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Dear readers,

Joyfully we announce that the second edition of SEEFOR journal has emerged! Five papers in this edition are bounded with concept familiar to all of us- the concept of Sustainable Forest Management (SFM). It is about taking care of ecological, economic and social aspects in forest management in order to maintain continuity of myriad of benefits forests provide to society. In a time when all scientific community is buzzing on climate change this is more salient than ever. Assessment of SFM in Croatia is dealt with Lovrić et al. by using quantitative Criteria and Indicators brought by Forest Europe (previously MCPFE). Continuous measurement of forest stock, stand structure and like is important quantitative input for all further research on forests. Novotny et al. brings overview of forest measurement data in well-known protected area in Croatia and UNESCO heritage site- The Plitvice Lakes. How to maintain provision of forest services by using different payment mechanisms (i.e. green tax and carbon credits) is topic of two papers written by Nijnik et al. and Vuletić et al. These two papers were presented at the International Conference-Forum Emerging Economic Mechanisms: Implications for Forest-Related Policies and Sector Governance held in FAO, Rome on 5-7 October 2010, which together with Committee on Forestry Week gathered significant number of participants from all over the world. The last, but not the least, Kiš in paper on social conflicts between forestry and nature protection sector on Velebit Mountain in Croatia brings some results from his master theses. This study was included in regional study of forestry related conflicts in SEE region as a part of FOPER project (Forest Policy and Economics Education and Research).

Until next edition wish you a pleasant reading.

Dijana Vuletić, Editor-in-chief

Contents

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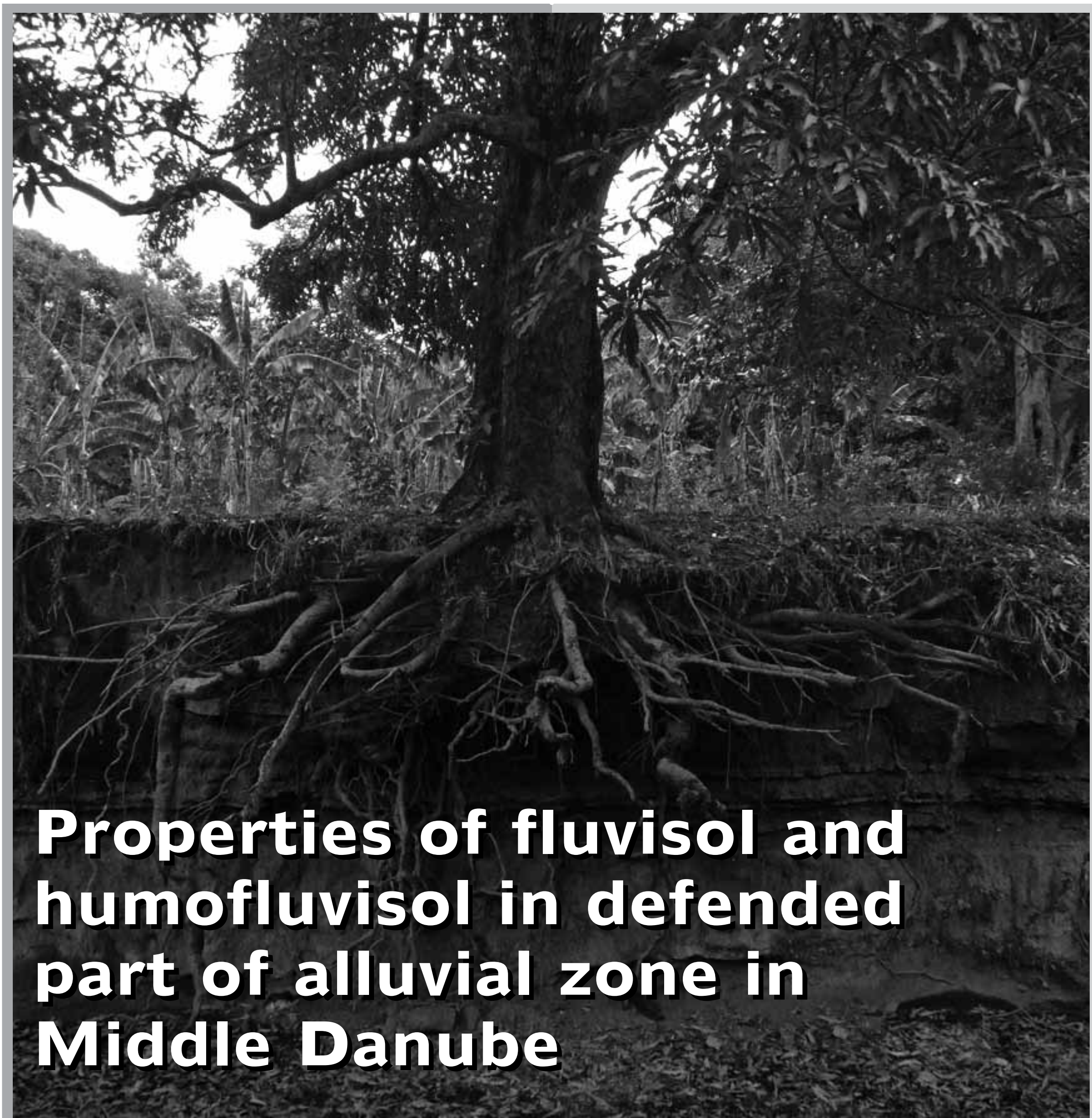
ORIGINAL SCIENTIFIC PAPERS



Properties of fluvisol and humofluvisol in defended part of alluvial zone in Middle Danube

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Background and purpose:
In paper analyzed the characteristics of the soil in the defend part of the alluvial plains in the Middle Danube region.

Material and methods:
The research was carried out in the protected part of the river Danube riparian zone. Particle size composition, density and specific gravity, as well as chemical properties were determined by standard laboratory methods.

Results and Conclusion:
At the investigated sites determinated two types of soil (humofluvisol and fluvisol). Within fluvisol were separated in two forms, namely: sandy and loamy. Content analysis and distribution of silt + clay fraction, and analysis of the timing and content of humus in the depth profile is determined by the closeness in the genesis of humofluvisol and loamy form of fluvisol. Application of multivariate analysis defined two categories of soil of ecological production.

Key words:
humofluvisol, fluvisol, Danube

INTRODUCTION

Soil formation in the alluvial plains is conditioned by the river transport competency, fluvial sedimentation and by the dynamics of surface and ground waters. The process of fluvial sedimentation is a dynamic and irregular process in space and time, which results in sudden changes of textural compositions in the vertical sections of the profiles (1, 2, 3, 4) at short distances and a prominent micro-relief (5, 6, 7, 8, 9, 10). Different conditions of soil formation conditioned significant differences between soil types, but also between lower systematic units (variety and form).
Previous research shows that the presentation of simple analytical parameters does not reveal clearly enough the differences between soil types, and especially the lower systematic units, so a more reliable criterion is the diagnosis by the derived parameters, such as: supplies of humus, fraction silt + clay and available water (10, 11, 12).
All regions of the world experienced an extreme accelertion of dam-building activity (13). River regulation have impact on the hydrology of the forest sites (14).
Similar observations are reported from Austria (15), and from United States (16). Depending on the severity of the alteration of lowering the water table and reducing annual amplitude, hybrid poplar stands have exhibited reduced productivity. For this reason, special attention should be focused to the defended part of the alluvial plain, because of the absence of flooding. Defended areas in Central Danube Basin were flooded until 1928. After the construction of levees (dams) to protect from the Danube floods, these areas receive additional moisture only by groundwater.
The consequence is the changed direction of the pedogenetic process compared to the part of the alluvial plain affected by flooding, which causes the changes of site conditions.
The differences are seen in the vegetation type compared to the part of the alluvial plain influenced by additional moisture and flood and underground waters.
For this reason, the properties of different soil systematic units were compared based on analytical indicators of their physical and chemical characteristics, distribution of characteristics per profile depth and analysis of fertility elements.

MATERIAL AND METHODS

The research was carried out in the protected part of the river Danube riparian zone.
The study sample plots are situated in defended part of alluvial plain near Novi Sad in three poplar plantation. Particle size composition (%) was determined by the international B-pipette method with the preparation in sodium pyrophosphate; Soil

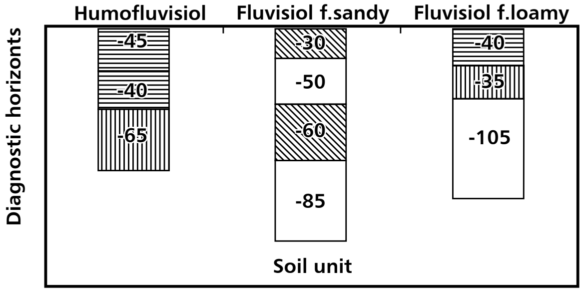

Figure 1
Morphological properties of study soils

particle classification in the particle size composition was based on Atterberg's classification; Specific gravity -Sp - (g/cm^3) was determined after Albert Bogs by using xylole as the inert liquid; Soil density -Sv - (g/cm^3) was determined in Kopecky cylinders volume 100 cm^3 (17).
Chemical characteristics were determined by laboratory research by the following methods: humus (%) after Turin modified by Simakov (18); reaction of soil solution was determined in H_2O and in KCl (19); the content of $CaCO_3$ was determined on Scheibler calcimeter.
Silt+clay and humus supply per hectare was calculated on basis of % and depth of each soil horizon depth and soil density.

RESULTS AND DISCUSSIONS

In WRB (20) fluvisols accommodate genetically young, azonal soils in alluvial deposits.

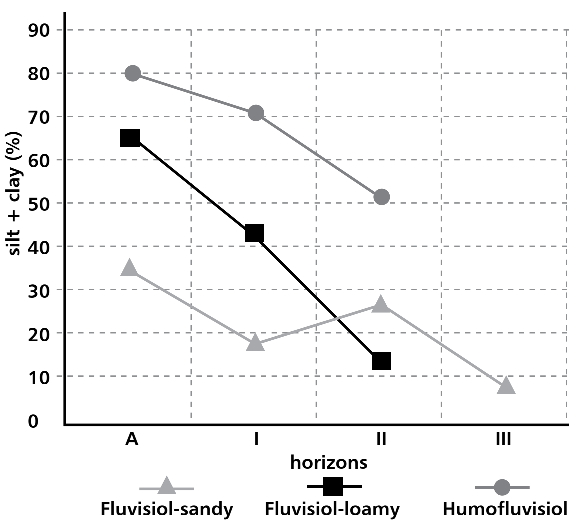

Figure 2
Distribution of the fraction silt + clay per profile depth

Fluvisols occupy some 350 million ha worldwide, of which more than half are in the tropics (20).
Poplar cultivation demand a differentation on more soil unit. For this reason we still use a regional soil Classification.
According to Soil Classification (21), two types of soil were recorded in the study field multiclonal poplar plantations, i.e.: fluvisol (morphological structure Ap–I-IIGso–IIIGso-Gr and Ap-IGso-IIGso-Gr) and humofluvisol (morphological structure Ap - C - Gso - Gr). Based on the above Soil Classification, two fluvisol forms were singled out based on the contents of the fraction silt + clay.
Based on the contents of these fractions, a sandy form (21.2 %) and a loamy form (39.8 %) of fluvisol were differentiated. The content of the fraction silt + clay in the sandy form has a discontinuous distribution per profile, which confirms the marked process of fluvial sedimentation in this form of fluvisol in the past. In the loamy form of fluvisol, the content of this fraction decreases regularly with depth, which indicates that the process of fluvial sedimentation was more steady and similar to the sedimentation process in humofluvisol (Figure 2).
Along with the content and distribution of the fraction silt + clay per profile depth, soil differentiation and diagnosis can also be based on the content and distribution of organic matter in the profile (11).
The average content of humus was the highest in humofluvisol, and the lowest in the sandy form of fluvisol. The analysis of humus content in the profile cross section shows that it decreases regularly with depth in the loamy form of fluvisol and in humofluvisol, which indicates a humus accumulation type of distribution of organic matter in the profile and a close genetic relation of these two systematic units of soil (Figure 3). However, in sandy fluvisol, the distribution of organic matter is conditioned by the discontinuity of the fraction silt + clay, as reported by Ivanisević et al (11).

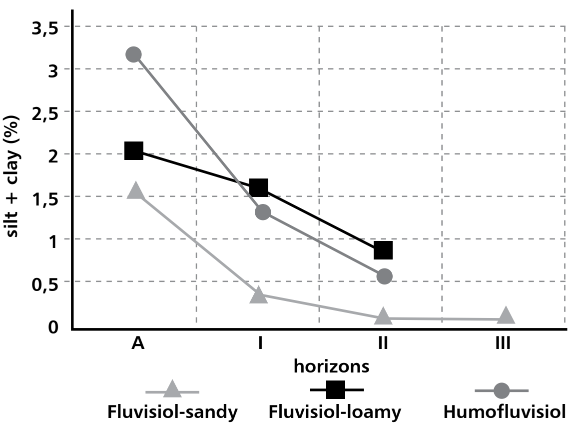

Figure 3
Humus distribution per profile depth

The above statement is also confirmed by the distribution of the supply of the fraction silt + clay and humus in the profile cross section.
The supply of silt + clay in humofluvisol was 13144 t/ha, in loamy fluvisol 7164 t/ha, in sandy fluvisol 5477 t/ha.
The results agree with the previous research by Ivanisevic (22) who reported for humofluvisol the supply of more than 10000 t/ha, loamy fluvisol - between 6500 and 8000 t/ha, and sandy fluvisol - less than 6500 t/ha. The supply of humus in humofluvisol was 335 t/ha, in loamy fluvisol 314 t/ha, and in sandy fluvisol 119 t/ha. These supplies agree with the previous research, as it was assessed that in the soils of the Middle Danube Basin the reserves of humus in humofluvisol were above 350 t/ha, in loamy fluvisol

from 250 to 300 t/ha, and in sandy fluvisol - less than 250 t/ha. The systematic units of the study soil were categorised by cluster analysis (Figure 4) and the groupings of individual layers of the study soil were compared (Figure 5).
Cluster analysis confirmed the grouping of loamy fluvisol and humofluvisol at short distances, which means that these soil systematic units are in a close evolution-genetic relation. In addition, this paper deals with the character of relations of individual layers in study soils.
This indicates the interrelationship (closeness) of individual process of soil formation, which are in a way reflected in the values of physical and chemical properties.Based on the cluster analysis dendrogram of the study soil horizons and layers (Figure 5) it was

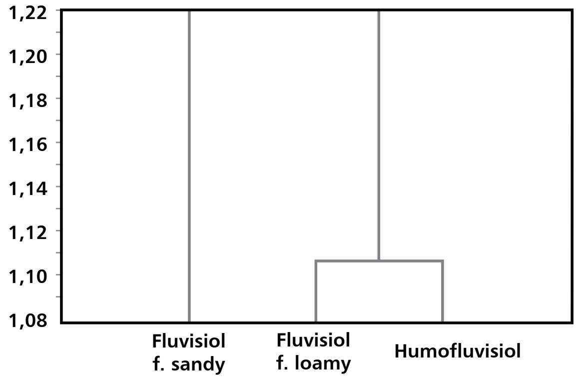

Figure 4
Cluster analysis dendrogram of the study soil systematic units

concluded that the processes of soil formation were close in loamy fluvisol and in humofluvisol.
This conclusion is supported by the grouping of humus accumulation horizons at short distances. The same Figure also shows that the conditions of soil formation of sandy fluvisol differed from the conditions in the two previously mentioned soil systematic units.
The Figure also shows the irregular grouping of layers and horizons below the humus accumulation horizon, which can be explained by the nature of soil formation in the alluvial plain.
The conditions of plant development deteriorated with soil depth which confirms the research by Zivanov (6) who reported that the depth of the profile from 30 to 150 cm is very important for poplar growing.

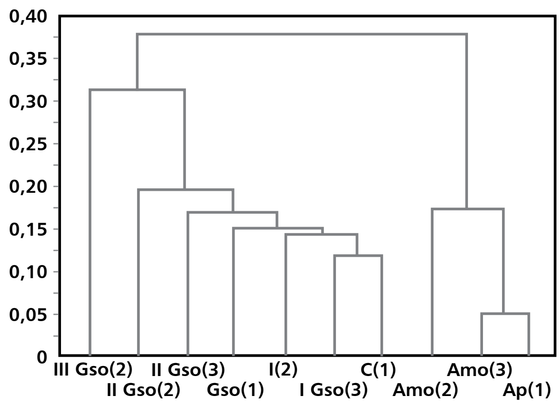

Figure 5
Cluster analysis dendrogram of the study soil horizons and layers (1 humofluvisol 2* sandy fluvisol 3* loamy fluvisol)*

CONCLUSIONS

The following conclusions can be made based on the above study:

- Two types of soil were in the Middle Danube Basin: humofluvisol and fluvisol. Fluvisol was differentiated into two forms, i.e.: loamy and sandy form of fluvisol;

- The analysis of distribution of the fraction silt + clay and the content of humus showed the closeness in the genesis of humofluvisol and loamy fluvisol as distinguished from sandy fluvisol;

- Depending on the accumulation of organic matter (humus), humofluvisol and loamy fluvisol are classified as humus accumulation types, while sandy fluvisol is a discontinuous type, i.e. it depends on the content of the fraction silt + clay.

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Structure and site potential of fir-spruce forests in Bosnia

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Background and purpose:
Regarding official management prescriptions managed fir-spruce forest stands, among others, in Bosnia are supposed to have all-aged structure. We compared the differences between actual and targeted structure in three fir-spruce stands in central Bosnia with special attention given to volume distribution throughout diameter classes. Therefore the aim of the research is to suggest silvicultural measures in order to achieve "ideal" structure on high potential forest sites.

Material and methods:
Collecting of field data was conducted in three managed fir-spruce stands (*Abieti – Piceetum illyricum*) at Dnolucka planina in central Bosnia. In each of them by one square-shaped sample area (0,25 ha) was set and inventory data were obtained by following standard procedure for permanent sample plots (total inventory). Data processing was performed by applying basic statistical methods.

Results and Conclusion:
It is known that timber overexploitation harms structure of forest stands; on the other hand, as the results in this paper show, scant management intensity doesn't provide "ideal" structure in fir-spruce stands on high potential sites either. Wood volumes obtained from sample plots in the stands range between 720,6 m^3/ha and 976,7 m^3/ha, which is quite above "normal" values established for managed all-aged forest stands, and hence neither of them has all-aged structure but rather some of transitional forms of uneven-aged structure.

Key words:
fir-spruce forest, stand structure, site potential, silvicultural measure

INTRODUCTION

The mixed fir-spruce forests in Bosnia and Herzegovina mostly represent secondary forest communities, i.e. transitory vegetation stage with progressive succession toward climate- regional communities of beech and silver fir with or without Norway spruce (1, 2). Optimization of choice of silvicultural system and skillfulness of its application in the field enable forest stands to develop in the direction of positive natural succession. However, fir-spruce stands often represent ultimate developmental stage due to a number of reasons (disorganized or illegal cuttings in the past, specific topography and soil properties, etc.).
In central Bosnia silver fir and Norway spruce occupy different soil types, while the bedrock is usually composed of limestone. Productivity of uneven-aged forests depends on the range of factors like: tree distribution, soil type, rainfall, light availabilty, etc. Biomass production can be positevely influenced by employing suitable silvicultural techniques with the aim of effective use of site potential, and thereby forest professionals do not pursue stand overstocking with trees of largest size but rather appropriate distribution of trees and volume throughout diameter classes, which provides ecological stability of a stand, high site potential and various structure of merchantable assortments.
Quantitative description of forest stand structure serves as a set of relevant information that forest practitioners use for regulating forest development dynamics and biomass production. Stand structure is often the primary component of the management regime because of its importance in multi-aged stocking control (3). In multi-aged stands, stand structure affects increment (4) and probably also species composition.
Nevertheless data collecting in the field is demanding and expensive, it is concurrently necessary for successful management planning. Once the field data are collected the forest structure can be swiftly and precisely described so that we can efficiently use it for assessment of silviculture influence on wood production.
Regarding that forest management of shade tolerant species (with different levels of tolerance) has „target“ to form and maintain all-aged structure, the subject of special interest among forest professionals is the degree of deviation of actual-stand structure elements from „balanced“ values that characterize all-aged selection stands.
However, all-aged structure is not only the result of natural processes. It is actually obtained and can be perpetually maintained only by regular and proper selection cuttings (5).
For that reason, all-aged forest cannot be identified with virgin forests as they are the result of nature and selection management (6). From management point of view, it is believed that those fir-spruce forests that have all-aged structure actually have ideal form of managed forest.
Specifically, our research was focussed: (i) to determine site potential of the mixed fir-spruce stands in central Bosnia and structural deviation of analyzed stands from standard equilibrium values, and (ii) to propose the most suitable silvicultural measures in order to achieve „targeted“ structure.

MATERIAL AND METHODS

Research was carried out in three forest (sub) compartments 81b, 82b and 82c sitauated at the elevation 1150 to 1250 m within management unit »Dnoluka«, forest management area »Srednjevrbasko« in central Bosnia.
These managed stands cover small areas of 4 to 12 ha each. In terms of phytocoenology the stands belong to the forest community *Abieti – Piceetum illyricum*, and according to eco-vegetation regionalization (1) they are located in the region of inner Dinaric massifs of central Bosnia. The stands fall into the class of high fir-spruce forests on deep brown soils and luvisols on limestone. Their topography is mostly in form of slight slopes (inclination 5° do 15°) with numerous depressions and they are exposed to north and northeast. Climate characteristics were determined by employing the method of Thornthwaite – Mather, and thereby the data from meteorological station in Jajce were used.
Annual climate class for the research area indicates moderate humid climate, while in the vegetation period subhumid wet climate predominates in the area.
In each stand by one square-shaped sample area (0,25 ha) was set and inventory data were obtained by following standard inventory procedure for permanent sample plots.
All trees with dbh above 5.0 cm are noticeably numbered, their diameters at breast height (1,30 m) and heights were measured, and 5 increment cores were taken from each diameter class in order to determine radial and volume increment. Data processing was performed by applying basic statistics with two-dimensional space, where axes represent the variables (X on the horizontal axis and Y on the vertical axis) and appropriate linear and non-linear regression lines (functions). Measured trees are grouped in diameter classes with a span of 5.0 cm. For analysis of radial increment, the number of statistical pairs (X, Y) is equal to the number of diameter classes multiplied by 5.
Tree height lines were constructed using Prodan's growth function (7). Site classes are determined by comparing the resulting height lines with the standardized height lines for silver fir and Norway spruce in Bosnia and Herzegovina, and wood volume by species was determined by using the existing volume tables (8). Volume increment was determined by applying Mayer's differential method (7).

RESULTS AND DISCUSSION

Structural elements of the stands

In the subject stands next structural elements were analyzed: dbh, height, number of stems per unit area, basal area, volume, and radial and volume increment.

Tree heights

Height curves clearly show that Norway spruce has somewhat bigger heights at the same dbh in comparison to silver fir in all subject stands. This regularity also was observed in virgin forests Perućica, Janj and Lom (9).

Table 1 *- Stand structure elements*

Stand	Stand structure elements per ha											
	Number of trees			Basal area m^2			Volume m^3			Ann. vol. increment m^3		
	fir	spruce	total	fir	spruce	total	fir	spruce	total	fir	spruce	total
81b	212	312	524	17,9	29,4	47,3	299,3	501,0	800,3	4,0	7,6	11,6
82b	420	352	772	21,0	26,9	47,9	319,8	400,8	720,6	3,5	4,1	7,6
82c	324	216	540	34,8	22,6	57,4	580,5	396,2	976,7	8,3	7,2	15,5

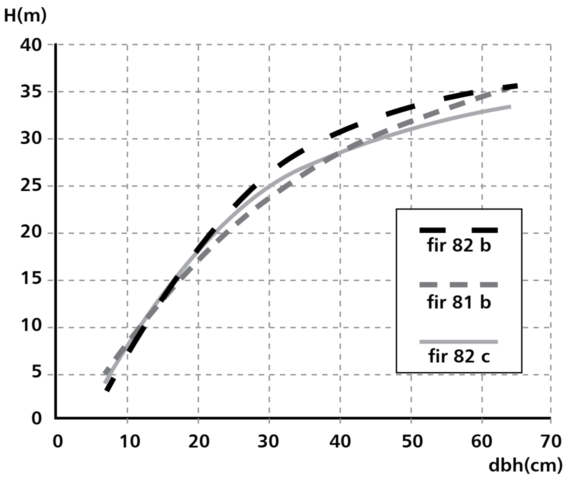


Figure 1 *- Height curves for silver fir*

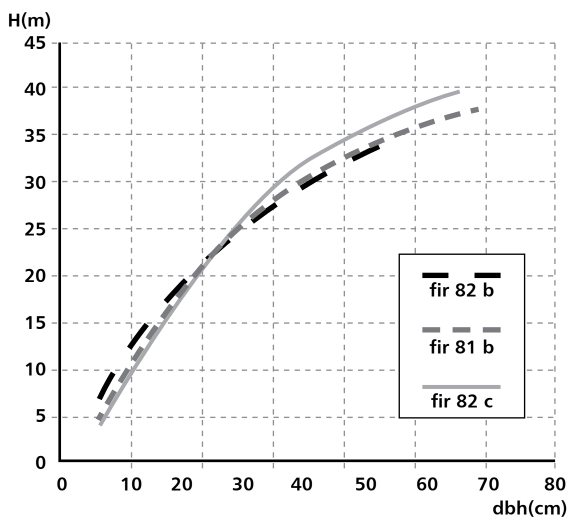


Figure 2 *- Height curves for Norway spurce*

For silver fir subcompartments 81b and 82b represent site class I and subcompartment 82c site class II. There are very suitable conditions for Norway spruce as well since subcompartments 81b and 82c represent site class I and subcompartment 82b provides site class II for spruce.

Tree distribution

Number of trees in a forest stand depends on numerous factors like: site class, canopy closure, composition ratio, management intensity, etc., which makes this element more susceptible to significant variations in comparison to other stand structure elements. In the subject stands tree distributions throughout diameter classes are shown in figures 3, 4 and 5.

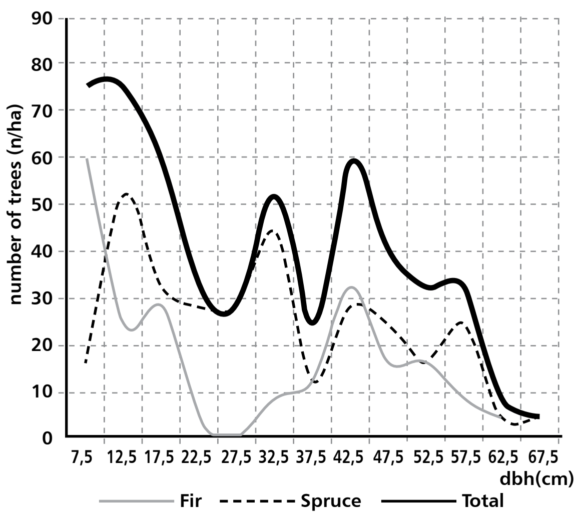


Figure 3
Tree distribution through diameter classes 81b

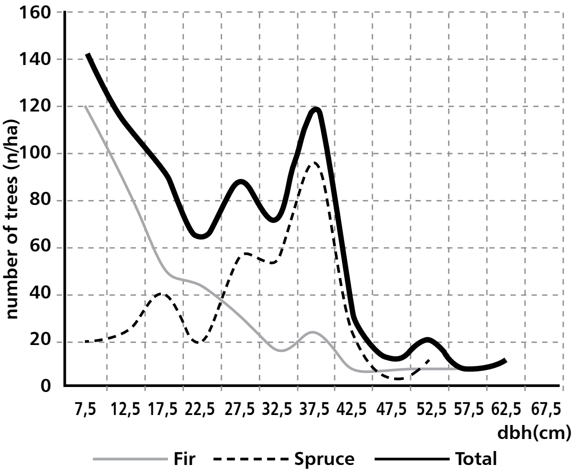


Figure 4
Tree distribution through diameter classes 82b

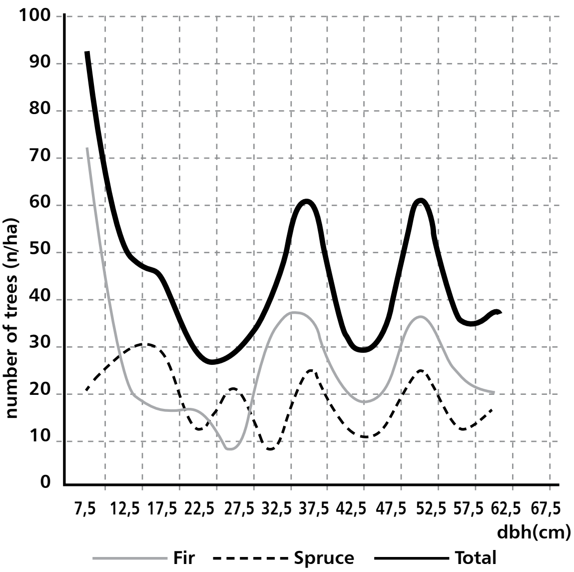


Figure 5
Tree distribution through diameter classes 82c

In the stand 81b Norway spruce predominates with 312 stems/ha or 59,5 %, and silver fir participates with 212 stems/ha or 40,5 %. In another two stands silver fir is more numerous.
In the stand 82b it has 420 stems/ha (54,4 %) compared with spruce that has 352 stems/ha (45,6 %); in the stand 82c silver fir predominates with 324 trees/ha (60 %) in relation to spruce that participates with 216 trees/ha (40 %).
Tree distribution of ideal all-aged forest stands mirrors in the notion that number of trees decreases gradually in form of hyperbola with an increase of diameter classes.
The figures 3, 4 and 5 clearly show that neither of analyzed stands meets the prerequisite to be called "balanced" or "ideal" from management perspective. Generally, we can say that all three stands have uneven-aged structure, but neither has „targeted" all-aged structure.

Basal area and stand volume

Basal area in the stands 81b and 82b is similar and amounts to 47,3 m^2/ha and 47,9 m^2/ha, respectively, while in the stand 82c it has noticeably higher value of 58,4 m^2/ha.
Silver fir has basal area ranging from ranging from 17,9 m^2/ha or 37,8 % (81 b), and 21 m^2/ha or 43,8 % (82 b) to 34,8 m^2/ha or 59,6 % (82 c). Norway spruce has basal area ranging from 22,6 m^2/ha or 40,4 % (82 c), and 26,9 m^2/ha or 56,2 % (82 b) to 29,4 m^2/ha or 62,2 % (81b).
Wood volume in the analyzed stands ranges from 720,6 m^3/ha (82 b) and 800,3 m^3/ha (81 b) to 976,7 m^3/ha (82 c).
Percentage share of silver fir in total volume is smallest in the stand 81b reaching 37,4 % or 299,3 m^3/ha, while in the stand 82c it has largest share with 59,4 % or 580,5 m^3/ha. Consequently, percentage share of Norway spruce is smallest in the stand 82c reaching 40,6 % or 396,2 m^3/ha, and largest in the stand 81b where it predominates with 62,6 % or 501,0 m^3/ha.
Percentage share of volume of silver fir and Norway

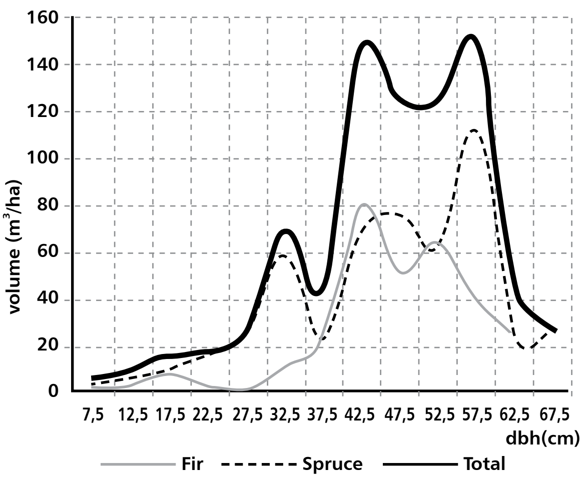


Figure 6
Volume distribution through diameter classes 81b

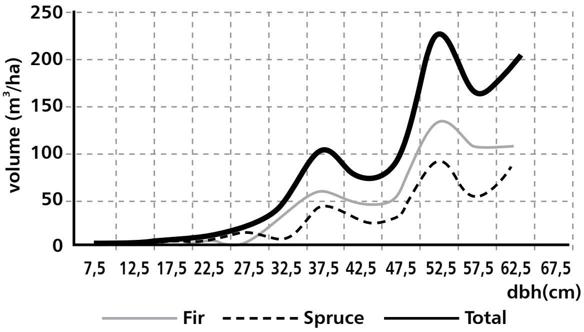


Figure 7
Volume distribution through diameter classes 82b

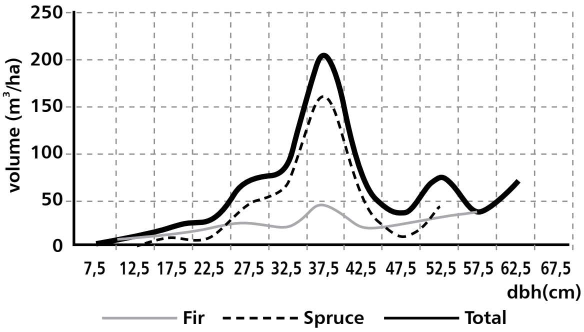


Figure 8
Volume distribution through diameter classes 82c

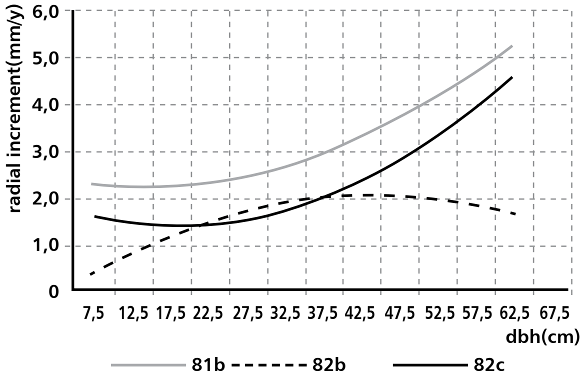


Figure 9
Influence of dbh on current radial increment of fir

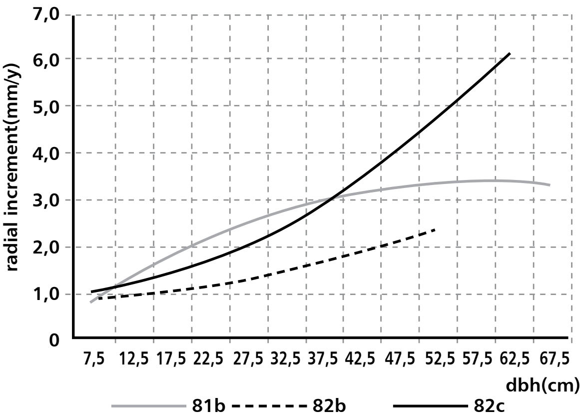


Figure 10
Influence of dbh on current radial increment of spruce

spruce in the stands 81b and 82c does not differ much from percentage share of tree distribution in the same stands. On the other hand, although the number of silver fir trees is greater from the number of spruce trees in the stand 82b (54,4 % fir : 45,6 % spruce), Norway spruce in total stand volume participates more than silver fir (55,6 % spruce : 44,4 % fir), which comes as a result of very emphasized domination of Norway spruce in diameter class with mid-point 37,5 cm.

Radial and volume increment

Radial increment

Dependence of current radial (diameter) increment on tree diameter is expressed with polynomial function of second order that says:

$$i_d = a + bd + cd^2$$

a, b, c – equation parameters
d – diameter at breast height (cm)
i_d – radial increment (mm)

Influence of dbh on current radial increment proved to be statistically significant at p-level 0.05 for both species. Figures 9 and 10 show that both species (except fir in the stand 82b) mostly do not reach the culmination of current radial increment at smaller diameter values.

Values of current diameter increment for silver fir range from 1,4 mm/year to 3,1 mm/year, and for Norway spruce from 1,3 mm/year to 2,9 mm/year. Average current diameter increment amounts to 2,3 mm/year for both species.

Volume increment

Current volume increment in the stands ranges from 7,6 m^3/ha (82 b) and 11,6 m^3/ha (81 b) to 15,5 m^3/ha (82 c). Each year on average silver fir participates with 3,5 m^3/ha (82 b) and 4,0 m^3/ha (81 b) to 8,3 m^3/ha (82 c), while Norway spruce contributes with 4,1 m^3/ha (82 b) and 7,2 m^3/ha (82 c) to 7,6 m^3/ha (81 b). In the stand 82b total number of silver fir trees is bigger

Table 2
Basic indicators of statistical dependence of dbh increment on dbh size

Silver fir						
Stand	**Site index**	**a**	**b**	**c**	**R^2**	**Se (mm)**
81 b	I	2,5478	- 0,0377	0,0013	28,0	1,45
82 b	I	- 0,3212	0,1087	-0,0013	41,5	0,60
82 c	II	1,9449	- 0,0586	0,0016	45,8	1,18
Norway spruce						
Stand	**Site index**	**a**	**b**	**c**	**R^2**	**Se (mm)**
81 b	I	- 0,0709	0,1172	-0,001	33,7	1,02
82 b	II	0,7488	0,0037	0,0005	25,2	0,77
82 c	I	0,3456	0,0476	0,0007	63,5	1,30

compared with spruce, but spruce is more frequent in diameter classes with mid-points ranging from 32,5 cm to 42,5 cm where maximum intensity of volume increment appears, which led to greater share of spruce in total volume increment in the stand.

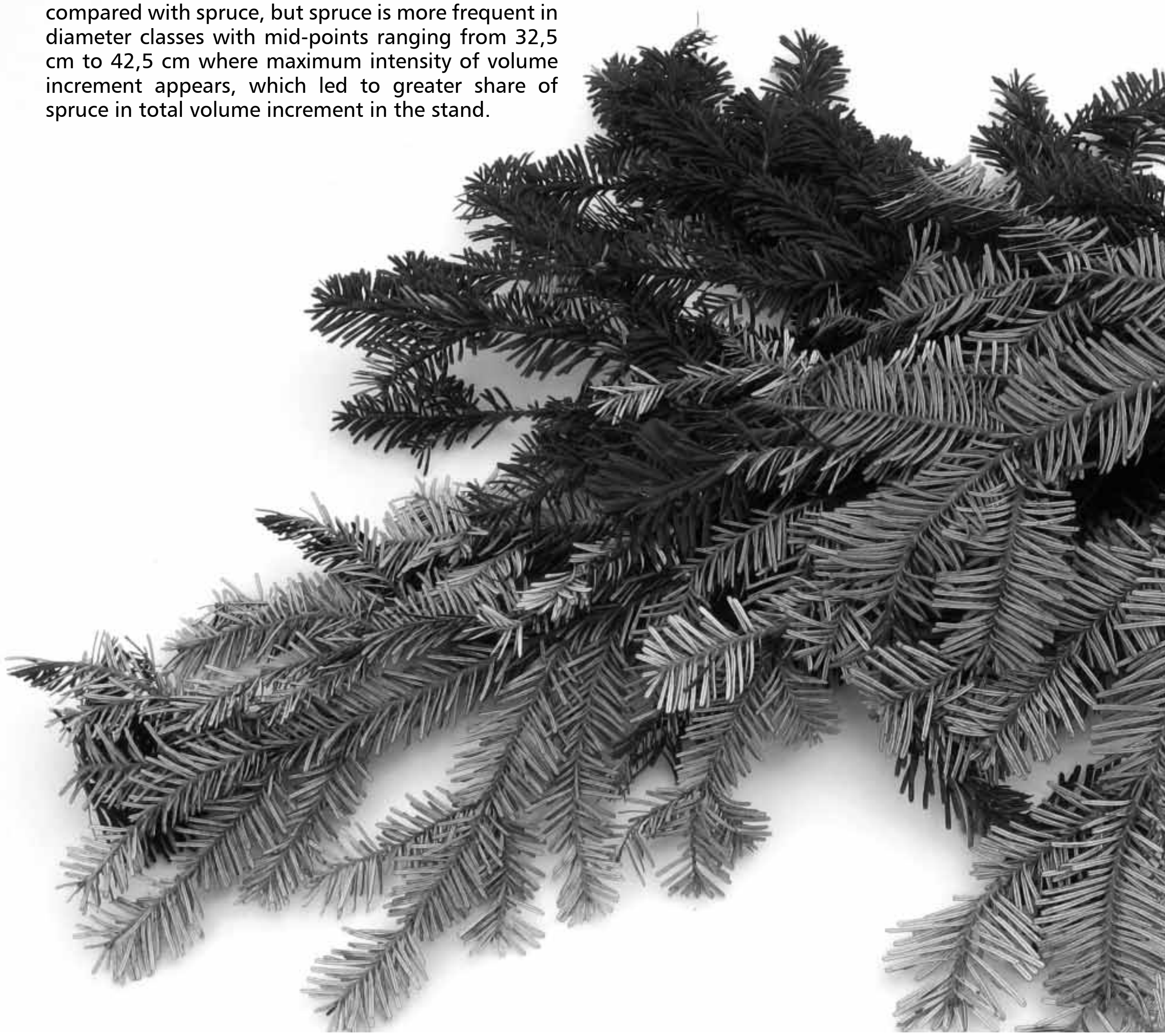
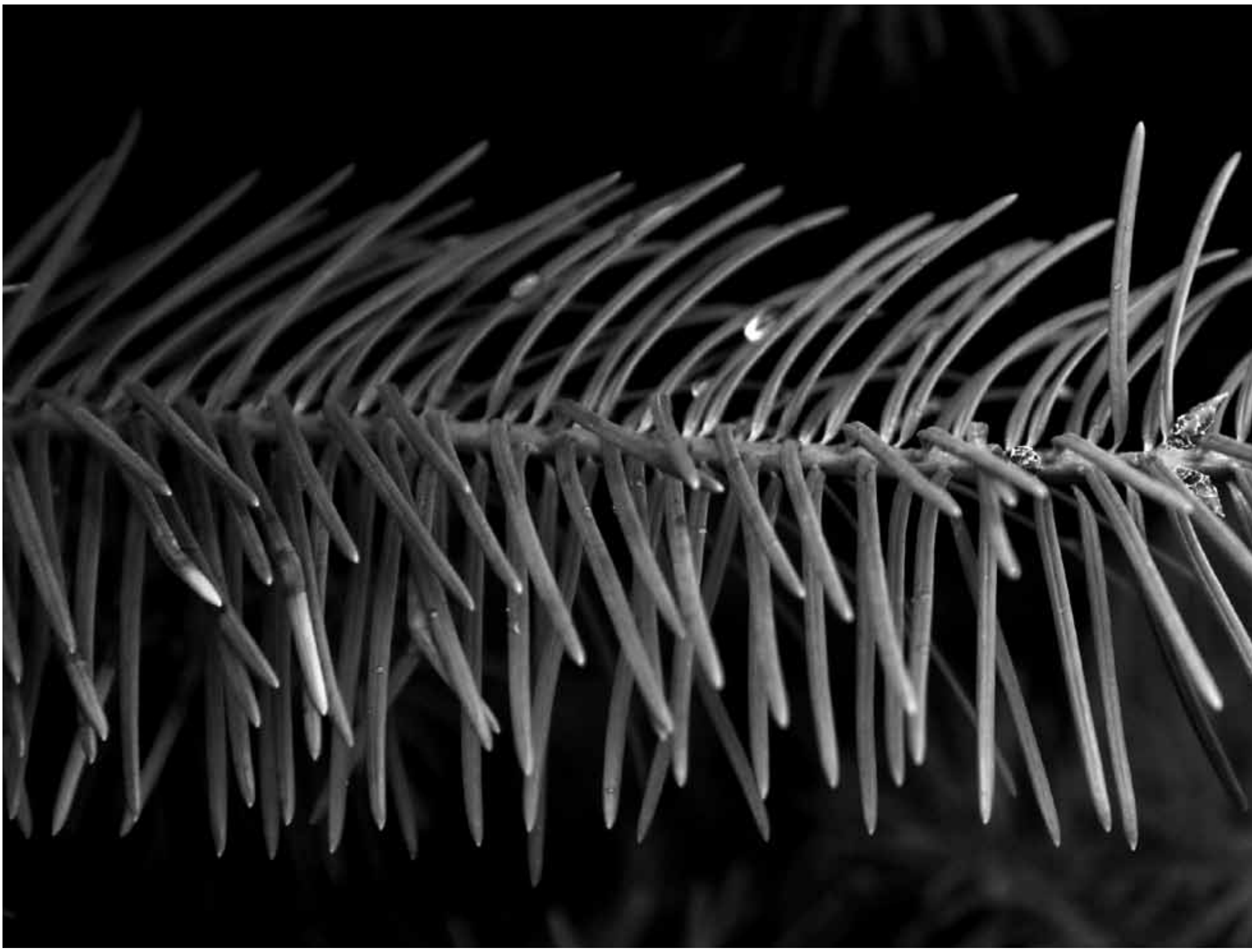


Table 3
Targeted structure elements for fir-spruce stands according to current management prescriptions

Tree species	Composition ratio	Canopy closure	Diameter class (cm)					
			5,1 - 10,0	10,1 - 20,0	20,1 - 30,0	30,1 - 50,0	50,1 - 80,0	Total
			m³/ha					
Silver fir	0,3		3,86	7,65	24,99	61,78	32,5	130,78
Norway spruce	0,6		9,91	17,13	52,5	113,39	50,08	243,01
Beech	0,1		2,26	3,67	9,79	16,85	2,48	35,05
Total	1	0,8	16,03	28,45	87,28	192,02	85,06	408,84

„Normal" volume

For high forests with natural regeneration that are managed by group selection and individual tree selection methods, planning of biotechnical measures relies inter alia on „normal" volume of forest type in the middle of harvesting cycle.
„Normal" or „balanced" volumes for forest types within forest management area „Srednjevrbasko" are calculated by simplified method of determination of normal state in selection forests (10).
Similar wood volumes were determined in small fir-spruce stands of virgin forest type at mountain Zlatar in Serbia (11).
Harvesting prescriptions take into account relationship between actual and "normal" volumes for all



forest types that naturally have uneven- or all-aged structure.
Although fir and spruce are predominant species in the studied stands a certain small ratio of beech is also expected to take part in this forest type.
According to prescribed silvicultural goals beech is considered to be a desirable species if it took part about 10 % (Table 3).
In the studied stands there are only 3 – 4 mature beech trees per hectare, so statistical analysis for beech was not possible. Targeted structure in Table 3 is not given for a particular stand but for the average stand of the fir-spruce forest type.
Rule book in effect for arrangement of management prescriptions for these forests contains next principle: if in a forest stand the actual volume is lower than optimal then harvesting intensity should be lower from volume increment for a given period of time; on the other hand, if the actual volume of a forest stand is greater than "normal" then harvesting intensity can be higher from volume increment for a given period of time, but total wood volume after harvesting operations should not fall below "normal" values at stand and forest type level.

Mere total wood volume, however, is not adequate gauge of stand structure.
Better insight we get when we distribute total volume throughout diameter classes. In well-managed selection forest neither too great nor too small wood volume is desirable.
"Balanced" volume enables intensive regeneration throughout the stand, dynamic ingrowth of juvenile trees in lower and transition to higher stands stories, and more vital trees (12).
Therefore forest managers tend to create a selection stand with optimal volume distribution throughout diameter classes.

CONCLUSIONS

It is known that timber overexploitation harms structure of forest stands; on the other hand, as the results in this paper show, scant management intensity does not provide "ideal" structure in fir-spruce stands on high potential sites either.
Wood volumes obtained from sample plots in the stands range between 720,6 m^3/ha and 976,7 m^3/ha, which is quite above "normal" values established for managed all-aged forest stands, and hence neither of them has all-aged structure but rather some of transitional forms of uneven-aged structure.
The difference between actual and targeted structure should be used to decide how many trees, and of which size, should be removed.
Most suitable silvicultural system for the class of high fir-spruce forest on deep brown soils and luvisols on limestone is group selection system. As of next management cycle silvicultural measures in form of harvesting operations should be intensified and allowable cut should be higher from volume increment for a given period of management (usually 10 years).
Targeted structure of the subject stands, however, does not have to be achieved in one-time harvesting cycle. Final desicion on how to conduct the transition from overstocked to „normal" forest stands also needs to be brought in agreement with scientific experience from applied forest ecology for a given forest type.
Regarding stand mixture beech proved to be endangered species in the studied stands. Therefore, it would be justifiable at least from ecological point of view, that silvicultural measures help beech regeneration to grow around individual beech trees within current fir-spruce stands so that beech as an inherent species can take greater part in the future stand mixture.
In future planning of silvicultural activities some breakdown within forest type might also be useful, for instance, if different targeted values for fir-spruce stands on different site classes be determined rather than base their management on the structure of average forest stand of the forest type.

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Growth response of Silver fir and Bosnian pine from Kosovo

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Background and purpose:
This paper explore the growth-climate relationships in total ring width chronologies of silver fir (*Abies alba* Mill.) and Bosnian pine (*Pinus heldreichii* Christ). The objective of this study is to quantify the climate influence on radial growth of both species. The relationships between climate and ring widths were analyzed using extreme growing years (called pointer years), simple correlations and response functions analysis (bootstrapped coefficients). The objectives of this study were: (1) to define the pattern of climatic response of each species. (2) to highlight the influence of local ecological conditions on tree's growth, and (3) to compare the response of silver fir and bosnian pine to climate.
Responses of total ring width to climate were estimated by establishing the mean relationship between growth and climate through simple correlations analysis and bootstrapped response functions. The response to climatic variability was also assessed by analyzing pointer years which correspond to abrupt changes in growth pattern and revealing the tree-growth response to extreme climatic events.
For the period 1908-2008 the mean sensitivity (MS) of total ring width chronology for Bosnian pine (0,209) was higher than silver fir(0,169,) suggesting that Bosnian pine is more sensitive to climate (pointer years were more frequent in ring width chronology of Bosnian pine than in silver fir ring width chronology).
The high values of first-order autocorrelations for Bosnian pine (0,674) indicated a strong dependence of current growth on the previous year's growth. Pointer years analysis underlined the high sensitivity to spring temperatures and precipitation for both species. Radial growth for both species depends strongly on spring climate variables (temperatures and precipitation) which play a significant role particularly for earlywood production.

Material and methods:
We selected 12 silver fir trees and 15 bosnian pine trees and took two 5 mm cores per tree perpendicular to the slope. Each core was mounted and sanded following standard dendrochronological procedures.Annual radial growth was measured with a measuring system LINTAB (Rinntech-Germany) where tree-ring widths were recorded using TSAPWin 0.55 software.
Each tree-ring width series was crossdated using visual comparisons and statistical parameters like: Cross Date Index-CDI (Schmidt 1987), an index of

synchronization estimated by TSAPWin derived from GLK% and t value (Baillie and Pilcher 1973). The value of CDI> 10 (Rinntech 2003) were considered as significant. The ARSTAN software was used to remove age trends in the ring width data and build site chronology. Indices were calculated as ratios between the actual and fitted values. Response from both species to climate was correctly shown by pointer years analysis, Pearson's correlation coefficients and DENDROCLIM (2002) software.

Results and Conclusion:
We compiled for each specie a mean chronology of radial growth with good replication. The chronology length of Silver fir is 64 years with mean tree-ring width 3.59mm (0.506), while the chronology length of bosnian pine is 104 years with mean tree-ring width 2.44 mm (± 0.482). The bosnian pine chronology was more sensitive than silver fir chronology (sensitivity 0,209 >0,169). Response of both species to climate was good. That was verified from pointer years analysis, Simple Pearson's correlation coefficients and DENDROCLIM (2002) software.
Pointer year analysis showed that spring temperatures and precipitation are the most important factors that enhance radial growth for both species. The pointer years 1953 and 1955 appear to be the most geographically extended pointer years throughout of Europe. The negative pointer year 1953 was identified in growth of silver fir by Serre Bachet 1986, and positive pointer year 1955 was also observed for silver fir in France.
Both species have reacted strongly to several pointer years but bosnian pine was more affected and more sensitive to climate than silver fir. For A.alba, high temperatures and plenty rainfalls during the first part of growing season are the keys for production of earlywood).
The response of Bosnian pine growth to climate was quite different than response of silver fir. Response functions analysis showed that precipitation during September is important for latwood production (growing season ends on October). While low temperatures during winter (January) and especially frosts cause substantial growth reduction, delaying the growth starting during spring.
Earlier studies has shown that phytosynthesis is possible for A.alba in winter, where high temperatures could play an important role in improving carbohydrate storage and growth at following year. For species grown under a Mediterranen climate high temperatures and low precipitation during growing season may cause water stress, which is the main limiting factor for tree growth. Although the drying season lasts in the study area for 2 months we didn't note any sign of defoliation or needle yellowing in standing trees.

Key words:
tree-ring width, pointer years, sensitivity, Pearson correlation, response-functions.

INTRODUCTION

Silver fir (*Abies alba* Mill.) is widely distributed in Europe and has been proved to be an important species for dendroecological studies. While Bosnian pine (*Pinus heldreichii* Christ.) has a limited distribution mainly in Balkan peninsula and south of Italy. The decline of Silver fir has been subject of great concern in Central Europe and North America since the early 1970's (1, 2).
From an ecophysiological point of view the shade tolerant Silver fir species appears to be rather a more frost and drought sensitive specie (3, 4). Silver fir and Bosnian pine are the most important conifer species regarding both, covered area and standing volume in Kosovo (Kosovo National Forest Inventory 2006). In Kosovo the natural distribution areas for Silver fir and Bosnian pine correspond to mountainous regions. So the natural mixed coniferous forests cover a wide range of substrate, topographic and climatic conditions. In Kosovo dendroecological studies are scarce. By means of this paper we present the first chronologies of tree-ring width for Silver fir and Bosnian pine and their response to climate. The objectives of this study were: (1) to define the pattern of climatic response of each species, (2) to highlight the influence of local ecological conditions on tree's growth, and (3) to compare the response of Silver fir and Bosnian pine to climate.
The response of tree-ring width to climatic variability was also assessed by analyzing pointer years which correspond to abrupt changes in growth pattern, simple correlations analysis and bootstrapped response functions (5).

MATERIALS AND METHODS

The study area belongs to Forest Economy of Koritnik 1, that is under administration of Forest Agency of Kosovo, Region of Prizreni (Figure 1). It has mountainous reddish-brown soils (Haplic Luvisoils) laid on ultrabasic

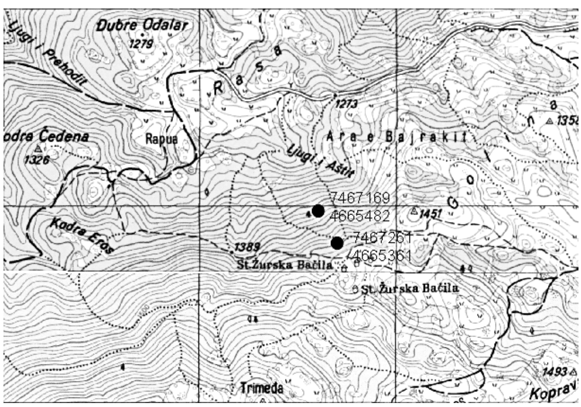


Figure 1
Location of forest plot in Koritnik Mountain (black circles show sample sites)

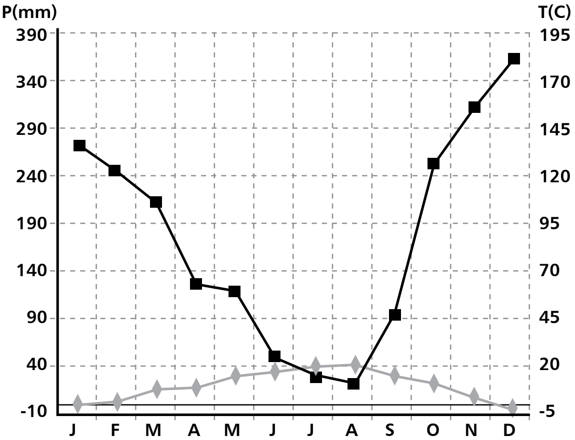


Figure 2
Climatic description of the study area based on climatic data from Dragashi meteorological station (period 1951-2008).

rock formation. Meteorological data are taken from nearby station of Dragashi commune. The climate in the area is Premountanious Mediterranen climate with a summer drought period of ca. 2 months (Figure 2). Maximum temperatures occur from July to August, while minimum temperatures are observed from December to January with a mean annual temperature 11,10 °C. Rainfall has a summer minimum value from June to August. During the 1951-2008 period, the lowest monthly temperatures in December, January and February occurred in 1951 (-5,7 °C), 1959 (-3,1 °C) and 1955 (-2,6 °C). Within the study area understory is missing because of dominant trees shadow, while the ground vegetation comprised species like: *Anemone nemorosa* L., *Rubus idaeus* L., *Pteridium aquifolium* L., *Euphorbia* sp, *Fragaria vesca* L. The radial growth of trees was estimated basing on increment cores taken from sampled trees in two plots. Sampling was carried out using a Pressler increment borer. Two cores per tree were taken at breast height (1,3m) in opposite directions and perpendicular with slope. We selected 12 Silver firs and 15 bosnian pines. Each core was mounted and sanded following standard dendrochronological procedures (5). Tree-ring width was measured to the nearest 0,01 mm in the two cores taken at 1,3m with a measuring system LINTAB (6). Tree-ring widths were recorded using TSAPWin 0.55 software (6). Each tree-ring width series was cross-dated using visual comparisons and statistical parameters like: Cross Date Index- CDI (7), an index of synchronization estimated by TSAPWin derived from GLK% (8) and t value (9). The value of CDI> 10 were considered as significant. The ARSTAN program (10, 11) was used to remove age trends in ring width data and build site chronology. The raw data of tree-ring width were standardized and detrended using a three- step process. First, a negative exponential function was fitted with raw tree-ring data. Second, a cubic smoothing spline with a 50% frequency cut off of 50 years was used to retain the high-frequency variability of radial growth. Third, the mean chronology was built using a robust mean in order to reduce the influence of extreme values (negative or positive) (10, 12). Signal strength in ring width chronology was tested using EPS – Expressed Population Signal (13). Only those series with a high common signal (EPS≥0.85) were included in the analysis. The remained autocorrelations were removed by autoregressive modeling. The residual series were averaged to create total ring width chronologies for each specie. Residual chronologies were compared with climatic data in correlation analysis and response function. For each tree-ring component the effect of climate on growth was investigated on two steps. First, pointer years were compared with climate data. Second, bootstrapped confidence intervals were used to estimate the significance of correlations and response function coefficients (14). Analysis was performed using 12 monthly climatic data (mean temperature and precipitation) of current growth year, starting from January till to December. The pointer years were defined for each tree-ring component as those calendar years when at least 75% of the cross-dated series presented the same sign of change: at least 10% narrower or wider than previous year. Pointer years were identified using Weisser software with a 7 year time window with three level of growth intensity (16, 17). The software package DENDROCLIM 2002 (15) was used to compute the statistical significance of the coefficients by calculating 95% quantile limits based on 1000 bootstrap re-sample of the data (14, 15).

RESULTS AND DISCUSSIONS

Growth dynamics

For both species we have estimated basic dendrometrical parameters. The dendrometrical data were provided from field measurements and are presented in the Table 1. Both studied species have comparable parameters regarding number of trees per hectare and mean diameter ate breast height, but Silver fir has significantly higher growing stock (775 m^3/ha) and basal area 60,9 m^2/ha than Bosnian pine (Table 1).
The mean tree-ring width chronology of *A. alba* Mill. is constructed by using 24 relative series taken from 12 dominant sample trees (Figure 3).
The chronology length is 64 years (time span 1946-2008) with mean tree-ring width 3.59 mm (standard deviation 0.506).
The Silver fir tree-ring chronology shows cyclic fluctuations during entire period of time (see Figure 3). The lowest radial growth is reached on year 1953 (2,51 mm), while the maximal radial growth in years 1958 (4,61mm) and 1994 (4,8 mm). The most important changes which represent long-term oscillations are noted during 1966-1977 period, where trend of radial growth is decreasing and during 1988-1994 period

Table 1
Site descriptions of the sampled plots

	Plot 1	Plot 2
Latitude (N)	7467169	7467261
Longitude (E)	4665482	4665361
Elevation (m.a.s.l)	1500	1540
Aspect	NE	NE
Slope (0)	16	30
Abies alba density (stems ha-1)	375	420
Abies alba average height (m)	23	26
Abies alba basal area (m^2ha-1)	58,4	63,4
Abies alba growing stock (m^3 ha-1)	720	830
Pinus heldreichii density (stems ha-1)	290	320
Pinus heldreichii average height (m)	21	24
Pinus heldreichii basal area (m^2ha-1)	40,4	42,4
Pinus heldreichii growing stock (m^3 ha-1)	462	506

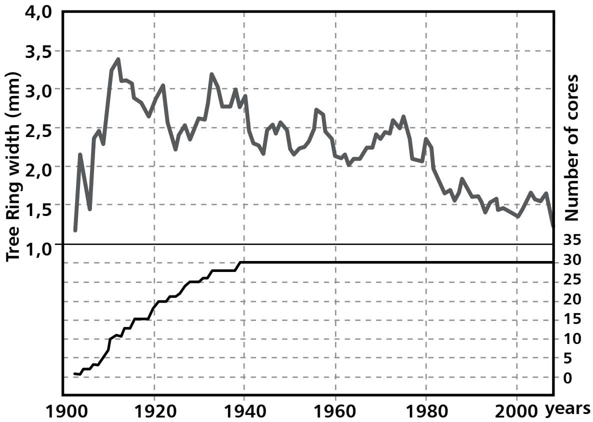


Figure 4
Raw tree ring width chronology of Pinus heldreichii. *Christ for Koritnik.Upper part of the graph is the raw tree-ring width chronology; lower part shows number of cores in particular year.*

radial growth has an increasing trend which culminate on year 1994. The period of Silver fir growth reduction (1966-1977) is also noted in whole Europe and in Piemonte-Italy too (18, 19).

The mean chronology of Bosnian pine is constructed by using 30 relative series taken from 15 dominant sample trees.

The chronology length (Figure 4) is 106 years (time span 1903-2008) with mean tree-ring width 2.44 mm (standard deviation ± 0.482). The chronology of Bosnian pine has an increasing trend till 1915 and this is related to the period of juvenile growth at the beginning of the life cycle. Then juvenile growth of radial growth is followed by a long-term oscillations period that last till to 1980. The longest period with descending trend extended from 1980 till to 2008.

Each period of acceleration in radial growth of Bosnian pine is followed by a period of radial growth reduction. Basing on ARSTAN software we have estimated for each specie's tree-ring width chronology the basic statistical parameters (Table 2).

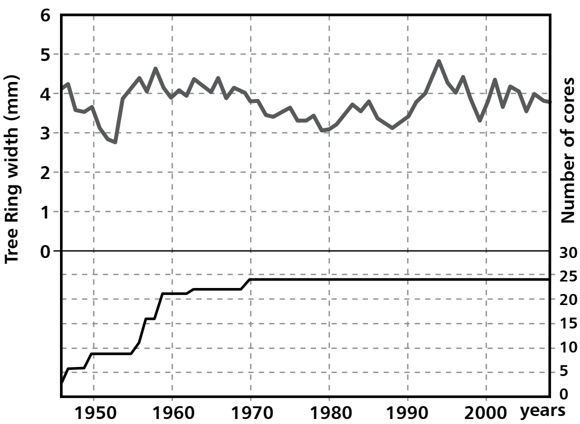


Figure 3
Raw tree ring width chronology of Abies alba *Mill. (Koritnik) for Koritnik. Upper part of the graph is the raw tree-ring width chronology; lower part shows number of cores in particular year.*

Table 2
Basic statistical parameters of tree-ring width chronology for both species

Forest species	Time span chronology	Mean ring width (mm)	Standart deviation	Autocorrelation AC(1)	Mean sensitivity
Silver fir	1946-2008	3.59	0.506	0.643	0.169
Bosnian Pine	1906-2008	2.44	0.482	0.674	0.209

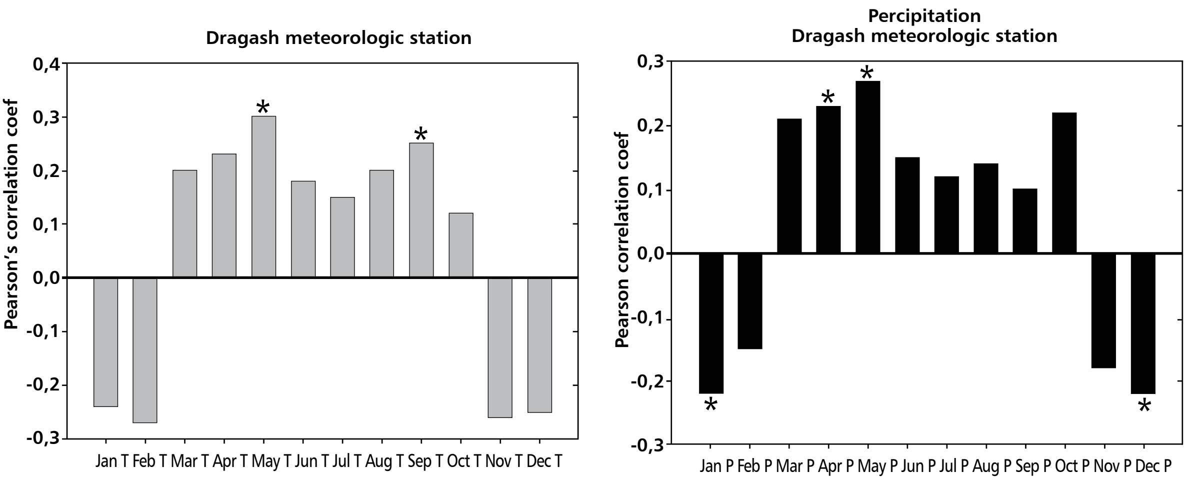
The statistical parameters estimated for each chronology showed that Bosnian pine chronology (MS 0,209) is more sensitive than Silver fir chronology (MS 0,169).Tree-ring width chronologies of both species were synchronized between each other and statistical parameters were estimated.
From estimation resulted that t-BP=0,63 and GLK = 50%. That means that growth behavior of both species was different although site conditions are similar.

Climate-growth relationship

Pointer years

Pointer years identified as years with extreme conditions reflected in tree-ring widths were identified for both species. Strong and negative reactions for Silver fir were observed in 1909, 1953, 1980 and 1995, while the positive pointer years were observed

Silver fir



Bosnian pine

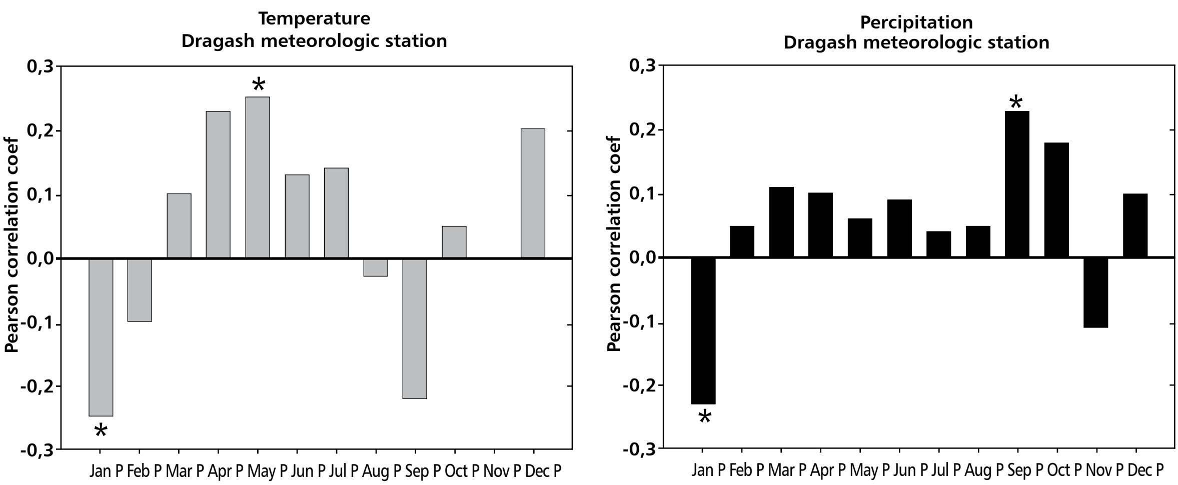


Figure 5
Simple response to climate conditions - Pearson's correlation coefficients between residual chronology and average monthly temperature and monthly sum of precipitation from local meteorological station Dragash-Kosovo. Black circles on the top of the bars show significant correlations.

in 1947, 1955, 1971 and 1994. For Bosnian pine negative pointer years identified from tree-ring width chronologies were: 1911,1951,1968,1997,1998, while the positive pointer years 1924,1940,1957,1973,1981. Pointer years were more frequent for Bosnian pine tree-ring width chronology than Silver fir chronology, meaning that its chronology is more sensitive to climate. Comparison of negative pointer years with climate data showed that main reason for reduction of radial growth were low temperatures. For example temperature in March and April 1980 are lower than long-term mean value for spring months (March
4,6 °C<7 °C; April 8,8 °C<12 °C). Growing period in 1980 started in May or one month later than normally. Annual precipitation in 1980 were 2622.3 mm (2404 mm long term mean value) and 893.3mm during growing season. The same situation was found in 2000, with one exception, amount of precipitation in current growing period (May-October) was 399.8 mm or 2 times lower than long-term average amount of precipitation during vegetation period (399.8 < 752.9 mm). So during this year except of temperature has influenced negatively on tree's growth, the low amount of precipitation.For Silver fir the negative pointer years have been 1955 and 1971, where summer temperatures have been lower and growing period has started with delay. The precipitation has been abundand during the spring months, but smaller in the rest months of year. For Bosnian pine the positive pointer years have been 1924, 1940, 1957, 1973,1981. By the comparison between radial growth with climate data in these years, it is noted that high temperatures and high amount of precipitation during spring months have been main factors that have influenced on radial growth.
This relationship was expected because the samples are collected in the altitude 1500 m a.s.l where the site conditions are not so extreme.

<u>Response to climate</u>

Response of residual chronology for both species to climate is estimated by using Pearson correlation coefficients. The threshold value of correlation is 0.25 for ($p<0.05$). Simple Pearson's correlation coefficients between local climatic data from Dragashi meteorological station and residual chronology of Silver fir showed significant ($p<0.05$) positive response with May and September mean monthly temperature and a negative response with winter mean monthly temperature. The response of Silver fir residual chronology to total monthly precipitation showed a positive response with summer monthly precipitation and a negative response with winter total monthly precipitation. That is important for annual radial growth because the vegetation period start in the middle of April. So the temperature and precipitation in the spring months are significant for earlywood formation. We also analyzed the response of Bosnian pine to climate variables. We noted a highly significant negative correlation between residual chronology with January climate variables (mean monthly temperature and monthly precipitation) and a significant positive correlation with May mean monthly temperature and September monthly precipitation. The response of Bosnian pine growth to climate is quite different than response of Silver fir growth to climate (Figure 5).
The response of Silver fir and bosnian pine index chronology to climate was also tested by means of DENDROCLIM 2002 software (Figure 6): For both species, precipitation during the end of second part of growing season (September) is important for latwood production (growing season ends on October). While low temperatures during winter (January) and especially frosts cause substantial growth reduction, delaying the growth starting during spring.

CONCLUSIONS

Wood anatomical features measured in tree-rings may offer opportunities for obtaining environmental information (20). In many studies growth rate is the only considered parameter (21, 22, 23) since ring widths are usually easy to measure and to interpret. Silver fir is a wide distributed specie, while Bosnian pine is e typical Balkan specie with limited distribution. They form together natural forest stands in Kosovo. Although they are growing under the same ecological conditions they showed differences in tree-ring width chronology. Pointer year analysis showed that spring temperatures and precipitation are the most important factors that enhance radial growth for both species. The pointer years 1953 and 1955 appear to be the most geographically extended pointer years throughout of Europe.
The negative pointer year 1953 was identified in growth of Silver fir (19) and positive pointer year 1955 was also observed for Silver fir in France (24). Both species have reacted strongly to several pointer years but Bosnian pine was more affected and more sensitive to climate than Silver fir. For Silver fir, high temperatures and plenty rainfalls during the first part of growing season are the keys for production of earlywood (24). The response of Bosnian pine growth to climate was quite different than response of Silver fir. Response functions analysis showed that precipitation during September is important for latwood production (growing season ends on October). While low temperatures during winter (January) play also an important role in determining growth, particularly for extremely thin tree-ring widths. Low winter temperatures and especially frosts cause substantial growth reduction, delaying the growth starting during spring. Earlier studies have shown that phytosynthesis is possible for A. alba in winter, where high temperatures could play an important role in improving carbohydrate storage and growth at foolowing year. For species grown under a Mediterranen climate high temperatures and

low precipitation during growing season may cause water stress, which is the main limiting factor for tree growth (25).
Although the drying season lasts in the study area for 2 months we didn't note any sign of defoliation or needle yellowing in standing trees.

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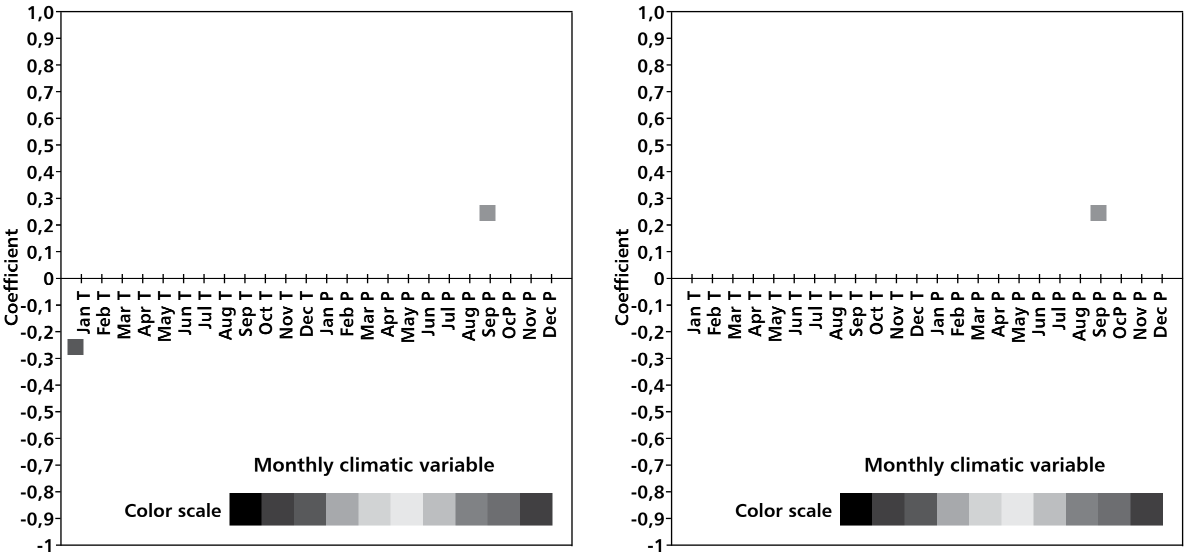
Silver fir



Bosnian fir

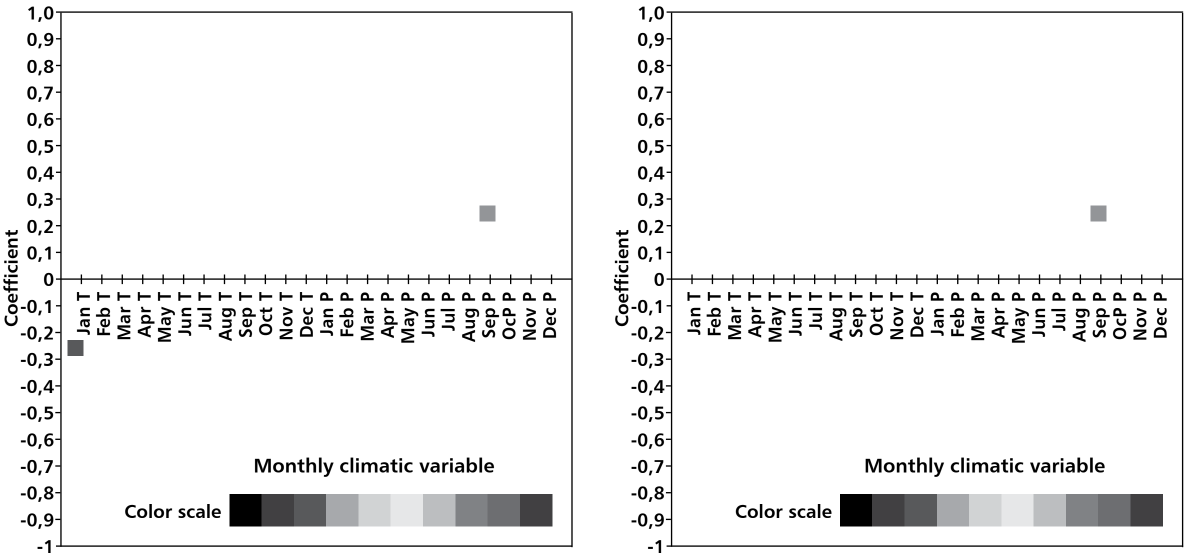


Figure 6
Significant correlations between annual radial growth and monthly climatic variables for both species.

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Gap-phase regeneration of a Central-European sessile oak-hornbeam forest

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Background and purpose:
Gap cutting can be regarded as a regeneration tool of close-to-nature forestry. However, very little is known about the gap-phase regeneration of sessile oak. This paper examines height growth of sessile oak (*Quercus petraea*) and hornbeam (*Carpinus betulus*) seedlings, as well as, spread of blackberry (*Rubus fruticosus*) in circular gaps of various sizes.

Material and methods:
Three gaps of 15 m (G15), three gaps of 30 m (G30) and two gaps of 45 m (G45) in diameter were cut in a sessile oak-hornbeam forest. Height of sessile oak and hornbeam seedlings, as well as, cover of soil moisture indicator plants and that of blackberry were monitored until the fourth year of the regeneration.

Results and conclusions:
Sessile oak grew faster in G30 than in G15, but the two larger gap types did not differ in this aspect. Intensity of hornbeam seedling development increased with gap size. Proliferation rate of blackberry was the highest in G45. Within the gaps, both sessile oak and hornbeam were the tallest in the centres. In the northern parts, competition ability of hornbeam decreased relatively to that of sessile oak. For spread of blackberry, the west locations were the most optimal. Development of both of sessile oak and hornbeam seedlings was related to soil moisture as indicated by the herb layer. It was concluded that regeneration of sessile oak could be made more secure if starting it with cutting small gaps (e.g. 0.5 tree height) and if these gaps are enlarged then gradually.

Keywords:
***Quercus petraea, Carpinus betulus, Rubus fruticosus*, regeneration, gap, soil moisture**

INTRODUCTION

Studying gap dynamics is essential in order to work out close-to-nature regeneration methods since temperate deciduous forests often regenerate themselves by spontaneous gap formation if forestry operations do not influence the natural processes (1). Thus, gap cutting can be regarded as a basic tool of continuous cover forestry (2).
Site conditions inside the gaps are spatially heterogeneous due to the differential shading by the neighbouring trees. South parts of the gaps are more shaded and cooler than the north parts therefore soil moisture content of the former is higher. However, fine-scale pattern of soil attributes may modify this phenomenon (3, 4, 5, 6, 7, 8). East locations can be drier than the west ones because they are exposed

to the warm west sunlight (5). Thus, a site gradient often occurs inside the gaps and affects tree seedling density and growth, as well as, spatial pattern of the herbaceous vegetation. It was hypothesized that various species grow differently at different location along this environmental gradient (9, 10). Therefore, gap-phase regeneration processes of mixed stands are especially important to understand (11).

Shading effects of the mother trees depend on the size of the gap. Larger gaps are more illuminated but relations between gap size and soil moisture content are less evident (6, 12, 13). Interception of the canopy and root concurrence of the parent stand decrease with gap area while soil temperature increases (12).

Although pedunculate and sessile oak (*Quercus robur* L. and *Q. petraea* (Mattuschka) Liebl.) are major tree species in many forest types throughout Europe, very little is known about their gap-phase regeneration (e.g. 14, 15, 16, 17, 18). High weed abundance and competition of fast growing associated tree species can make pedunculate oak regeneration in gaps rather difficult, similarly to the more traditional regeneration methods (18). Bobiec (16) found that in natural gaps of various sizes of a mixed deciduous forest (*Tilio-Carpinetum*) lime (*Tilia cordata* Miller) and hornbeam (*Carpinus betulus* L.) could regenerate well but pedunculate oak could regenerate hardly.

In mesic sites, gap formation or gap cutting promotes spread of blackberry (*Rubus fruticosus* agg.) (19, 20). Blackberry is known as one of the strongest competitors of sessile or pedunculate oak (19, 21, 22), though some results showed that pedunculate oak could grow over the blackberry layer (23). By contrast, Tobisch (19) noticed the opposite in a Central-European sessile oak-hornbeam forest.

So far, it has been not clarified how gap size influences the height growth of sessile oak and hornbeam seedlings, as well as, blackberry proliferation. It has been not studied, either, how differently seedlings of sessile oak and hornbeam grow and how cover of blackberry changes in various topographical positions within gaps of a given size. This paper addresses these questions by studying circular gaps of 15, 30 and 45 m in diameter (i.e., approximately 0.5, 1 and 1.5 tree length) in a sessile oak-hornbeam stand. Furthermore, spatial differences of seedling height were related to blackberry cover and soil moisture content as indicated by the herb layer.

It was hypothesized a priori that height growth of both of sessile oak and hornbeam, as well as, blackberry abundance increase with the size of the gap due to the higher illumination, smaller canopy precipitation interception and weaker root concurrence of the parent stand. For sessile oak and hornbeam seedling development, the central part of the gaps was supposed to be the most optimal which is well-illuminated and have high soil moisture content. Blackberry was assumed to spread most slowly in the dry north and east parts. Moreover, positive relation was thought between soil moisture content and height growth of the analyzed tree species seedlings, negative relation was hypothesized between development of sessile oak seedlings and blackberry cover. However, due to their fast growth, hornbeam seedlings were assumed to be able to grow over the blackberry layer, thus, no significant relations were foreseen between blackberry abundance and seedling growth.

MATERIAL AND METHODS

The experimental site (47°09’ N, 17°00’ E) occurs at 220 m a.s.l. on a slight (5°) northeast slope. The forest is located near river Rába in southwestern Hungary. The soil is acidic brown forest soil with medium (70 cm) rootable depth developed on gravel. The annual precipitation is 700 mm of which 237 mm falls during the main growing period (1^{st} May - 31^{st} July). The mean annual temperature is 9.4°C.

The study stand is a typical sessile oak-hornbeam forest in which the upper layer is dominated by sessile oak beneath which hornbeam forms a lower canopy layer. Turkey oak (*Quercus cerris* L.) can be also found in the upper layer in small amounts. The stand was 107 years old in 2004 when the regeneration was started. No shrub layer had developed before the intervention and the herb layer was very sparse.

The regeneration was based on the crop of 2003. The study forest was fenced in 2004, before starting the experiment. During the winter of 2004-2005, eight circular gaps were cut. Three of them were 15 m (i.e., 0.5 tree length; G15), three gaps were 30 m (i.e., 1 tree length; G30) and the remaining two were 45 m (i.e., 1.5 tree length; G45) in diameter. Distances between two adjacent gaps were at least 30 m.

In the first year of the regeneration, number of sessile oak seedlings greatly decreased. Under the Hungarian site conditions, sessile oak mass crops are infrequent, therefore in order to increase sample sizes, two-year-old seedlings were planted in each gap with density of 1 seedling/m^2 in November 2005. Before planting, blackberry was removed manually and mechanically from all of the gaps. Despite these artificial influences, gaps and topographical positions within the gaps remained comparable because planting and blackberry removal were done identically in all gaps. Since the autumn of 2005, natural processes have not been disturbed by any other human operations.

Sampling was carried out annually from the initial stage (2004) to the fourth year of the regeneration (2008), except for 2007 when it was not performed. Height of all sessile oak and hornbeam seedlings was measured and cover of blackberry and total cover of soil moisture indicator plants was assessed visually in 1 x 1 m quadrats distributed along two transects in each gap. The transects were oriented N-S and E-W and intersected in the middle of the gaps. The quadrats were continuously placed along the transects hence the number of the quadrats depended on the size of the gaps (Table 1). Cover values were estimated

Table 1

Sampled area (in m²) of various topographical positions within the experimental gaps of different sizes. Method – regeneration technique applied; Location – topographical position inside the gaps; One gap – sampled area within one gap of a given size; Total – total sampled area in all gaps of a given size; transect – sampled area of the 1-m-wide transects (which equals the number of the 1 x 1 m sampling quadrats distributed along the transects); additional – sampled area of the additional 0.5 m-wide sampling units placed at both sides of the 1-m-wide transects; G15, G30, G45 – gaps of 15 m, 30 m and 45 m in diameter, respectively; S, C, N, E, W – south, central, north, east and west parts of the gaps, respectively. Note that the intersection area of the transects was sampled only once during a sampling occasion hence sampled area of the central part is not simply twice as big as that of the other parts (see Figure 1).

Method	Location	One gap		Total	
		transect	additional	transect	additional
G15	S	5	5	15	15
	C	9	7	27	21
	N	5	5	15	15
	E	5	5	15	15
	W	5	5	15	15
G30	S	10	10	30	30
	C	19	17	57	51
	N	10	10	30	30
	E	10	10	30	30
	W	10	10	30	30
G45	S	15	15	30	30
	C	29	27	58	54
	N	15	15	30	30
	E	15	15	30	30
	W	15	15	30	30

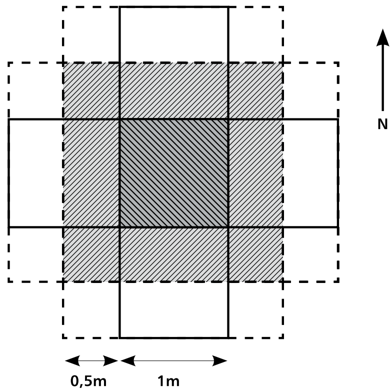


Figure 1
Intersection of the two transects in the middle of the gaps. The 1-m-wide transects are marked with solid lines, whereas the additional 0.5 m-wide sampling units are indicated by dashed lines.

during the spring and the summer aspect. Height of seedlings was measured in autumn by when growth had stopped. Soil moisture indicators were defined according to soil moisture requirements of the species presented by Borhidi (24). Thus, species with an indicator value of WB ≥ 7 (estimated on a scale of 1-12) were regarded as soil moisture indicators.

In order to increase sample sizes, sessile oak seedlings were sampled in additional 0.5-0.5 m-wide areas at both sides of each 1 x 1 m quadrat from 2005 to 2008 (Figure 1, Table 1). However, for some analyses, data of seedlings occurred within the original 1 x 1 m quadrats were used only (see data analyses section).

Temporal and spatial changes of seedling height were analysed by single classification ANOVA-s. However, assumptions of parametric ANOVA could not be met therefore the F statistics were tested by randomization (25, 26, 27). The randomization tests were performed by randomly permuting the assignment of observations to the groups. The sizes of the groups were fixed. Resampling number was 1000 in each case. Two types of tests were carried out. On the one hand, gap sizes were compared. On the other hand, differences between topographical positions within the gaps were examined for each gap size. Both types of tests were done for every sampling year.

Effects of gap size were studied in a planned manner. That is, the smallest and the largest gaps were related to the medium-size ones. Within a given gap size, five topographical locations (south, centre, north, east and west) were distinguished by dividing each transect into three equally-long parts (Table 1). Spatial differences between the locations were analyzed in an unplanned way which means that every possible comparison was performed. Thus, significance level was modified by the Bonferroni-Holm method (26). It must be noted, that the Bonferroni-Holm method makes significance tests rather conservative, thus, the probability of type II error increases. Therefore, the power (the probability of rejecting the null hypothesis when it is false) of the tests decreases and the null hypothesis is accepted too often. However, there were no reasons to make a priori decided (planned) comparisons. To investigate the competition between sessile oak and hornbeam more thoroughly, height of the tallest sessile oak seedling was subtracted from that of the tallest hornbeam seedling (or sapling) by 1 x 1 m quadrats for the fourth year of the regeneration. In the case of sessile oak, only data of seedlings occurred within the original quadrats were used for this type of examinations. Values of height differences (VHD) were evaluated similarly to the height data. It should be taken into consideration that sample sizes are equal to the numbers of those quadrats in which at least one sessile oak and one hornbeam seedling were found. However, unfortunately, in the largest and in the smallest gaps number of these quadrats was very small in some topographical positions. Despite this fact, results on spatial differences of VHD are shown for these gap types, too, in order to achieve a better understand of the data.

Spread of blackberry was characterized by 'change in cover' values (CCV) which were calculated simply by subtracting the cover values estimated in given sampling years from those assessed in the following sampling years (CCV = C_{t2}-C_{t1}). CCV were determined for each quadrat. Summer abundance of blackberry was used for the analyses since it was higher than the spring cover. CCV were evaluated similarly to the height data of seedlings. Multiple regression analyses were applied to relate height of sessile oak and hornbeam seedlings to cover of blackberry and to soil moisture as indicated by herbaceous species. The dependent variables were the height of the tallest sessile oak seedlings within the original 1 x 1 m quadrats (!) and that of the tallest hornbeam seedlings. Blackberry cover and abundance of soil moisture indicators were used as independent variables. The spring and the summer cover values were combined. That is, each species was characterized by the higher value. The reason for not studying light indication of the vegetation was the fact that the amount of light reaching the herbaceous layer is strongly influenced by the growth and closure of the regeneration. Thus, light intensity which seedlings and saplings are exposed to may greatly differ from that which can be utilized by the herbs. Colinearity between the independent variables was studied by variation inflation factors (VIF; 26). If the independent variables are uncorrelated, the largest VIF is close to 1. If the largest VIF is higher than 100, the computation becomes inaccurate (26).

Regression analyses were done for the fourth year of the regeneration since it was supposed that spatial differences in height of seedlings and in cover of various species increase with time. Altogether six regression analyses were performed according to the two tree species and three gap sizes. Observation numbers equalled the numbers of those quadrats in which at least one sessile oak or hornbeam seedling could be found. Residuals were analyzed in order to check the goodness of fit and to detect the outliers (26). Outliers were determined by the method of Hoaglin and Welsch (28) which applies the leverage coefficients and the standardized residuals simultaneously. If it was necessary, the computation was repeated after omitting the outliers. By the multiple regression analyses, coefficients of multiple determination (R^2) and standard partial regression coefficients were calculated.

The square roots of the former ones are the multiple correlation coefficients. The significance of the coefficients of multiple determination was checked by a randomization procedure during which the relationship between the dependent and the independent variables was randomly permuted but the relationships between the independent variables remained unchanged. This type of tests gives good results according to Manly (29).

Resampling number was 1000 in every test. The standard partial regression coefficients showed to what extent each independent variable explained the variance of seedling height. Species names follow Flora Europaea (30). The applied software was the Biomstat 3.3 (31) package.

Table 2

Number of seedlings measured during the sampling period. Abbreviations are explained at Table 1.

Species	Method	Year	S	C	N	E	W	Total
Q. pet.	G15	2004	10	15	7	32	6	70
		2005	20	11	5	35	27	98
		2006	46	62	42	74	56	280
		2008	46	68	42	74	56	286
	G30	2004	57	100	86	50	78	371
		2005	92	91	67	66	52	368
		2006	119	131	133	150	81	614
		2008	119	131	133	150	81	614
	G45	2004	6	193	20	109	72	400
		2005	23	134	35	84	75	351
		2006	49	133	58	184	81	505
		2008	49	113	58	184	81	485
Car. bet.	G15	2004	28	115	89	39	109	380
		2005	314	337	188	235	178	1252
		2006	453	443	221	257	231	1605
		2008	234	184	108	146	107	779
	G30	2004	208	338	132	76	255	1009
		2005	861	1078	592	1139	583	4253
		2006	892	606	566	744	505	3313
		2008	316	423	289	472	263	1763
	G45	2004	22	205	129	100	61	517
		2005	71	309	357	180	184	1101
		2006	249	324	266	304	232	1375
		2008	114	151	131	128	131	655

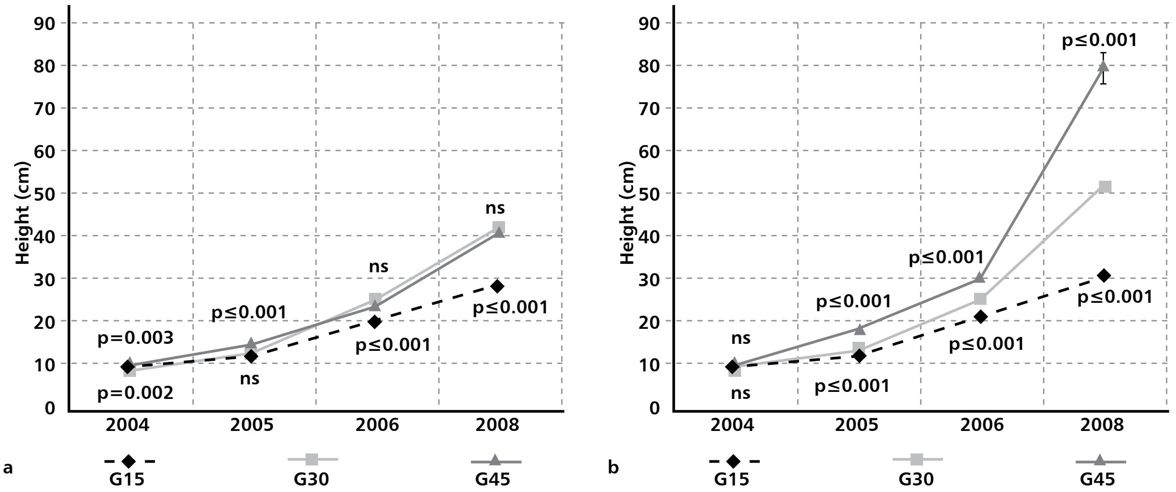


Figure 2
Height of sessile oak (a) and hornbeam (b) seedlings before (2004) and after cutting gaps of various sizes. Medium-size gaps were compared to the largest and to the smallest ones. Significance levels are given at the markers of the latter gaps. Standard errors are shown by whiskers. Where they are not indicated, standard errors were smaller than the size of the markers. Observation numbers are included in Table 2. The legend is shown on Figure 2a. ns – not significant; other abbreviations are explained at Table 1.

RESULTS

Although differences between gap sizes in height of sessile oak seedlings were very small (< 0.5 cm) before starting the regeneration, they were significant (Figure 2, Table 2). However, from 2006 to 2008, differences between G30 and G45 were insignificant. Oak seedling development was the most slowly in the smallest gaps. Intensity of hornbeam seedling growth increased with the size of the gaps. During the first four years of the regeneration, hornbeam grew over sessile oak to the lowest extent in G15, whereas at $p \leq 0.05$, G30 and G45 did not differ significantly in this aspect ($p = 0.07$; Figure 3, Table 3).
Speed of blackberry proliferation was similar in the smaller (G15 and G30) gaps while it was significantly higher in G45 than in G30 (Figure 4, Table 4).
Height of both sessile oak and hornbeam seedlings was spatially homogeneous at the initial stage (Figure 5). In the case of hornbeam, there was only one significant difference at this time but in absolute value, even it was rather small (< 1cm; Table 5).

Table 3
Number of those 1 x 1 m quadrats in which both sessile oak and hornbeam occurred in the fourth year of the regeneration (2008). Abbreviations are given at Table 1 and 2.

Method	S	C	N	E	W	Total
G15	9	21	6	9	11	56
G30	22	35	26	20	22	125
G45	10	30	8	23	18	89

No considerable spatial differences evolved in height of sessile oak seedlings of G15 during the first four years of the regeneration. Although some positions differed significantly in some years, by the autumn of fourth year, differences between them had become insignificant. In the larger gaps, development of

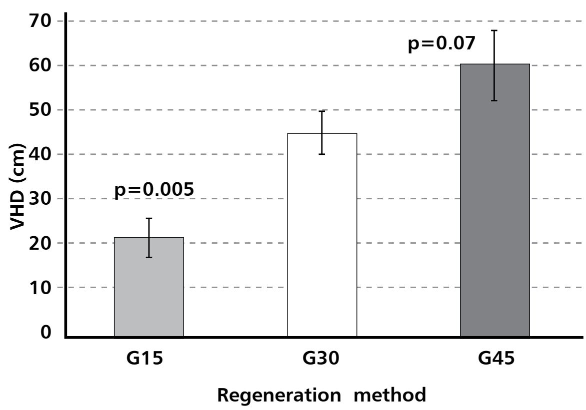


Figure 3
Differences between height of the tallest hornbeam and that of the tallest sessile oak seedlings (VHD) in the fourth year of the regeneration (2008). Height of the tallest sessile oak seedling was subtracted from that of the tallest hornbeam seedling (or sapling) by 1 x 1 m quadrats. Medium-size gaps were compared to the largest and to the smallest ones. Significance levels are given at the bars of the latter gaps. Standard errors are shown by whiskers. Observation numbers are included in Table 3. Abbreviations are given at Table 1.

Table 4
*Spread of blackberry following cutting gaps of various sizes. The cells contain average values (in %) of change in cover during a given period. Standard errors are shown in brackets. By the significance tests, medium-size gaps were compared to the largest and to the smallest ones. Significance levels are indicated by asterisks in the upper index of values of the latter gaps. Observation numbers equal the numbers of the 1 x 1 m quadrats (Table 1). *** - $p \leq 0.001$. Abbreviations are given at Table 1.*

Period	G15	G30	G45
2004-5	0.38(0.17)	0.39(0.18)	3.03(0.79)***
2005-6	0.90(0.35)	1.33(0.55)	6.38(1.15)***
2006-8	4.30(0.82)	6.01(1.21)	19.87(1.94)***

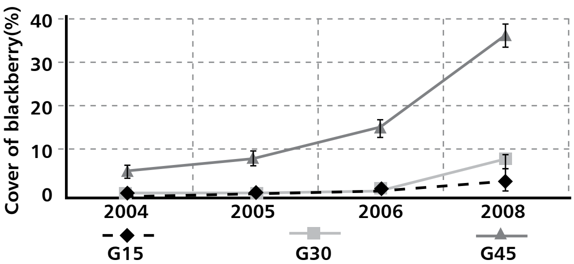


Figure 4
Spread of blackberry following cutting gaps of various sizes. For results of significance tests, see Table 4. Explanations are given at Table 1 and Figure 2.

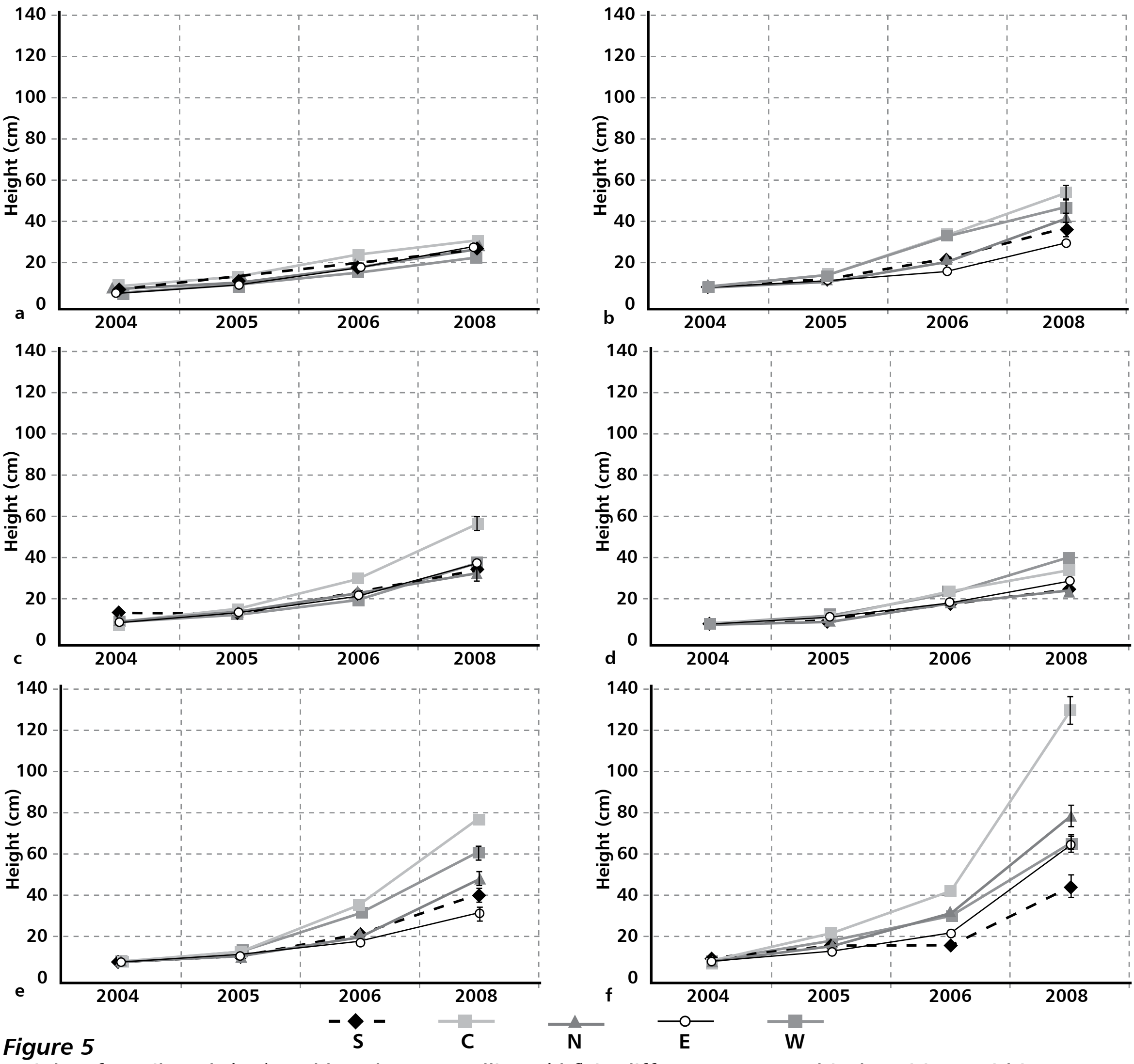


Figure 5
Height of sessile oak (a-c) and hornbeam seedlings (d-f) in different topographical positions within gaps of 15 m (a, d), 30 m (b, e) and 45 m (c, f) in diameter before (2004) and after gap cutting. Observation numbers are included in Table 2. Results of significance tests are described in Table 5. The legend is shown on Figure 5a. Other explanations are given at Table 1 and Figure 2.

Table 5

Results of significance tests carried out on height data of sessile oak and hornbeam seedlings (spatial analyses). The cells contain the numbers of those years of the regeneration period in which the corresponding two locations were significantly different at p ≤ 0.05 (i.e. 0 – 2004; 1 – 2005; 2 – 2006; 4 – 2008; none – the two locations were not significantly different in any of the sampling years). The table consists of six half-matrices. Three of them refer to sessile oak (upper half-matrices) and the other three refer to hornbeam (lower half-matrices). To make the results clearer, the backgrounds of the former matrices are shaded. Abbreviations are given at Table 1 and Figure 2.

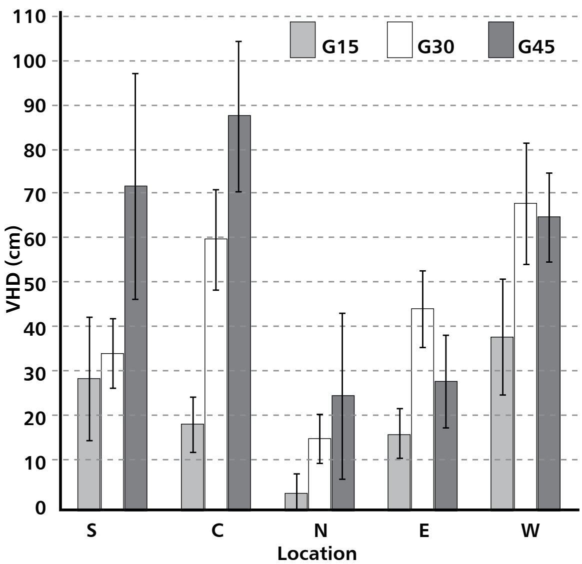
Method	Location	S	C	N	E	W
G15	S	-	none	none	none	none
	C	2,4	-	2	1,2	none
	N	1	1,2,4	-	none	none
	E	1	1,2	none	-	1,2
	W	2,4	none	1,2,4	1,2,4	-
G30	S	-	1,2,4	1	1,2,4	1,2
	C	1,2,4	-	2,4	1,2,4	none
	N	ns	1,2,4	-	2,4	2
	E	2,4	1,2,4	1,2,4	-	1,2,4
	W	1,2,4	0,4	2,4	1,2,4	-
G45	S	-	1,2,4	none	none	none
	C	1,2,4	-	4	2,4	2,4
	N	2,4	1,2,4	-	none	none
	E	2,4	1,2,4	1,2	-	none
	W	2,4	2,4	none	1,2	-

sessile oak seedlings was the fastest in the centres. Independently from the gap size, hornbeam seedlings grew at the highest speed in the middle of the gaps. Furthermore, development was intensive also in the west parts of G15 and G30. In G15, the difference between the central and the west parts was not significant at all during the whole sampling period. Hornbeam grew over sessile oak to the lowest extent in the north parts of the gaps (Figure 6). However, VHD differed significantly only in G30.

Figure 6

Differences between height of the tallest hornbeam and that of the tallest sessile oak seedlings (VHD) in different locations of gaps of various sizes in the fourth year of the regeneration (2008). Height of the tallest sessile oak seedling was subtracted from that of the tallest hornbeam seedling (or sapling) by 1 x 1 m quadrats. Observation numbers are included in Table 3. VHD was significantly smaller in the northern part than in all other parts but the southern position in G30. The other comparisons did not give any significant results. Further explanations are given at Table 1 and Figure 3.

Blackberry cover increased mostly in the west parts of the gaps, regardless the size of the gaps (Figure 7, Table 6). This result proves that the phenomenon that spread of blackberry was the fastest in G45 is



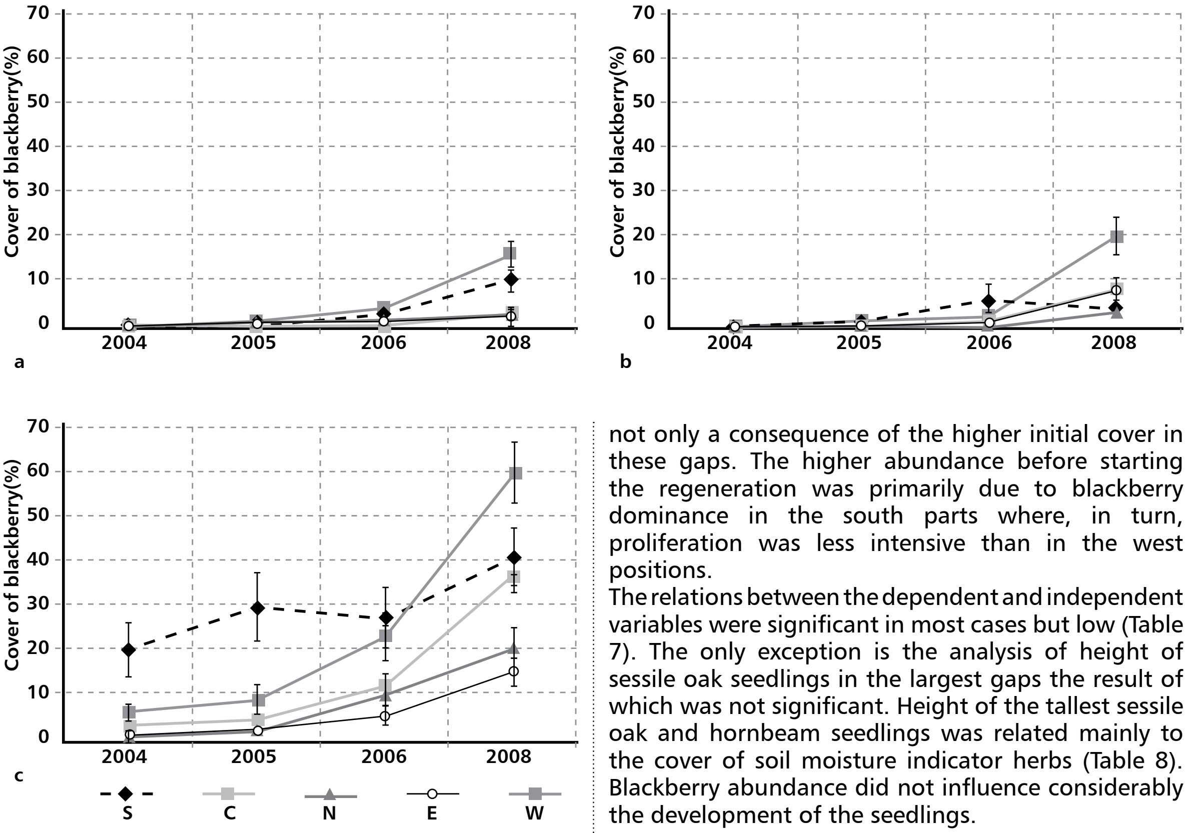


Figure 7
Spread of blackberry in gaps of 15 m (a), 30 m (b) and 45 m (c) in diameter. For results of significance tests, see Table 6. The legend is shown on Figure 7a. Explanations are given at Table 1 and Figure 2.

not only a consequence of the higher initial cover in these gaps. The higher abundance before starting the regeneration was primarily due to blackberry dominance in the south parts where, in turn, proliferation was less intensive than in the west positions.
The relations between the dependent and independent variables were significant in most cases but low (Table 7). The only exception is the analysis of height of sessile oak seedlings in the largest gaps the result of which was not significant. Height of the tallest sessile oak and hornbeam seedlings was related mainly to the cover of soil moisture indicator herbs (Table 8). Blackberry abundance did not influence considerably the development of the seedlings.

Discussion

The results show that even in the smallest gaps, soil moisture and light conditions were sufficient for sessile oak seedlings to grow continuously during the first four years of the regeneration, though seedling

Table 6
Spread of blackberry in different locations of gaps of various sizes (spatial analyses). The cells contain average values (in %) of change in cover during a given period. Standard errors are shown in brackets. The significantly different values ($p \leq 0.05$) are marked with different letters in the upper indices. Observation numbers equal the numbers of the 1 x 1 m quadrats (Table 1). Abbreviations are given at Table 1.

Method	Period	S	C	N	E	W
G15	2004-5	0.60(0.32)	0.00(0.00)	1.00(0.74)	0.00(0.00)	0.67(0.66)
	2005-6	1.93(1.21)^{ab}	0.27(0.27)^{a}	-0.47(0.89)^{ab}	0.20(0.20)^{ab}	3.20(1.18)^{b}
	2006-8	8.07(1.89)^{ab}	2.40(1.13)^{bc}	1.13(1.60)^{bc}	0.20(0.35)^{c}	11.60(2.67)^{a}
G30	2004-5	0.50(0.52)	0.42(0.28)	0.10(0.10)	0.00(0.00)	0.93(0.80)
	2005-6	4.73(3.11)	0.77(0.43)	0.17(0.17)	0.20(0.14)	1.33(0.62)
	2006-8	-1.67(2.30)^{b}	7.13(2.40)^{ab}	3.40(1.85)^{b}	2.37(1.13)^{b}	17.70(3.61)^{a}
G45	2004-5	9.53(3.73)^{a}	1.23(0.55)^{b}	2.23(1.13)^{ab}	1.23(0.54)^{ab}	2.73(2.21)^{ab}
	2005-6	-2.30(2.59)^{a}	7.82(2.00)^{b}	7.07(2.36)^{ab}	3.57(1.44)^{ab}	14.30(3.71)^{b}
	2006-8	13.40(3.06)^{b}	24.57(3.89)^{ab}	10.93(3.85)^{b}	9.53(2.90)^{b}	36.20(5.18)^{a}

Table 7
*Results of multiple regression analyses. R^2 – coefficient of multiple determination; R – multiple correlation coefficient; n – number of observations (quadrats where at least one sessile oak or one hornbeam seedling occurred); WB – standard partial regression coefficient of cover of soil moisture indicator herbs; RUB – standard partial regression coefficient of blackberry cover; VIF – the largest variation inflation factor; * - 0.01 ≤ p ≤ 0.05; ** - 0.001 ≤ p ≤ 0.01; *** - p ≤ 0.001. Further explanations are given at Table 1.*

Method	Regression	*Q. pet.*	*Car. bet.*
G15	R^2	0.308***	0.227***
	R	0.555	0.476
	n	67	72
	WB	0.557	0.475
	RUB	0.019	-0.008
	VIF	1.015	1.014
G30	R^2	0.065*	0.112***
	R	0.254	0.334
	n	129	168
	WB	0.255	0.333
	RUB	-0.002	0.009
	VIF	1.014	1.008
G45	R^2	0.023	0.092**
	R	0.15	0.301
	n	95	144
	WB	0.145	0.281
	RUB	-0.008	-0.056
	VIF	1.107	1.11

development was slower than that in the larger gaps. However, it can be supposed that due to the strong competition of hornbeam, sessile oak could not utilize the advantages caused by the larger size of the gaps (i.e., stronger illumination, lower canopy precipitation interception and lower root concurrence of the parent stand) if increasing gap size over one tree length. Although differences between the heights of the tallest seedlings did not differ significantly between G30 and G45, hornbeam grew faster in the latter case if considering data of all seedlings. Thus, shading effect of hornbeam was presumably higher in G45. Competition pressure of hornbeam was the lowest in G15.

The spatial analyses on seedling development suggest that even in the smallest gaps, differences in site conditions between the topographical positions influenced the regeneration processes. The reason for the fact that it could be recognized only in the case of hornbeam may be partly the slower development of sessile oak. Thus, more time would have been needed for evolution of significant spatial differences in height of oak seedlings. Another reason can be that variability of light conditions was smaller within G15 than those within the larger gaps (4).

In the centres of the gaps, soil moisture became probably higher compared to the other parts (5, 6) and this facilitated height growth of both tree species.

Table 8
Soil moisture indicator herbaceous species occurred in the gaps. No. of quadrats – number of those 1 x 1 m quadrats in which the given species occurred.

Species	No. of quadrats
Cardamine impatiens **L.**	278
Urtica dioica **L.**	230
Solidago gigantea Aiton	193
Galium aparine **L.**	180
Festuca gigantea **(L.) Vill.**	141
Carex divulsa Stokes	89
Erigeron annuus **(L.) Pers.**	81
Lapsana communis **L.**	63
Athyrium filix-femina **(L.) Roth**	58
Stachys sylvatica **L.**	38
Juncus effusus **L.**	12
Cucubalus baccifer **L.**	6
Polygonum minus Hudson	5
Dryopteris carthusiana **(Vill.) H.P. Fuchs**	4
Epilobium obscurum Schreber	4
Polygonum hydropiper **L.**	4
Echinochloa crus-galli **(L.) Beauv.**	2
Eupatorium cannabinum **L.**	2
Juncus tenuis Willd.	2
Leontodon autumnalis **L.**	2
Rumex sanguineus **L.**	2
Solidago canadensis **L.**	2
Poa trivialis **L.**	1
Polygonum lapathifolium **L.**	1
Epilobium hirsutum **L.**	1
Lycopus europaeus **L.**	1

Influence of canopy precipitation interception and root concurrence of the parent stand is the lowest in the middle of the gaps. Considering hornbeam, this hypothesis is further supported by the intensive development in the west parts because soil moisture content of these parts is higher than that of the east or north positions (5). In the south parts, low light intensity could decrease growth of hornbeam. However, it is not clear why west parts of G45 are much less favourable for hornbeam development than the centres of these gaps. It was reported in earlier studies that fine-scale spatial pattern of soil attributes could modify the effects of differential shading by the parent stand on soil moisture in larger gaps more than in smaller ones (6).

The relatively good properties of west parts of G15 and G45 cannot be recognized in the case of sessile oak, presumably because of the above-mentioned reasons (slower growth rate of oak, competition pressure of hornbeam, less variable site conditions in the smallest gaps and fine-scale pattern of soil attributes in the largest gaps). However, in G30, the central and the west parts did not differ significantly in any of the sampling years, though differences between the west and some other parts were also insignificant in the fourth year of the regeneration. This result implies that for sessile oak growth, site conditions of the west parts were of transitional character between the centres and the other peripheral positions. The key role of soil moisture content in regeneration is confirmed by the results of the multiple regression analyses, too. The reason for the weak relationship is not clear but suggests that many – presumably sometimes stochastic – factors may influence regeneration processes simultaneously. Another explanation for the low values of the coefficients can be that light and soil moisture act synergistically therefore examining only one of these factors may be not sufficient enough to explain the spatial variance occurred in seedling development. In G45, the high hornbeam concurrence could further decrease the relationship between soil moisture and the height of the tallest sessile oak seedlings. Dryness and high illumination of the north parts of the gaps increased the competition ability of sessile oak relative to that of hornbeam in gaps of one tree height in diameter. Hornbeam is a mesophilous species contrarily to sessile oak that is more dry-tolerant and light-demander. Thus, differences between heights of the tallest sessile oak and hornbeam seedlings were the smallest here. The insignificant differences in VHD between various locations in the smallest and in the largest gaps may be the consequences partly of the low observation numbers and partly of the conservative character of the significance tests (see the description of the applied methods). Presumably, the latter is the

explanation of the insignificance of the quite large difference between the south and north parts of G30, too. Despite the insignificant results, the trend that VHD are the smallest in the north parts can be recognized also in G15 and in G45. The data suggest that although optimal conditions for both sessile oak and hornbeam occurred at the same positions inside the gaps, the outcome of their competition varied along the environmental (soil moisture and light) gradient. Schütz (11) reported that hornbeam development was the most intensive at the edge of the gap studied. The differences between results of Schütz (11) and those of the present experiment are consequences of the considerable differences of site conditions of the study stands. The annual precipitation that the beech forest studied by Schütz (11) received was 1190 mm, contrarily to the 700 mm that can be utilized by the sessile oak-hornbeam stand of the present experiment. Thus, it can be assumed that soil moisture content played a more important role in determining hornbeam growth in the latter case. Similarly to hornbeam, blackberry was also favoured by the increasing gap size due to the modified site conditions. For spread of blackberry, both of the strongly illuminated (north) and the relatively dry (east) locations were more or less unfavourable. Regardless the size of the gaps, the west parts seem to be the most optimal for proliferation, whereas in G30 and G45, the central location is of a transitional character between the west and the other peripheral parts. The results also show that in the larger gaps, shadiness of the south parts inhibited blackberry growth, too. The reason for the phenomenon that in G15, blackberry cover increased in the south positions more than in the centres is not clear. In contrast to the initial hypothesis, blackberry cover was not negatively related to sessile oak seedling development. However, this observation is in accordance with studies of Evans (23) and Harmer et al. (21) which showed that blackberry did not definitely decrease the growth of pedunculate oak seedlings. Instead, seedling establishment and survival are inhibited mainly by high blackberry abundance (21, 22). At the same time, in another sessile oak-hornbeam forest, Tobisch (19) found that spread of blackberry impeded regeneration of sessile oak in gaps of one tree height in diameter during the first five years of the regeneration. Tobisch (19) concluded that intensive weed control operations are needed to regenerate sessile oak successfully in the applied gap type. Again, the contradictions between the present experiment and the study of Tobisch (19) can be explained by the differences of the site conditions of the forests examined. The soil of the stand investigated by Tobisch (19) was of a transitional type between ranker and some brown forest soil (i.e., clay migration was noticeable but to a lower extent than in the case of brown forest soils). Furthermore, the mean annual precipitation was 790 mm and seepage water occurred, too. Due to these factors, blackberry proliferation was much more intensive.

Summarizing the results it can be concluded that under the studied site conditions, concurrence of the associated tree species could be reduced during the first years of the regeneration period if cutting as small gaps as 0.5 tree height in diameter. According to former experiments (32, 33), during the period when competition pressure is relatively low, sessile oak seedlings strengthen. However, if cutting larger gaps, concurrence of the associated tree species increases suddenly and sessile oak seedlings do not have time to prepare for the intense competition. If seedlings have time to strengthen, their competition ability increases due to two reasons. They will have strong roots which will facilitate height growth intensity (32, 33) after enlarging the gaps. Furthermore, seedlings with stronger root systems are more biotic and abiotic damage-resistant (34).

Another advantage of the smaller gaps is that their area is more easily reached by sessile oak acorns from trees surrounding the gaps than the area of the larger (e.g. at least one tree height in diameter) gaps because of the low dispersion ability of the heavy oak acorns (19, 22). It is very important since even if the gaps are cut above dense sessile oak regeneration, seedling number may decrease considerably after gap creation due to the disturbance effects caused by felling and harvesting, as well as, by microclimatic changes (19). Thus, regeneration of sessile oak can be made more secure if starting it with cutting small (e.g. half tree height in diameter) gaps and if these gaps are enlarged then gradually according to seedling development (see also 18). The present experiment shows that ecological characteristics of different locations of the circular gaps are markedly different and this influences height growth of sessile oak and hornbeam seedlings. A practical regeneration method may be choosing a position which seems to be suitable for silvicultural aims and then lengthening the gap in order to increase the proportion of the chosen part. For example, in the northern parts of the gaps, both competition of hornbeam and blackberry proliferation were low. Thus, the northern zone may be chosen and the gaps may be lengthened in east-west direction. In addition to decrease the initial size of the gaps, cutting elliptical gaps may be also an effective close-to-nature regeneration technique. However, it should be taken into consideration that if increasing the northern part of the gaps, more stems of sessile oak trees may produce epicormic branches since trees at the north edge of the gaps are exposed to direct sunshine for the longest time (19). Moreover, ecological characteristics of the elliptical gaps cannot be derived directly from those of circular ones because shading effect or root concurrence of the parent stand may prevail differently. Studies on dynamics of elliptical gaps would be very useful either from scientific or from silvicultural point of view.

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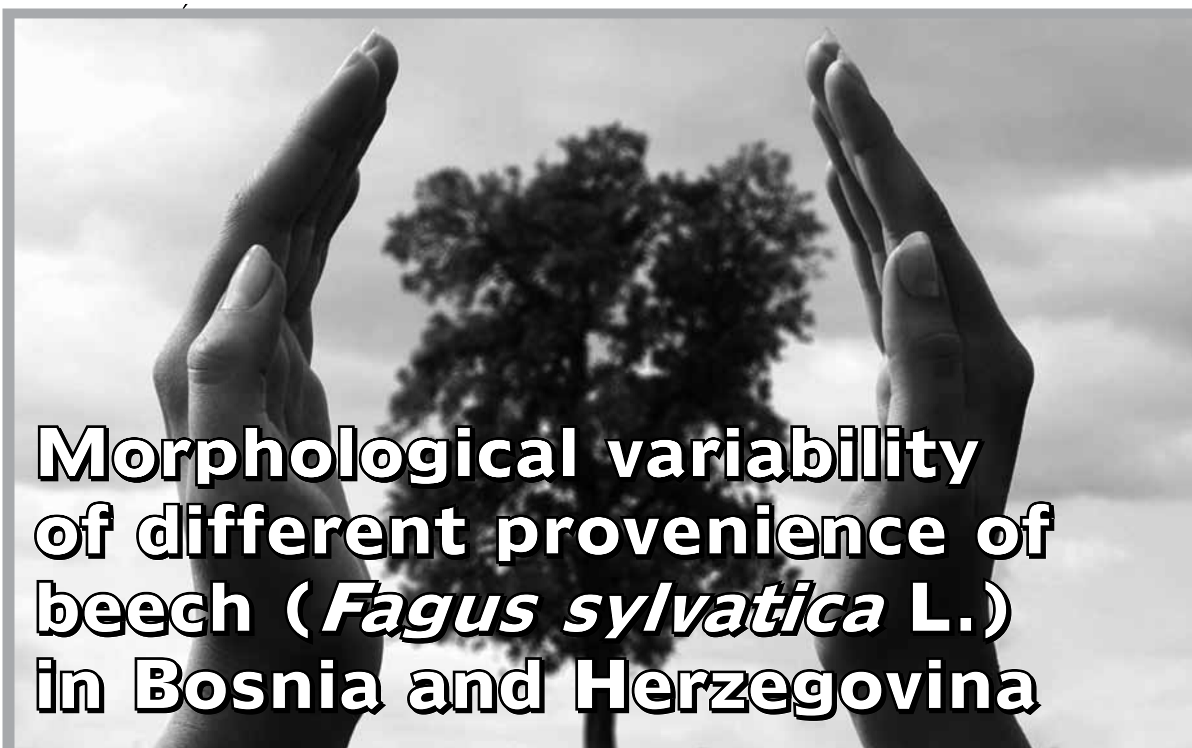

Morphological variability of different provenience of beech (*Fagus sylvatica* L.) in Bosnia and Herzegovina

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Background and purpose:
In this paper was researched the morphological variability of seed and one-year seedlings of beech of different proveniences from the major part of its natural dispersing in Bosnia and Herzegovina (from the Bužim, Bugojno, Banja Luka, Bosansko Grahovo, Posušje and Olovo).

Material and methods:
There were researched: length (l), width (w) and mass (m) of the seed, of the deducted parameters was calculated the coefficient of the shape of seed which was presented by relation of length and width of the seed ($C_{l/w}$). On the seedlings were measured the diameter at the neck of the root (D_{nr}) and height of the seedlings (H).

Results and Conclusion:
The largest seed was identified in the provenience Banja Luka (l=16.17 mm, w=8.15 mm, m=0.275 g), while the smallest was in provenience Bosansko Grahovo (l=15.47 mm, w=7.22 mm, m=0.143 g). Mean values of the mentioned indicators of seed for all proveniences from Bosnia and Herzegovina were: mean length of seeds 15.65 mm, mean width of seeds 7.91 mm, average mass of the seeds 0.218 g. Coefficient of the shape of seeds ($C_{l/w}$) had the mean value of 1.99. Seedlings of beech were the most developed in the provenience Olovo (D_{nr}=3.50 mm, H=12.49 cm), and the smallest dimensions had the seedlings form the provenience near Posušje (D_{nr}=2.83 mm, H= 9.38 cm). The mean diameter of the seedlings of beech for all proveniences was D_{nr}=3.16 mm, mean height H=11.54 cm. Results of the conducted researches point to expressed morphological variability of seed and seedlings of the researched proveniences of "Bosnian" beech which points to the needs for established horizontal and vertical seed regions of this species in Bosnia and Herzegovina.

Key words:
beech, seed, seedlings, proveniences, morphological variability

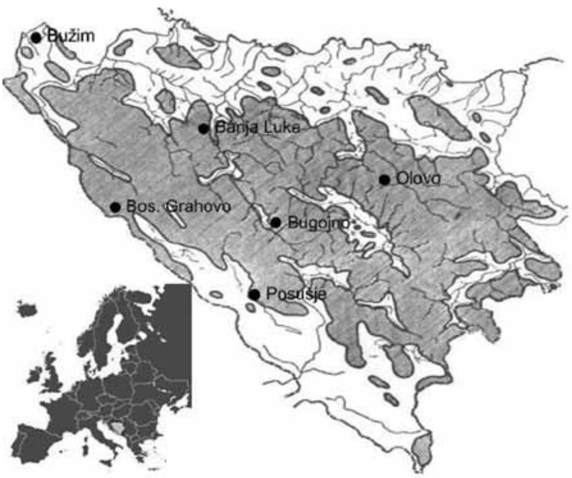
INTRODUCTION

Beech (*Fagus sylvatica* L.) is a significant tree species in the area of Central and South Europe, where it helds a dominant place in terms of surface, economic and other values (1). In the area of South-East Europe, it participates with 12 million ha in vegetation cover. In Serbia it covers about 1.25 million ha or 50 % of total surface under forests (2). In Croatia, beech is not only the most disperse species (744-796 ha), but it is also the first per its share in timber stock. In timber reserves of Republic Croatia, beech participates with about 36 % (3). The beech also has almost the same importance in Bosnia and Herzegovina where its share in timber stock is about 47 % of total timber mass, or 74 % mass of deciduous trees, with the total surface of high beech forests of 347-310 ha and with average reserve of 204.2 m^3/ha (4). This illustrates the importance of beech as the species from both the economic and ecological aspect. Beech is almost exclusively renewed in natural way, which is the basic assumption of its biological diversity, production ability and stability (1). In Bosnia and Herzegovina, however, the largest complexes of high beech forests were turned into stamp forests and lower degraded phases: brush-woods and scrubs, by unorganized and uncontrolled cutting; Also natural regeneration was difficult (5, 6). To make afforestation successful, it is necessary to obtain good planting material, especially on surfaces whith advanced level of degradation, and where the status of stand is significantly changed. Until present, little has been done on production of planting material and growing of forest cultures of beech (7, 6). By the end of 1950s, research on variability of beech indicated that it belongs to the group of less-diverse tree species. It resulted in the initiative to intensify the research on genetic variability of beech conducted throughout Europe, encompassing over 800 populations of beech (1).

These researches have great significance regarding enriching the beech, especially in selection of adequate proveniences for planting in particular habitats. That significance is increased in regard of seed-production and extraction of seed areas, with a goal to select more superior proveniences with favourable characteristics and to preserve genetic resources of the beech. In the sense of targeted selection seed material, Gradečki et al., (8) conducted the research of some morphological and physiological characteristics of seed of beech in Croatia, and they have identified significant differences in the size of morphological indicators of seed compared to the origin. For the production of quality planting material, apart from the favourable conditions provided in nurseries, it is necessary to have good quality of seed material. This paper describes the laboratory researches on morphological variability and quality indicators of seed of different proveniences of beech and field researches of the growth of saplings in the first year after the planting and the impact of morphological indicators of seed to the quality of saplings in the first year of growth.

MATERIAL AND METHODS

The seed of beech was collected in late September and early October 2007 at six localities in Bosnia and Herzegovina (1. Bužim, 2. Bugojno, 3. Banja Luka, 4. Bosansko Grahovo, 5. Posušje and 6. Olovo). Selection of localities was conducted in a way to encompass as many ecological-vegetation areas in Bosnia and Herzegovina as possible and from the stands of beech from different altitudes, but with as even as possible structural characteristics: the level of composition, development phases of the stands, and appearance. The basic indicators of the area and the localities for collection of seeds are given in Table 1 and presented in the Map 1 (according Fukarek 1970).



Map 1
Localities of researched proveniences of beech within its natural areal in Bosnia and Herzegovina (according Fukarek 1970)

Table 1
Localities of particular proveniences with geographic coordinates

No.	Proveniences	Locality	Altititude (m)	Geog. coord.
1.	Bužim	"Glinica"	300 – 350	N=45° 05´, E=16° 05´
2.	Bugojno	"Skrta-Nišan	600 – 700	N=43° 50´, E=17° 25´
3.	Banja Luka	"Osmača-Tisovac"	630 – 780	N=44° 39´, E=17° 10´
4.	Bos. Grahovo	”Peulje”	830 – 850	N=42° 40´, E=18° 40´
5.	Posušje	”Bosiljna”	860 – 950	N=43° 28´, E=17° 20´
6.	Olovo	„Patkovac”	950 – 1050	N=44° 10´, E=18° 30´

Of the total quantity of collected seed, samples were taken from not les than 1,000 grains of each provenience. Measuring of length (l), width (w) and mass of seed (m) were conducted on these samples (Fig 1). The length and width of seeds were measured by digital calipers with a precision of 0.01 mm and the mass of seed was identified by digital scale with a precision of down to 0.01 gram.

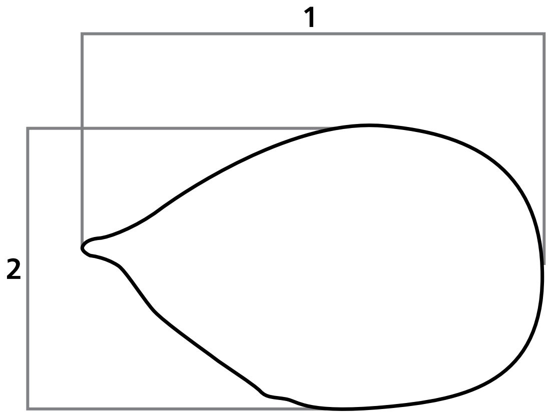


Figure 1
Measured parameters on seed
(1 – length of seed, 2 – width of seed)

The percentage of humidity was identified by method of drying chamber at 130 °C, the seed was dried for 1 hour and after that it was measured on scale. Absolute mass of seed was identified on four tests/trials with 100 grains of seed each, taken from the component of pure seed. By calculation of mean value by the method of ISTA, the mass of 1,000 grains of seed was identified. Vitality of seed was identified by indigo-carmine method (seed was previously submerged into water for 24 h, and than embryos were explanted, which were treated in 0.05 % solution of indigo-carmine in the duration of 2h at 30 °C in thermostat, in dark).
The seed of beech was stratified by cold-wet procedure in silicate sand, where it stayed for five weeks. After that, in mid-April 2008, the planting in the nursery "Sedrenik" was conducted. The seed was planted in the quantity of 180 - 200 gr/m^2 seedbeds, or 800-1,000 seeds/m^2. Similar quantities in their experiments were used by some other authors (7, 9, 10). After the planting, the seed was covered by the layer of silicate sand of thickness of 2 – 2.5 cm.
At the end of vegetation period the measurement was conducting of morphological indicators of saplings, diameter at the neck or the root and the height of seedlings. Diameters at the neck of the root were measured by digital calipers with the precision of 0.01 mm and the height of seedlings by ruler at precision of 1 mm. Data obtained by measurement of individual morphological parameters of seed and saplings were entered into statistical software: "WINSTAT" and "STATISTICA" where the statistical processing of it was conducted. The analysis of variance and identified dependence of individual measured parameters were conducted by establishing correlation analysis as well as cluster analyses.

RESULTS OF RESEARCH

Morphological indicators of seed of beech

Mean length of the seed
The length of the seed as morphological indicator was measured, for each provenience, at the sample of at least 1,000 seeds. Figure 2 shows mean values and variation of the length of seeds within particular proveniences.
Regarding the mean length of seeds, the provenience Bužim had the highest, both mean and maximal values, while the provenience Posušje had the lowest values of this characteristic. Then, the analysis of variance was conducted, the results of which were presented in Table 2.

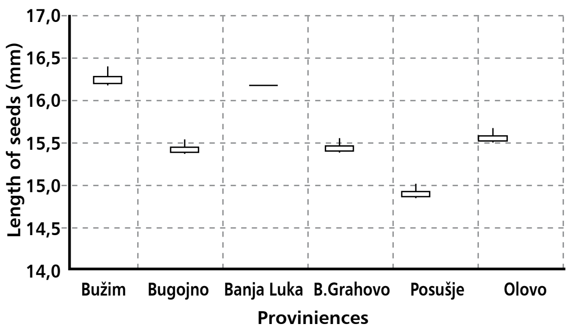


Figure 2
Mean length of seeds (mm) per proveniences

By the analysis of variance, statistically significant differences have been identified at the probability of 95 % with small coefficient of variability for the researched indicator within proveniences. Proveniences are distributed in 5 Duncan test groups. Provenience from Bužim has the largest average lengths of seeds (16.29 mm) and statistically it differs from all other proveniences, while provenience Posušje has the smallest average length of seeds of 14.93 mm and by that indicator it is significantly different from other proveniences. Proveniences Bosansko Grahovo and Bugojno belong to the same Duncan test group and per size of mean length of seed are in the middle. Although the difference between the largest and smallest average length of seed is small and it is 1.36 mm, the statistical differences between proveniences appeared due to small variation of the research characteristics within proveniences. Therefore the average coefficient of

Table 2
Analysis of variance of the length of seeds per proveniences (St. dev. = standard deviation, CV= coefficient of variability)

Rang	Proveniences	N	Mean (mm)	St. dev.	CV (%)	Duncan test - grouping
1.	Bužim	1005	16,29	±0,099	9,84	a
2.	Banja Luka	1000	16,17	±0,004	7,40	b
3.	Olovo	1005	15,57	±0,061	6,28	c
4.	Bos. Grahovo	1000	15,47	±0,066	6,93	d
5.	Bugojno	1000	15,45	±0,063	6,58	d
6.	Posušje	1000	14,93	±0,057	6,13	e
Sum/mean		6010	15,65	±0,058	7,19	-

variability was 7.19. The average length of seed for all proveniences of Bosnian beech was 15.65 mm.

Mean width of seeds

The width of seeds is the characteristic which was measured in the same samples like for length, and the results are shown in the Figure 3.
Maximal mean value of the width of seeds was identified at the provenience Bugojno, which is followed by the provenience near Olovo, while the lowest mean value was recorded at provenience from the area of Bosansko Grahovo.
Also, deviations from the mean value are very small, and it is the same like in the case of length of seeds, which points to the small within-the-proveniences variability considering this characteristic. Results of the analysis of variance of the width of seed characteristics are presented in
Table 3.
By the analysis of variance, at the probability of 95 %, statistically significant differences in the width of seed of beech were identified between each of the observed proveniences.
Proveniences were designated to 6 Duncan test groups. Mean values vary in the interval from 7.22 mm to 8.36 mm, with rather small variation coefficients.

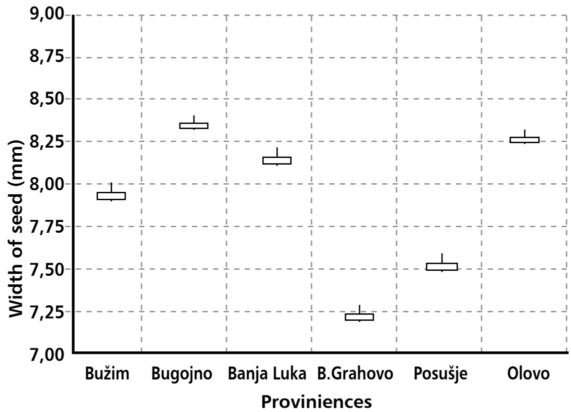


Figure 3
Width of seed (mm) per proveniences

The larges mean value of the width of seed was shown in the provenience of Bugojno which is statistically and significantly different from other proveniences, while the smallest width of seed was at the provenience of Bosansko Grahovo which belongs to the last Duncan group. The average value of the width of seed for all proveniences is 7.91 mm.

Table 3
Analysis of variance of width of seed per proveniences (St. dev. = standard deviation, CV= coefficient of variability)

Rang	Proveniences	N	Mean (mm)	St. dev.	CV (%)	Duncan test - grouping
1.	Bugojno	1000	8,36	±0,04	7,71	a
2.	Olovo	1005	8,27	±0,04	8,49	b
3.	Banja Luka	1000	8,15	±0,05	9,31	c
4.	Bužim	1005	7,95	±0,06	11,54	d
5.	Posušje	1000	7,52	±0,04	7,79	e
6.	Bos. Grahovo	1000	7,22	±0,04	7,99	f
Sum/mean		6010	7,91	±0,04	8,81	-

Coefficient of the shape of seeds ($C_{l/w}$)

As the indicators of the shape of seed, the relation between length (l) and width (w) of the seed is very interesting. For every seed per proveniences, this relation was calculated in the form of coefficient $C_{l/w}$, the results of which were presented in Figure 4 and Table 4.
It is apparent from the table that there are statistically significant differences in the coefficient of the shape of seed between researched proveniences. Based on the results of the analysis of variance, 5 Duncan groups were designated.

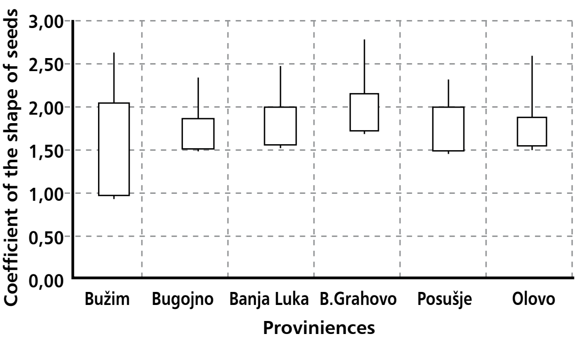


Figure 4
Coefficient of the shape of seeds (Cl/w) per proveniences

Morphological indicators of saplings

Diameter at the root neck
Researches on morphological indicators of beech saplings were conducted at five proveniences of beech. Provenience Bosansko Grahovo in these researches was not represented due to the lack of saplings. Seed of this provenience was not sufficiently germinated and there was no sufficient number of saplings to conduct measurements on it.The identified mean values of the diameter of root neck of saplings of different proveniences of beech are presented in Figure 5.

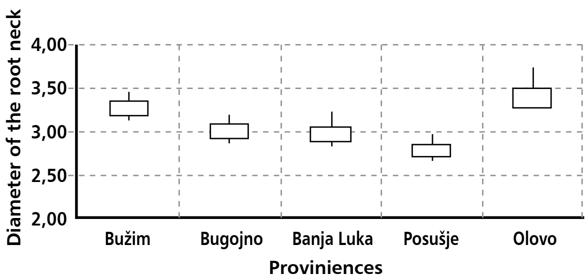


Figure 5
Diameter at the root neck (mm) per proveniences

Table 4
Mean values of the coefficient of seeds Cl/w, per proveniences (St. dev. = standard deviation, CV= coefficient of variability)

Rang	Provenijences	N	Mean (mm)	St.dev.	CV (%)	Duncan test - grouping
1.	Olovo	93	3,50	±0,235	32,53	a
2.	Bužim	93	3,33	±0,146	21,32	a
3.	Bugojno	92	3,08	±0,167	26,24	b
4.	Banja Luka	91	3,04	±0,184	29,16	b
5.	Posušje	83	2,83	±0,126	20,46	b
Sum/mean		452	3,16	±0,172	25,94	-

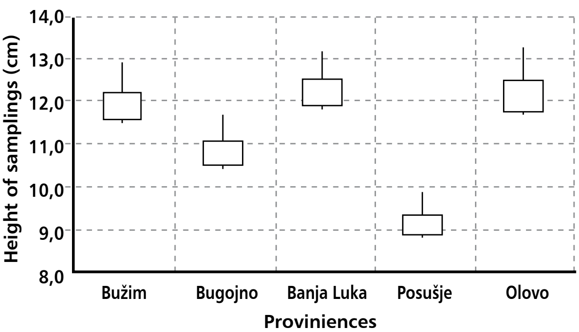


Figure 6
Height of saplings (cm)

The highest mean values of diameter at the root neck were recorded at saplings from the provenience Olovo. The lowest mean diameter at the root neck was shown in the provenience Posušje.
In order to identify statistically important differences in the size of diameter at the root neck the analysis of variance was conducted with Duncan test. Results of testing are shown in the Table 5.
By the analysis of variance of the tested characteristics, with the probability of 95 %, two Duncan test groups were separated, which are significantly different. In the first group, with higher mean diameter at the root neck, the proveniences are: Olovo and Bužim and in second: Bugojno, Banja Luka, and Posušje.

Table 5
Analysis of the value of diameter at the root neck of saplings per proveniences
(St. dev. = standard deviation, CV= coefficient of variability)

Rang	Provenijences	N	Mean (mm)	St.dev.	CV (%)	Duncan test - grouping
1.	Olovo	93	3,50	±0,235	32,53	a
2.	Bužim	93	3,33	±0,146	21,32	a
3.	Bugojno	92	3,08	±0,167	26,24	b
4.	Banja Luka	91	3,04	±0,184	29,16	b
5.	Posušje	83	2,83	±0,126	20,46	b
Sum/mean		452	3,16	±0,172	25,94	-

The highest variation coefficient of the measured characteristic was shown in the provenience Olovo.

Height of saplings

Mean height of saplings of different proveniences of beech was shown in the Figure 6. The highest mean height of saplings was identified at the provenience Banja Luka (12.51 cm) and the lowest at the provenience Posušje (9.38 cm).
Results of the analysis of variance are shown in the Table 6. By testing the significant differences between proveniences in reference to the mean height of saplings, it was possible to separate three Duncan groups. In first, with highest values of mean height, the following proveniences were separated: Banja Luka, Olovo and Bužim, in second Bugojno and in third with the lowest mean height, the provenience Posušje.
The same situatin is with the diameter at the root neck, where the highest variations of height of saplings was recorded at the provenience of Olovo (CV = 29.65).

DISCUSSION AND CONCLUSIONS

Results of the researches conducted on seed and saplings of beech in its natural habitat in Bosnia and Herzegovina confirm wide morphological variability of this species. If we consider the length of seed as morphological indicator of its variability, we can conclude that the within-the-provenience variability is very small, while the analysis of variance identified that the majority of proveniences are mutually statistically different.
Therefore, we have identified very narrow amplitude (1.36 mm) of this indicator where the lowest value is on the beech from Posušje (14.93), and the highest is in the provenience Bužim (16.29 mm). These values do not deviate in any provenience significantly from the average in the Balkans region (11).
The researches on the morphology of seeds were also conducted by other researchers in neighboring countries. The obtained values in such researches were expected and they range within similar relations as our results. Absolute value of mean values for all proveniences is 15.65 mm, while (8) for proveniences of the Republic of Croatia give the mean length of seed of 14.89 mm.
This data surely confirms the morphological diversity of beech in rather small area.
In his book, Stilinović (11) says that the average length of beech acorn of Mezian beech in literature sources was designated in the amount of average of 16 mm (it ranges from 14-19 mm).
On the other hand, the group of researchers (12) have shown significant variability of this indicator depending on the provenience of seed, where the

Table 6
Analysis of the variance of height of saplings per proveniences
(St. dev. = standard deviation, CV= coefficient of variability)

Rang	Provenijences	N	Mean (cm)	St. dev.	CV (%)	Duncan test - grouping
1.	Banja Luka	91	12,51	±0,675	25,91	a
2.	Olovo	93	12,49	±0,763	29,65	a
3.	Bužim	93	12,24	±0,686	27,20	a
4.	Bugojno	92	11,09	±0,603	26,23	b
5.	Posušje	83	9,38	±0,501	24,48	c
Sum/mean		452	11,54	±0,646	26,69	-

measured length of beech acorn was 15.38-17.05 mm. The last mentioned researchers have clearly defined that there exists the directly proportional correlative connection between altitude and the length of beech acorn.
Similar tendencies were also recorded in less expressed form in our researches.
Looking at the obtained results for the width of seed, we can conclude that the variability within proveniences is even lower than in the characteristics for the length of seed, and the within-the-provenience variability is higher.
According to the analysis of variance, every provenience belongs to separate group which is statistically significantly different from the other. Mean value of the width of seed for the observed proveniences which was obtained by research is 7.91 mm and it ranges in the amplitude from 1.14 mm (Bosansko Grahovo 7.22 mm, Bugojno 8.36 mm). Researches of this indicators conducted by Gradečki, et al., (8) show slightly higher values (9.53 mm) for the area of Croatia.
Seeds of beech from the area of Bosanko Grahovo are two times longer than wider; while the seeds from area of Bugojno have a bigger “belly”. Variation coefficient in this indicator was the lowest, while the highest variability was recorded at the mass of seed. Reasons for that have to be found in the fact that the deducted coefficients are under higher genetic control than the measured indicators.
According to Reyment (13) it is considered that these characteristics, which describe the shape, show much, better the filogenetic and genetic relations between organisms (14).
According to the correlation analysis, dependences of length and width of seed were identified, where the correlation coefficient is 0.545 while between the length and mass is 0.456 and between width and mass is 0.608.
The obtained results can be explained by fact that every tree species has particular form of seed which is genetically conditioned and for sure some deviations may occur, but in the majority of cases it is approximately permanent relation of the length and width of the seed.
Mass of the seed, above the dimensions in great extent depends on the percentage of humidity in the seed, so than the impact of the dimensions is rather small.
Absolute mass (weight of 1,000 seeds) ranges in the interval from 143.2 g (Bosansko Grahovo) to 274.8 g (Banja Luka). Almost by 100 % is higher the number of seeds in one kilogram if compared between the largest and the smallest seed (number of seeds from 3,700-7,000). Researches conducted in Serbia show smaller differences (12) and they range from 241.14 up to 336.54 g.
Similar results were also given in the literature (15) where the average values recorded 250 g. According to the last mentioned sources, the number of seeds is

4,000 pcs/1 kg, while in Serbia for mezian beech the number of seeds in one kg ranges from 3,000-4,150 grains.

In order to have a complete picture of the usable value of the seed, it would also be necessary to identify some of the internal indicators.

In the first place it is related to germination capacity of seed. Since this is the tree species which is passing trough harder and longer process of germination, we have chosen to identify the vitality by one of the most common methods (Indigo-carmine) and we have identified that it has a very wide range (from 49-91 %), which points to expressed inter-provenience variability.

Except for the above given indicators within these researches we have measured the height of the seedling and the diameter at the neck of the root of the saplings of beech.

Speaking about the diameter at the neck of the root, it is visible that this indicator does not have the strength for identification of inter-provenience variability, since its measuring was conducted on plants which were planted or were not cleared from substrate.

This value shows that after the measurement of the diameter, it is necessary in average about 90 plants per provenience to obtain the value of amplitude of 0.67 mm between the "thickest" (2.83 mm-Posušje) and the "thinnest" (3.50 mm-Olovo).

At the end, based on the presented, we could state that there is hardly any difference between mean diameters of the proveniences. One more reliable parameter that gives better guidelines for identification of significant differences between proveniences is the indicator of height of saplings (one-year plants). After measurements of 90 plants per provenience, we have identified that the average value for "Bosnian" beech is 11.54 cm, and the amplitude between the highest (12.51 cm-Banja Luka) and the shortest provenience (9.38 cm-Posušje) is 3.14 cm.

The highest mean values of the slimness level (relation H/D) were identified in saplings from the area of Banja Luka, and the lowest values at saplings of the provenience from the area of Posušje. These values are really good indicators for correct selection of proper provenience for particular habitat.

The correlation analysis was conducted on the data obtained by measurements of the researched parameters, however, there was no significant dependence between observed parameters of seed and growth of saplings, e.g. largeness of the seed does not correlate with altitude and diameter of saplings.

In order to assess the genetic distance between analyzed proveniences based on very modest indicators, yet a large number of measurements (over 15.000), the cluster analysis was conducted. Dendrogram of cluster-analyses is showing that proveniences from Posušje and Bosansko Grahovo

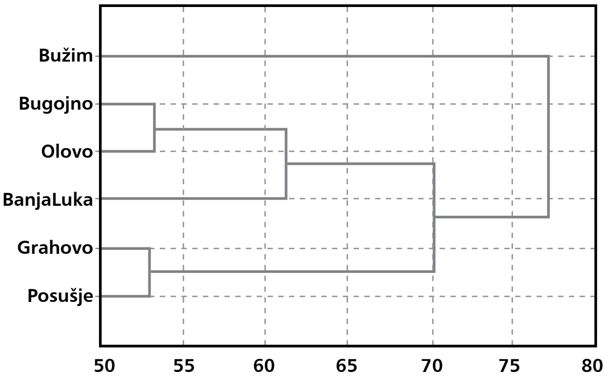


Figure 7
Dendrogram of cluster analyses made based on the measured data on length, width, mass and mass of dry substance of the seed of the analyzed provenienences.

are grouped at the smallest genetic distance, and at Great distance on the other hand are Bugojno and Olovo (Figure 7).

The provenience of Banja Luka is between these two very close groups, which is more similar, due to smaller genetic distance, to the group of proveniences from Bugojno and Olovo. Proveniences Grahovo and Posušje together with previously mentioned three proveniences in one wider range make the group which is altogether very distant from provenience Bužim. It means that the researched proveniences show two, genetically very distant groups with expressed diversity obtained by measurement of morphological-metric parameters.

Grouping of proveniences in cluster-analysis can also be explained by its geographic position where more or less expressed even climatic conditions in Grahovo and in Posušje prevail, and moderate variant of these factors are Bugojno and Olovo. As we have already stated, the highest genetic diversity is recorded at beech from Bužim, which for sure can be attributed to particular territorial isolation from the impact of other proveniences.

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