests, in which all three edificators achieve large stem dimensions, both in height and width, and most of them live to an old age. Taking into account the importance of mixed forests of beech, fir and spruce, they should be protected from further deterioration in future. For that reason, these forests were selected for the groundwork of this research.

The stability of these stands, according to Hartman (1999), is reflected in the ability of beech to act like alabaster and fill in the gaps that result from the death of certain trees, and in the extraordinary ability of fir to persist in shade,

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interposing itself among shoots of the beech. Fir trees can stay in a latent state for up to 330 years (Banković et al. 1994). On the basis of 230 trees felled in select stands in Serbia, Pantić et al. (2011) stated that the duration of the vegetative time for fir trees on Mt. Goč was up to 330 years, while the stagnation stage on Mt. Tara was up to 185 years. Higher plant density is more favourable for spreading and survival of fir trees, while lower plant density better suits the more heliophilic beech.

Growth and productivity of beech depend on silvicultural form, habitat and stance features. In optimal habitats in Serbia (Medarević 2005) beech trees can attain heights of 45 meters and above, and stem diameters of up to 1.5 m. In closed stands, young specimens of this species are characterised by pronounced heliotropic growth. Although it tolerates shade well, particularly in youth, its growth and increment depend very much on the quantity of light. Absence of light can slow down beech growth significantly.

Study of the pattern of stem development, as well as observing the stands in general, reveals, first of all, the biological features of certain tree species and their productive capacity. Such studies, in addition to their theoretical contributions, also have practical importance: they are an important component in determining the most favourable management practices (Banković and Pantić 2006).

Stem analysis is a procedure used to establish the stem growth in the past by directly measuring accumulated increments in height and thickness. The analysis determines the dimensions and the volume that the stem had at the end of certain life stages. The recommendation of Husch (1963) was accepted, according to which forming and marking of ten-year periods in cross sections are done from the periphery towards the centre.

## MATERIALS AND METHOD

Eight permanent experimental plots were set up, of which four are on sites with limestone and four are on sites with silicate soils. Four experimental plots (OP1-OP4) were set up in the vicinity of the village Vrba (site Vukodol), which is on limestone soil, and the other four (OP5-OP8) were set up in the vicinity of the mining settlement, Šula, where basic eruptives occur as parent substrate. On these sites (Vukodol and Šula) pedological profiles were opened, too, in order to obtain more exact data on soils.

The main criteria for selection of stands where the permanent experimental plots were set up was that they had to be among the best stands for a specific environmental unit (homogeneous, and with optimal inventory size and structure) and that all of them, under all separate environmental units, were at approximately the same developmental stage (Jović et al. 1991). In the process of selecting the experimental plots, care was taken to ensure that the conditions of homogeneity of habitat and stand circumstances were met.

For the purpose of analysing the developmental features of individual stems, one medium dominant tree of each of the species represented was felled from

each of the permanent experimental plots. These were stems of extraordinary age and dimensions. The age of the spruce trees was over 250 years, while the fir trees were up to 300 years of age.

Image 1. Samples for analysis of a beech stem
*Slika 1. Uzorci za analizu jednog bukovog stable*

The analysis established the dimension and volume of the stem at the end of certain life stages.

Round cross cuttings (tree cookies) were analysed, taken at heights of 0.30 m, 1.30 m, and 5.30 m, and then at every 2 meters to the top of the stem. The data obtained were processed with support from specialised data processing programs adjusted to "Apple Macintosh" personal computers at the Department for Increment, Technical University Munich.

The recommendation of Husch (1963) was accepted, according to which forming and marking of ten-year periods in cross sections are done from the periphery towards the centre. In that way, the oldest (central) period at the cross section remains largely incomplete.

Although applicability of this method was disputed in the United States, because, according to Meyer (1953), analysis of one or several stems is not enough to establish with adequate confidence the patterns of increment of a stand, and hence it is not possible to make development forecasts; this has been the most frequently used method, and the one still applied, in European forestry science and practice. According to the European school of thought, this is the most accurate method for determining the development and increment of volume and its elements during the whole lifetime of a tree.

Image 2. Marking of ten-year periods in cross sections of felled trees
*Slika 2. Obilježavanje 10-godišnjih perioda na poprečnim presjecima*

## RESULTS AND DISCUSSION

Stem analysis is a procedure used in order to establish stem growth in the past by directly measuring accumulated height and width increments (Husch, B. 1963). Felling of four trees from the experimental plots (OP1 - OP4) set up in the vicinity of the village of Vrba (Vukodol site), which is on limestone soil, and of four trees from experimental plots in the vicinity of the mining settlement, Šula, where basic eruptive occurs as the parent substrate, and subsequently analysing the development of their stems resulted in important conclusions on the homogeneity of conditions for the growth of dendrofloral elements and their correlation depending on habitat conditions.

The analyses of physical properties of soil showed that sandy loam is present at the Vukodol site (samples M1 and M2), while the first layer at the Šula site (sample M3) was clay loam by texture, and the second (sample M4) was light loamy soil (Table 1).

Table. 1. Physical properties of soil
*Tabela 1. Fizičke osobine zemljišta*

| No. prof | Site (location) | Sample | Depth (cm) | Granulometric composition in % | | | | | | Hygroscopic humid. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 2.00-0.25 | 0.25-0.02 | 0.02-0.002 | < 0.002 | Total sand | silt + oam | |
| 1 | Vukodol | M 1 | 0-5 | 32.56 | 39.84 | 17.50 | 9.80 | 72.70 | 27.30 | 4.57 |
| | | M 2 | 6-60 | 31.52 | 37.02 | 19.25 | 11.91 | 68.85 | 31.15 | 2.05 |
| 2 | Šula | M 3 | 0-5 | 0.74 | 32.06 | 44.50 | 22.70 | 32.80 | 67.20 | 3.15 |
| | | M4 | 6-60 | 0.19 | 26.01 | 33.65 | 40.15 | 26.20 | 73.80 | 2.82 |

Lines of beech height development basically have an S-shaped flow with a relatively long spurt phase (from 60 to 100 years) at the Vukodol site (Chart No.

1), a phase of unhindered development – with a swing lasting from 20 to 40 years and the slow-down phase lasting over the following 20 years.

In regard to the assessment made above, the spurt phase at the Šula site was shorter (40 to 60 years), the swing phase was 20 years and the slow-down phase was 20 years (Chart No. 2).

Development lines from the breast diameter of analysed beech stems from the Vukodol site (Chart No. 3) also have an S-shape flow. The stage of slower growth of breast diameters from experimental plots 1 and 2 lasted for quite a long time (90 to 100 years), followed by a phase of more intensive thickness development of 30 years. In these trees, somewhat slower intensity of growth of breast diameters has been noted in the last 10 years. The analysed beech trees from experimental plots 3 and 4 show a somewhat different flow of thickness development. The phase of slower diameter growth (20-30 years) was followed by a phase of intensive growth of breast diameters until the age of 80, followed by a slow-down phase of 20 years.

From the Šula site (Chart No. 4), beech stems from experimental plots 5 and 7, exhibited a phase of slower growth in diameter (40-50 years), and followed by a more intensive width growth of these stems. In beech stems from experimental plot 8, for the phase of intensive diameter growth in the first 40 years, it can be noted that the intensity of growth in width fell. The analysed beech stem from experimental plot 6 is characterised by quite a balanced upward flow of the breast diameter development line.

The volume development lines of beech in Vukodol have a similar flow (Chart No. 5). The period of vegetation, which lasted 60 years in stems from experimental plots 3 and 4, and 100-110 years in stems from experimental plots 1 and 2, was followed by a clear upward trend of the lines. On the Šula site, the vegetation period was somewhat shorter (20-60 years), followed by an upward trend of volume development lines, which was not quite as clear (Chart No. 6).

After the low values of the current volume increment of beech stems analysed from the Vukodol site, for 40 years (beech 3 and beech 4), and for 80 years (beech 1 and beech 2), "waking up" of volume increment is quite clear until peak values were reached, followed by the wavy flow of the current increment curve (Chart No. 7).

A shorter phase of insignificant volume increment can be noted, judging by the current increment curves of the beeches from the Šula site (Chart No. 8). After about 20 years with an upward trend in these curves, stagnation in values of the current volume increment can be noted, probably caused by unfavourable positioning of the trees in the stand.

Average volume increment in beech culminates quite late, as a rule after 150 years, while in intensively thinned stands it is after 100 years (**Medarević,** 2005). Average increment in better productivity classes ranges between 10 and 14 $m^3 \cdot ha^{-1}$. In poor habitats, the culmination takes place even later, while the increment at the moment of culmination (in well grown stands) is about 2.5 $m^3 \cdot ha^{-1}$.

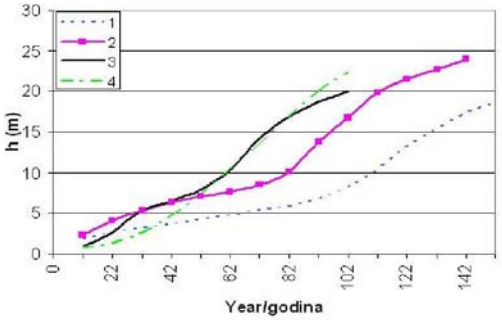


Chart 1. Height development – Vukodol
*Graf. 1. Razvoj visina - Vukodol*

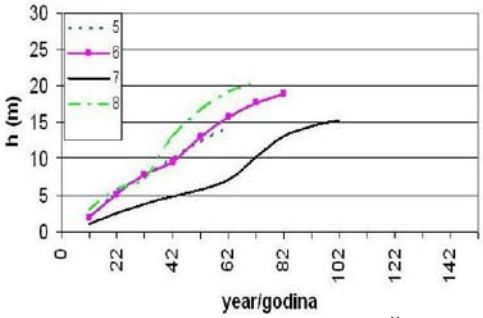


Chart 2. Height development – Šula
*Graf. 2. Razvoj visina - Šula*

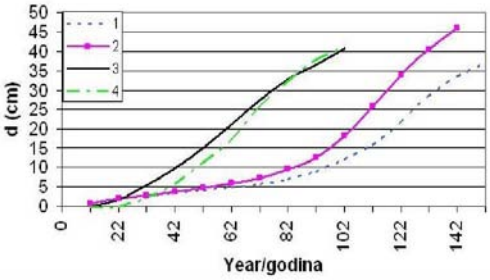


Chart 3. Breast diameters development – Vukodol
*Graf. 3 Razvoj prsnih prečnika - Vukodol*

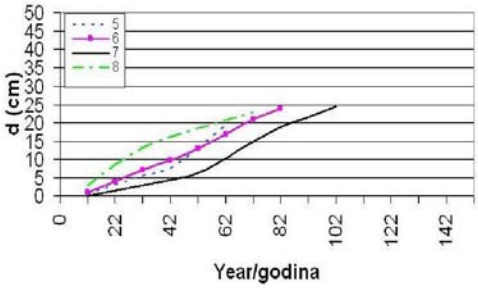


Chart 4. Brest diameters development – Šula
*Graf. 4. Razvoj prsnih prečnika - Šula*

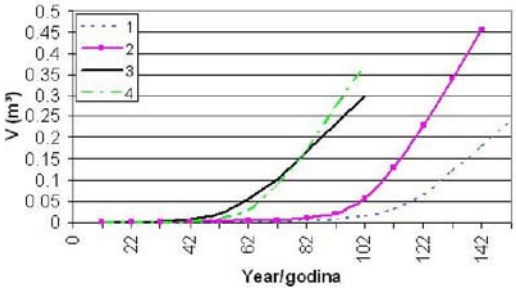


Chart 5. Volume development – Vukodol
*Graf. 5. Razvoj zapremina - Vukodol*

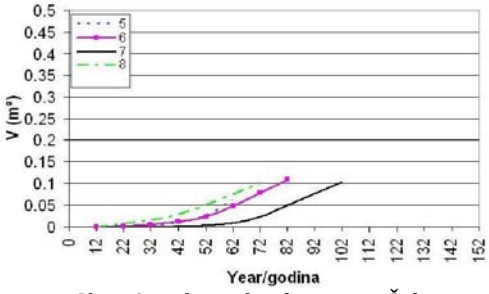


Chart 6. Volume development – Šula
*Graf.6. Razvoj zapremina - Šula*

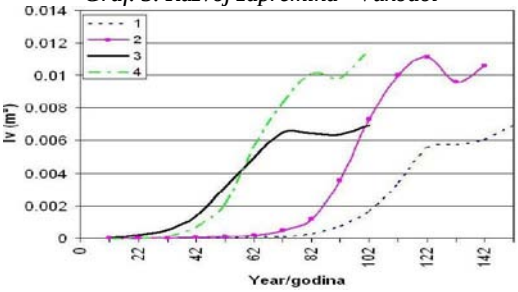


Chart 7. Volume increment – Vukodol
*Graf. 7. Zapreminski prirast - Vukodol*

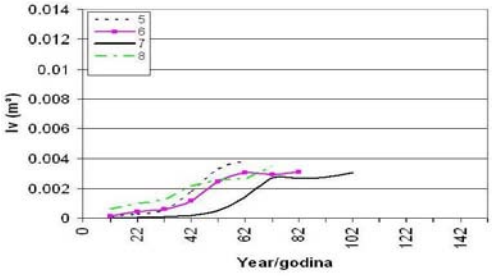


Chart 8. Volume increment – Šula
*Graf. 8. Zapreminski prirast - Šula*

## CONCLUSION

Some general characteristics of development of the stems analysed are as follows:

- The period of slow growth (the so-called vegetative time) lasted longer in stems from the Vukodol site;
- The analysed beech stems from Vukodol are older and of larger dimensions, with a longer vegetative stage;
- The analysed beech stems from the Šula site show slightly pronounced growth intensity, particularly in height (with the exception of beech from OP 7).

The wavy flow of curves in the current volume increment can be explained by occasional deterioration of the canopy, releasing the trees from shade and re-establishing the full plant density by extension of the crowns of overstore trees.

The results presented suggest that keeping beech in a stand for longer periods is justified, and therefore there is a wide range of potential management practices when it comes to beech.

The results confirmed that beech is a species that has a good height and volume increment at an advanced age. Average volume increment in beech culminates quite late. Late culmination of an average volume increment suggests that planning longer rotation is economically justified. This should be considered with some caution, since it can be risky in some cases, as occurrence of red heartwood and other damage can significantly reduce the value of the volume produced.

The research of the flow of growth and attainable dimensions of concrete dendroflora elements, in this case in beech, in forests with preserved stands as in Mt. Ljubišnja, doubtlessly contributes to setting the objectives of forest management in this and similar forest communities.

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## DEVELOPMENT OF BEECH TREES IN MIXED FORESTS OF SPRUCE, FIR AND BEECH (*PICEETO-ABIETI-FAGETUM*) ON MT. LJUBIŠNJA

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***Summary***

Felling of four trees within the experimental fields (OP1 - OP4) that have been set near the village of Vrba (Vukodol site), which is on a limestone base, and four trees from experimental fields in the vicinity of the mining village of Sula, situated on basic eruptives, with later stem analysis of these trees, gave us important conclusions about the basic characteristics of beech growth in these forest communities. This provided insight into the relations and impact of habitat characteristics on the development of beech trees in mixed stands of beech, fir and spruce on Mt. Ljubišnja.

The given results are a contribution to the understanding of complex systems such as these forest communities. To meet the growth and achievable dimensions of beech trees from stands like those that have been studied on Mt. Ljubišnja, while observing a high level of conservation, would provide a significant contribution to the creation of forest management goals in these and similar forest communities.

The results confirmed that beech trees at a very advanced age could have a good height and volume increment. The average increment of beech culminated very late. These facts may be applicable in designing management goals for these and similar stands.