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Original scientific paper

VARIABILITY OF THE WIDTH OF DOUGLAS- FIR (*Pseudotsuga menziessii* /Mirb./Franco) NEEDLES IN PROVENANCE TESTS

Vera LAVADINOVIĆ[1], Vukan LAVADINOVIĆ[2], Zoran PODUŠKA[1], Milan KABILJO[1]

Abstract: *Introduced tree species which have a wide natural range of distribution should be tested in experiments with different provenances. Douglas-fir is a very productive conifer species in its natural forest stands of America and Canada. Because of its high value, it is very popular in the countries of Europe and New Zealand as a conifer species suitable for reforestation. Its genetics and ecological adaptability can be confirmed by the investigations of its variable morphological traits, which is the aim of this research. Needle characteristics and needle morphology play a very important role in the performance of plant functions. Needle structure has a great influence on the plant life-cycle and their resistance to water loss, temperature and CO_2 levels. The characteristics and morphology of needles were studied in order to determine whether there are differences between the provenances. Two experimental plots with twenty Douglas-fir provenances originally from North America were established in Serbia. A two-way analysis of variance was aimed at a closer study of the effects of the interaction of the site conditions of Douglas-fir provenances in the test locations in Serbia on the morphological traits of the needles.*

Keywords: Douglas-fir, provenance, width of needles

VARIJABILNOST ŠIRINE ČETINA DUGLAZIJE (*Pseudotsuga menziessii* /Mirb./Franco) U PROVENIJENIČNIM TESTOVIMA

Izvod: *Introdukovane vrsta drveća, koje imaju širok spektar prirodnog areala, treba da bude testirane u ogledu sa različitim provenijencijama. Duglazija je veoma produktivna četinarska vrste u svojim prirodnim šuma Amerike i Kanade. Zbog svoje visoke vrednosti ona je najpopularnija u zemljama Evrope i Novom Zelandu, kao*

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odgovarajuća vrsta četinara za potrebe pošumljavanja. Genetika i ekološka adaptivnost mogu biti potvrdjeni ispitivanjem morfoloških promenljivih karakteristika, koji su i cilj ovog istraživanja. Karakteristike i četina i morfologija je veoma važna za biljne funkcije. Struktura četina su sa značajnim uticajem na životni ciklus biljaka i otpornost na gubitak vode, balans temperature i nivoa CO_2. Karakteristike četina i morfologija, analizirani su u *cilju da prepoznaju da li postoje razlike između istraživanih provenijencija. Dva eksperimentalna ogleda sa dvadeset provenijencija duglazije su osnovana u Srbiji sa orginalnim semenskim materijalom iz Severne Amerike. Dvofaktorijalna analiza varijanse imala je za cilj bliže ispita efekta interakcije uslova staništa provenijencija duglazije u ogledima u Srbiji na morfološke karakteristike četina.*

Ključne reči: Duglazija, provenijencija, širina četina

1. INTRODUCTION

Intense climate change has threatened natural regeneration of ecosystems and native species are losing the optimum conditions under which they can survive. The changing water regimes, temperatures and soil structure have inevitable implications for vegetation. Therefore, the adapted reforestation strategy should consider the introduction of adaptive and promising tree species as one of the possible solutions. Introduction of trees include adaptation, productivity and successful growth in new environmental conditions.

If a species has a wide natural range of distribution, it is important to choose the most appropriate provenance. Successful introduction requires the control of genetic material and its testing by provenance test (Rehfeld, G.E. 1989).

Douglas-fir (*Pseudotsuga menziessii* /Mirb./ Franco) is the most successful and ecologically-adapted introduced species in Europe (Hermann, R. K. 1987). It was introduced into Europe in 1825 by a Scottish botanist David Douglas (Allen, GS, Owens, J. N. 1972). Its natural range extends from British Columbia in the north as far as New Mexico in the south (Allen, G.S., 1942; Alexander, R.R. 1988). More genetics research is being done on Douglas-fir than any of its associates (Adams, W.T., *et al*. 1990; Bialobok, S., Mejnrtowicz, L. 1970; Campbell, R.K. 1979, 1992; Campbell, R.K., Sugano, A.I. 1993; Erikson, G., Ekeberg, I. 2001; Nicholas, D.Dean 1963; Rehfeld, G.E. 1989; Wright, J.W., *et al*. 1971).

Adaptation of introduced species to new environments is one of the greatest challenges to forest trees (Arno, S.F. 1990). Of all strategy questions regarding Douglas-fir, long-term adaptation causes the most serious concern. No geneticist will ever be able to use as expensive and effective methods, involving virtually infinite time and numbers of trees, as were employed in natural selection for adaptation to the local environment and climate. Genetically improved and locally adapted Douglas-fir, confined to favorable sites, should contribute significantly to the economy of temperate zone forests of the world. (Silen, R.R., 1978).

The main parts of the plant water transpiration system are located in leaves. Needle characteristics and needle morphology play a very important role in the performance of plant functions. Needle structure has a great influence on the plant life-cycle and their resistance to water loss, temperature and CO_2 levels. The analysis of morphological and anatomical characteristics of needles can be a significant indicator of the ecological adaptability of introduced species to new sites. Identification of these characteristics is important for the description of the plant reaction to environmental stress. It is important to realize that genetic variation and differentiation may represent alternative modes of adaptation to diverse environmental conditions. (Martha E. Apple *et al*. 2000; Urbaniak, Kalinski L, R Popielarz, 2003). The aim of the study was to compare the mean width of Douglas-fir needles of different provenances in order to determine whether there are variations in the morphology of Douglas-fir needles from two sites in Serbia.

2. MATERIALS AND METHODS

The research area included Douglas-fir provenances of different locations originating from the natural range of this species in North America. The geographical coordinates of the tested provenances are shown in Table 1 below.

The original Douglas-fir seeds of different provenances (Table 1 `Number of provenance`) were used to produce seedlings and set up two experiments at different sites. One experiment was set on Mount Juhor (central Serbia) on the site of mountain beech forests (*Fagetum moesiaca montanum* Jov. 1976- Jovanović, B. 2000) and the other in Tanda near Bor (eastern Serbia) on the site of Hungarian oak and Turkey oak forests (*Quercetum frainetto-cerris* Rud. 1949- Jovanović, B. 2000). The field experiments were based on the principle of the `random block system` (a randomized block design with a random arrangement of provenances). The experiments were part of long-term research on the properties of Douglas-fir (Lavadinović, V., Koprivica, M. 1996, 1999, Lavadinović, V., Isajev, V. 2003).

Table 1. *Geographical coordinates of the tested Douglas-fir provenances*

Identification Number of Provenance	Our mark	Latitude (º N)	Longitude (ºE)	Altitude (m)
Oregon 205–15	1	43.7	123.0	750
Oregon 205–14	2	43.8	122.5	1200
Oregon 202–27	3	45.0	122.4	450
Oregon 205–38	4	45.0	121.0	600
Washington 204–07	9	49.0	119.0	1200
Oregon 205–13	10	43.8	122.5	1050
Oregon 205–18	11	44.2	122.2	600
Oregon 202–22	12	42.5	122.5	1200
Washington 202–17	15	47.6	121.7	600
Oregon 201–10	16	44.5	119.0	1350
Washington 201–06	17	49.0	120.0	750
Oregon 202–19	18	45.3	123.8	300
Washington 204–09	19	49.0	119.3	900
Oregon 205–11	20	45.0	123.0	150
New Meksiko 202–04	22	32.9	105.7	2682
New Meksiko 202–10	23	36.0	106.0	2667
Oregon 202–31	24	44.3	118.8	1500
Oregon 205–29	26	42.6	122.8	900
Oregon 204–04	30	45.0	121.5	900
Washington 205–17	31	47.7	123.0	300

For the analysis of the morphometric traits of Douglas-fir needles at the two sites, only the samples of selected provenances were taken. The selection of the provenances from which the needles would be taken was done on the basis of the results obtained in the study of the variability of growth elements (Lavadinović, V. Koprivica, M. 1999). The samples were taken from two provenances whose trees had minimum, average and highest mean values of the studied growth elements. Fresh needles were fixed in 50% ethyl alcohol and transported to the laboratory where permanent anatomical sections of 30 randomly selected needles were made. The permanent anatomical preparations were cut using a microtome at 17 μm thickness in the middle of the needle, then stained with Safranin red and Toluidine blue and washed with water, after which the ethyl alcohol dedehydration was applied increasing the alcohol concentration from 50% to 96%. The fixation of the sections was completed with xylene for a period of several hours, after which the needles were glued to glass with Canada balsam, glass covered and dried in an oven at a temperature of 60°C.

3. RESULTS AND DISCUSSION

3.1 The two-way analysis of variance for the width of needles

As can be seen from the results of the analysis of variance shown in Table 2:

a) there are statistically significant differences in the mean values of the width of Douglas-fir needles of the Juhor site and the Tanda site;
b) there are statistically significant differences in the mean values of needle width between the provenances of the same site;
c) with certain provenances, the interaction between the `site` and `provenance` factors affects the mean width of the needles.

Table 2. *The two-way (site of X provenances) analysis of variance for the width of needles*

Source of variation	Sum of squares	Degree of freedom	Variance	F- ratio	p-value
A: Site	$1.38756 \cdot 10^6$	1	$1.38756 \cdot 10^6$	334.27	0.000
B: Provenance	$3.37372 \cdot 10^6$	5	674743.0	162.55	0.000
Interaction AB	$3.53721 \cdot 10^6$	5	707441.0	170.42	0.000
Error	$1.44457 \cdot 10^6$	348	4151.08		
Total	$9.74306 \cdot 10^6$	359			

3.2 The impact of the site on the needle width

The least significant difference test was used to determine the impact of environmental factors of a site on the variability of the width of Douglas-fir needles.

Table3. *LSD test of the impact of the sites of Juhor and Tanda on the needle width*

Site	Sample size	Mean value	Error of mean differences	Homogeneous groups
Juhor	180	1396.75	4,80224	X
Tanda	180	1520.92	4,80224	X

Comparison	Differences	+/– Limits
Juhor–Tanda	*–124.167	
13.3574		

* indicates statistically significant differences

The presented data (Table 3) show that there are statistically significant differences in the mean width of Douglas-fir needles between the sites of Juhor and Tanda. The average width of the needles in Tanda (1520.92 µm) is significantly higher than on Juhor (1 396.75 µm), and the test confirms the impact of environmental factors of these two sites on the differences in the size of needles. The obtained data are graphically represented (Graphs 1 and 2).

3.3 The impact of provenances on the needle width

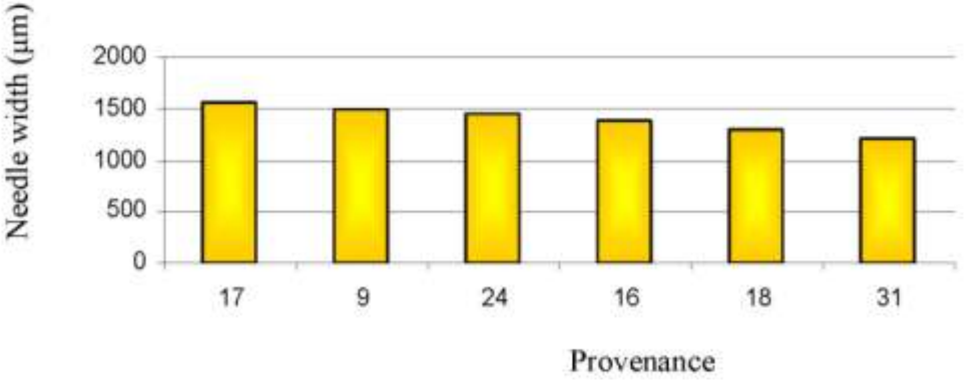
Table 4. *LSD test of the impact of provenances on the width of needles*

Provenance	Sample size	Mean value	Error of mean differences	Homogeneous groups
18	60	1340.75	8.31773	X
31	60	1367.5	8.31773	X
9	60	1438.75	8.31773	X
16	60	1480.75	8.31773	X
17	60	1486.75	8.31773	X
24	60	1638,5	8,31773	X

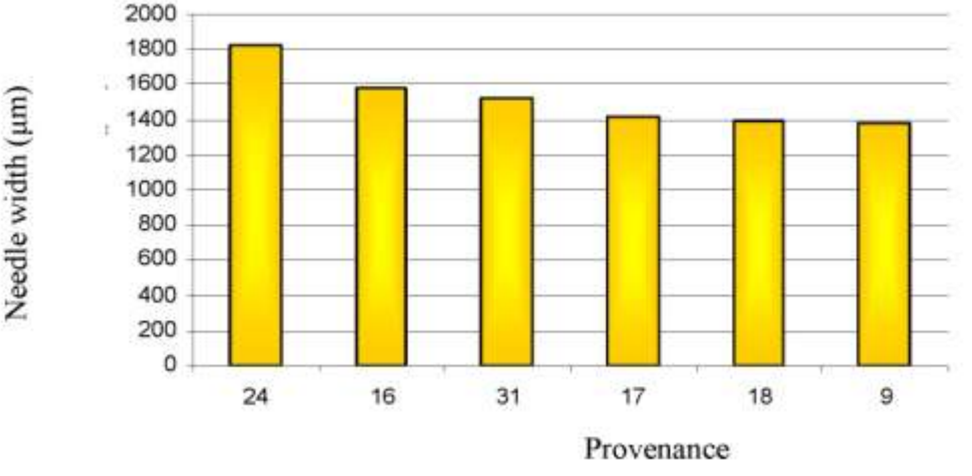
Comparison	Differences	+/– Limit
9–16		*– 42.0
23.1357		
9–17	*– 48.0	23.1357
9–18		* 98.0
23.1357		
9–24		*–199.75
23.1357		
9–31		* 71.25
23.1357		
16–17	–6.0	23.1357
16–18	* 140.0	23.1357
16–24		*–157.75
23.1357		
16–31		* 113.25
23.1357		
17–18		* 146.0
23.1357		
17–24		*–151.75
23.1357		
17–31		* 119.25
23.1357		
18–24		*–297.75
23.1357		
18–31		* –26.75
23.1357		
24–31		* 271.0
23.1357		

* statistically significant difference.

Although Table 4 of the analysis of variance clearly shows that there are statistically significant differences in the width of needles between certain provenances, LSD test shows that some provenances (16 and 17) are homogeneous in this character, *i.e*. the differences in the mean values of the needle widths are not significantly different.



Graph1. *Interprovenance variability of the needle width at Juhor site*



Graph 2. *Interprovenance variability of the needle width at Tanda site*

4. CONCLUSION

Douglas-fir is a species with broad ecological amplitude which is confirmed by its natural range of distribution. It is a conifer species suitable for introduction, but it is resonable to test the suitability of its provenances before introduction.

As an exotic species, Douglas-fir need to be provenance tested before introduction. Its genetics and ecological adaptability can be confirmed by the investigations of its morphologically variable characters, which is the aim of this research. For that reason, two experimental plots with twenty Douglas-fir provenances orginally from North America were established in Serbia.

A two-way analysis of variance was aimed at a closer study of the effects of the interaction of the site conditions of Douglas-fir provenance test locations in Serbia on the morphological characters of the needles. The ANOVA results of the analyzed morphological characters of needles show that there are statistically significant differences between the provenances (Graphs 1 and 2). The LSD test shows that the provenances are homogeneous, *i.e*. that the differences in their mean values are not statistically significant. The lower range of character variation in these provenances, compared to others, can be conditionally considered as a consequence of their genetic similarity which conditioned similar phenotype expressions in the interaction with the external factors of the sites where the tests were established.

ACKNOWLEDGEMENTS

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REFERENCES

Adams, W.T., Johnson, G., Copes, D.L. and others (1990): Is research keeping up with the needs of Douglas-fir tree improvement programs? Western Journal of Applied Forestry. 5(4): 135-137.

Alexander, R.R. (1988): Forest vegetation on National Forests in the Rocky Mountain and Intermountain regions: habitat types and community types. USDA Forest Service, General Technical Report RM-162. Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO: 47.

Allen, G.S. (1942): Douglas-fir (*Pseudotsuga taxifolia* Lamb. Britt.) A summary of its life history. B.C. For Serv. Res. Note No. 9: 27.

Allen, G.S., Owens, J.N. (1972): The life history of Douglas-fir. Environment Canada, Canadian Forestry Service, Ottawa, ON: 139.

Arno, S.F. (1990): Ecological Relationships of Interior Douglas-fir. Symposium Proceedings: “Interior Douglas-fir the species and its management.” Spokane, Washington, USA.

Bialobok, S., Mejnrtowicz, L. (1970): Provenance differentiation among Douglas-fir seedlings. Arbor. Kronickie, Rocy. 15, Nadbitka: 197-219.

Campbell, R.K. (1979): Genecology of Douglas-fir in a watershed in the Oregon Cascades. Ecology 60(5):1036-1050.

Campbell, R.K. (1992): Genotype environment interaction: a case study for Douglas-fir in western Oregon. Res. Pap. PNW-RP-455. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 21.

Campbell, R.K., Sugano, A.I. (1993): Genetic variation and seed zones of Douglas-fir in the Siskiyou National Forest. Res. Pap. PNW-RP-461. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest R. S. 23 p.

Erikson, G., Ekeberg, I. (2001): An introduction to Forest genetics, Genetics variation and provenance research. ISBN91-576- 6032-8. SLU Reoro Uppsala

Hermann, R.K. (1987): North American tree species in Europe. Jour. of Forestry 85 (12): 27-32.
Jovanović, B. (2000): Dendrologija. Šumarski fakultet Univerziteta u Beogradu.
Martha E. Apple, David M. Olszyk, Douglas P. Ormrod, James Lewis, Darlene Southworth and David T. Tingey (2000): Morphology and stomatal function of Douglas fir needles exposed to climate change: Elevated CO_2 and temperature.*International Journal of Plant Sciences.*Vol. 161, No. 1 (January 2000), Pp. 127-132
Lavadinović, V., Isajev, V. (2003): Genetic diversity of Douglas-fir provenances in Serbia. International scientific conference, 75 Years of the research Institute, Bulgarian academy of sciences. Sofia, Bulgaria. Proceedings of scientific papers: 85
Lavadinović, V., Koprivica, M. (1996 a): Tracheid width of different Douglas fir (*Pseudotsuga taxifolia* Britt.) Provenances in test plantations in the region of Serbia. Proceedings of the 2nd International Conference on the Development of Wood Science Technology and Forestry, Sopron, Hungary: 277-286
Lavadinović, V., Koprivica, M. (1999 a): Development of young Douglas – fir stands of different provenances on oak site in Serbia. Novas Tecnologias, Editado por Ana Amaro & Margarida Tome. Empirical and Process-Based Models for Forest Tree and Stand Growth Simulation ISBN:972-689-154-X. Deposito legal: 139925 / 99. Edicoes Salamandra, LDA Lisboa, Portugal: 231-241
Nicholas, D.Dean (1963): The influence of environment, genetics, and growth characteristics on tracheid length and specific gravity variation in a Douglas-fir provenance study. M.S. thesis. Oreg. State Univ., Corvallis: 43 p.
Rehfeld, G.E. (1989): Ecological adaptations in Douglas-fir (*Pseudotsuga menziesii* var.*glauca*): synthesis. For. Ecol and Manage. 28: 203-215.
Silen, R.R. (1978). Genetics of Douglas-fir. USDA Forest Service, Research Paper WO-35. Washington,DC, p 34.
Urbaniak L, Kalinski L, Popielarz R (2003) Variation of morphological needle characters of Scots pine (*Pinus sylvestris* L.) populations in different habitats. Acta Soc Bot Pol 72:37–44
Wright, J.W., Kung, F.H., Read, R.A., Lemmien, W.A., Bright, J.N. (1971): Genetic variation in Rocky Mountain Douglas-fir. Silvae Genet. 20 (5): 54-60

VARIABILITY OF THE WIDTH OF DOUGLAS- FIR NEEDLES IN PROVENANCE TESTS

Vera LAVADINOVIĆ, Vukan LAVADINOVIĆ, Zoran PODUŠKA, Milan KABILJO

Summary

The ecological and economic role of introduced tree species is of great significance for the forestry of Serbia. Introduction is carried out with promising species whose genetic value and potential can be confirmed after the transfer of seed into new ecosystems. Introduction of conifer species aim to ensure the same quality and productivity as in their natural environments, thus justifying the process of introduction. The effects of successful introduction require the control of genetic material and their provenance testing. In Canada and North America, Douglas-fir (*Pseudotsuga menziesii* / Mirb. / Franco) is one of the most important biological and economic conifer species. It is also one of the species with the widest range of natural distribution which stretches from the Pacific coast to the Rocky Mountains, New Mexico and Canada. If a species has such a wide natural range, it is important to choose the most appropriate provenance. Therefore we tested morphological

traits of Douglas-fir needles of different provenances at two sites in Serbia. Analysis of variance and Least Significant Difference Test (LSD test) at the level of provenances within the same locality and between localities showed statistically significant differences between the sites, while the multi-factor analysis determined the impact of two factors (provenance, site) on the specific property. It was concluded that:

- within the sites, all the observed traits showed statistically significant differences in the mean values at the provenance level, which indicated that they were not caused by random, but by internal factors of the treatment; LSD test, however, pointed to the existence of several small homogenous groups for each trait, indicating lower genetic variability of the provenances that make homogeneous groups;
- all the properties measured at the site level show statistically significant differences with higher mean values of all measured properties at Tanda site than at Juhor site;
- There is an interaction between the factors of variability (site and provenance), *i.e.* a change in one variability factor causes a change in the other factor.

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Original scientific paper

THE COMPARATIVE ANALYSIS OF THE STATE OF DENDROLOGICAL PLANTS IN BELGRADE PARKS, SERBIA

Tatjana ĆIRKOVIĆ-MITROVIĆ, Ljiljana BRAŠANAC-BOSANAC,
Katarina MLADENOVIĆ, Ivan MILENKOVIĆ[1]

Abstract: *This paper presents the results of the conducted research of the health status and seed yield of the dendrological species in five parks situated in areas with different degrees of pollution. According to the volume of seed yield, selected trees in SIV Park had the lowest yield, somewhat higher yield were displayed by the trees in Banovo Brdo Park, then Pioneer Park and Topčider Park, whereas the most abundant yield was that of the trees in Academic Park. On the other end, as per visual assessments of the health state, the trees in Pioneer Park showed the best health condition, the second best had the trees in SIV Park (air pollution zone), then the trees in Topčider Park and Banovo Brdo Park, while the lowest average score was assigned to the trees in Academic Park. Results of the conducted research suggest that the condition of dendrological plants in these parks is significantly dependent in the protection and care measures taken.*

Key words: parks, Belgrade, health status of trees, seed yield of trees.

UPOREDNA ANALIZA STANJA DRVENASTIH BILJAKA U PARKOVIMA BEOGRADA, SRBIJA

Abstract: *U radu su prikazani rezultati istraživanja zdravstvenog stanja i obilnosti uroda drvenastih biljaka u pet parkova koji se nalaze u uslovima različitog stepena zagađenosti. Prema obilnosti uroda najmanji urod imala su izabrana stabla u parku SIV, zatim u parku Banovo brdo, Pionirskom parku, Topčideru, a najbolji urod stabla u Akademskom parku. Prema vizuelnoj oceni zdravstvenog stanja najbolja su stabla u Pionirskom parku, zatim parku SIV (zona sa zagađenim vazduhom), Topčiderskom parku, parku Banovo brdo, a najnižu prosečnu ocenu imala su stabla u Akademskom parku.*

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Rezultati istraživanja ukazuju da stanje drvenastih biljaka u ovim parkovima značajno zavisi od mera nege koje se sprovode.

Key words: parkovi, Beograd, zdravstveno stanje stabala, obilnost uroda stabala.

1. INTRODUCTION

Urban parks have a strategic importance for quality of life in our urbanizing society and play a significant role in increasing the livability of cities (Biddulph, 1999). Within the complex of environmental factors through the mutual plant/man impact, depending on whether their interplay leads to enhanced and progressive environment, parks are priceless to a sustainable urban development. In environmental terms, urban areas are specific to the survival and development of plants due to various adverse conditions typical of such areas (small quantities of water, restricted space for root system growth, air pollutants, etc.). Therefore monitoring of the condition of dendrological plants in parks is of a great significance since determining the health status and seed yield enables recommending implementation of appropriate protection and care measures to the park plants.

2. MATERIAL AND METHOD

The relevant parks were selected according to their locations in Belgrade. Parks in the very downtown Belgrade were selected (Academic Park and Pioneer Park) as well as those at the rim of the central urban area (SIV and Banovo Brdo) and one in the forest park area (Topčider Park).

The selected parks are situated in in areas with different degrees of pollution, in the following zones (Aničić Urošević et al., 2015):

- *Pioneer Park* – in a zone with **high air pollution** and traffic flow of above 3,500 vehicles per hour;
- *SIV Park* – in a zone with **air pollution** and traffic flow of 2,000 to 3,000 vehicles per hour;
- *Banovo Brdo Park* and *Academic Park* – in zones with **moderate air pollution** and traffic flow of 1,000 to 2,000 vehicles per hour;
- *Topčider Park* – in a zone with **low air pollution** and traffic flow of below 1,000 vehicles per hour.

Source: https://www.planplus.rs/

Figure 1. *Location of parks in Belgrade*

Species and individual plants were selected according to the share of the specific species in the total number of trees in the parks under observation. The number of selected trees per species differed from one park to another, depending primarily on their share in the total number of trees in the relevant park. The trees subject to research totaled 37 in Pioneer Park, 15 in Academic Park, 29 in Banovo Brdo Park, 37 in SIV Park and 17 in Topčider Park. The aggregate number of trees selected and assessed counted 135 – 72 coniferous and 63 deciduous trees.

During vegetation in the years 2015/16 all trees in the aforesaid Belgrade parks were examined in in order to evaluate the general condition of the tree species.

Analyses of the seed yield and its volume were performed using the adapted Kaper scale for forecasting seed yield within a stand (Stilinović, 1985, Isajev et. al., 1998) (Table 1).

Table 1. *Yield scoring scale*

Category of yield volume – score		**Quantitative yield volume parameters**
0	**-**	No fruit
1	**Very poor**	Insignificant number of fruits in trees
2	**Poor**	Small number of fruits in trees
3	**Medium**	More observable fruits in trees
4	**Good**	Sufficient fruits in trees
5	**Very good**	High volume of fruits in trees

The examination of the health of trees involved detection of mechanical, phytopathological, entomological and acarological damages to the tree crowns, tree trunks and root collar zone.

Fieldwork was conducted twice during a single vegetation period, in spring and in summer. Biotic and abiotic damages were identified in all trees. In order to determine the as-is health condition of trees and identify any health impairing factors, visual assessments of health status and of assimilation area loss and discoloration were made for the trees under observation. In June and July defoliation was assessed, while discoloration was inspected in the observed trees in August, applying ICP Forests methodology (Anonymous, 2006; 2010).

Visual assessment of the health of trees was provided for all trees under observation according to the scale presented in Table 2.

Table 2. *Scale for the visual assessment of the health status of trees*

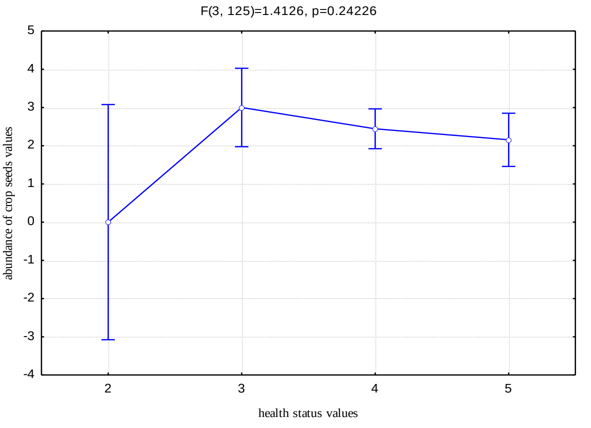
Visual assessment of the health of trees		Quantitative parameters
1	**Dead tree**	-
2	**Tree dying out**	significantly reduced leaf assimilation area, progressive rot in trees and branches, poses a public safety issue
3	**Tree with significant damage**	presence of damage to the foliage, trunk and branches with possibility of recovery, tip burns, rot in trunk and/or branches
4	**Tree with minor damage**	rare and random damage to the foliage, trunk and branches, with a small number of dry branches
5	**Healthy tree**	without visible symptoms of damage to the foliage, trunk and branches, or with insignificant damage

Young, newly planted trees were exempt from the assessment of the health status, with remarks recorded on any abiotic and/or biotic damages present.

The data processing and analyses were done in Microsoft Office Excel 2007 and Statistica 7 statistical software application.

3. RESULTS AND DISCUSSION

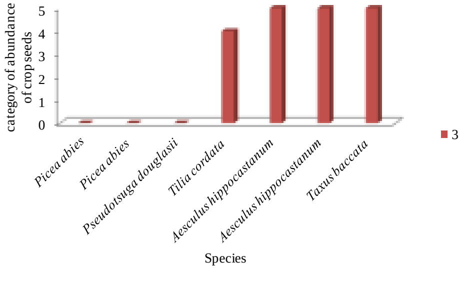
In the parks under observation there were neither dead trees nor those assigned score 1 among the selected trees, whereas only two were classified into score 2 category. These two trees bore no fruits. Graph 1 presents the average scores for seed yield volume (abundance) against the assessed health status with a 0.95 confidence interval for all parks under observation. The best health status-to-yield ratio was exhibited by the trees assigned score 3 for the health status (presence of damage to the foliage, trunk and branches with possibility of recovery, tip burns, rot in trunk and/or branches).



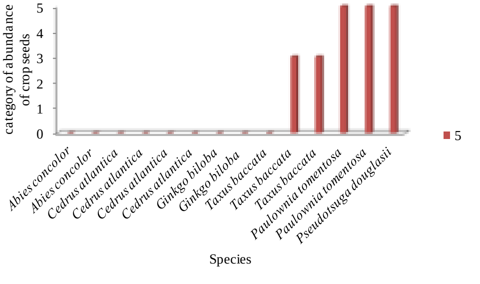
Graph 1. *Average scores for the volume (abundance) of seed yield against the assessed health status with a 0.95 confidence interval*

Trees dying out (birch and European yew trees) were identified only in Banovo Brdo Park, with significantly reduced leaf assimilation area and progressive rot in trees and branches. These trees bore no fruits. Trees assigned scores 3, 4 and 5 had poor to medium seed yield on the average.

When observed at the individual park level in terms of the worst and best health status trees (Graph. 2a-e), it was found that in Pioneer Park spruce and Douglas fir trees with significant injuries bore no fruits, small-leaved lime trees had good yield, while a single European yew tree and two horse chestnuts had very good yield. Among the trees with the same health status in Academic Park, one horse chestnut scored 3 for yield, while one horse chestnut, cedar and small-leaved lime each scored 5.

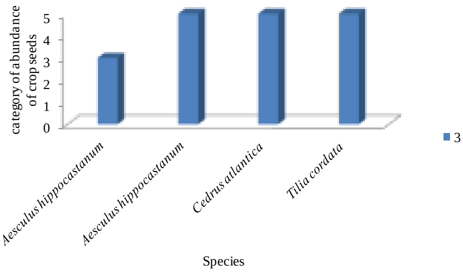


Visual evaluation the health status 3

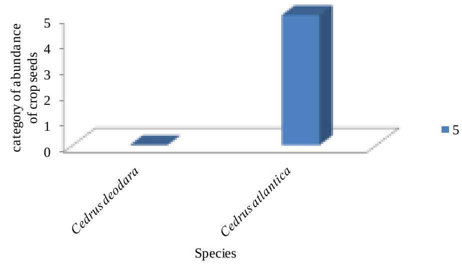


Visual evaluation the health status 5

a) Pioneer Park

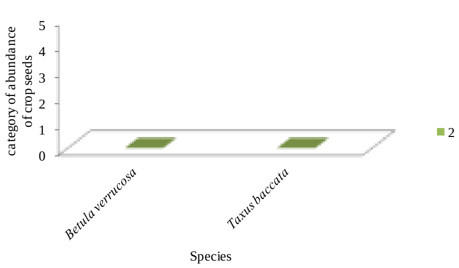


Visual evaluation the health status 3

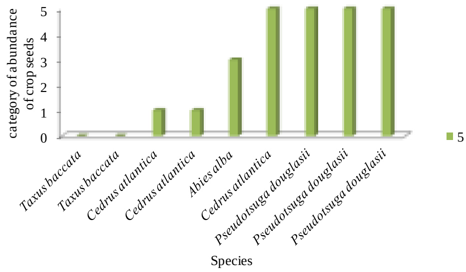


Visual evaluation the health status 5

b) Academic Park

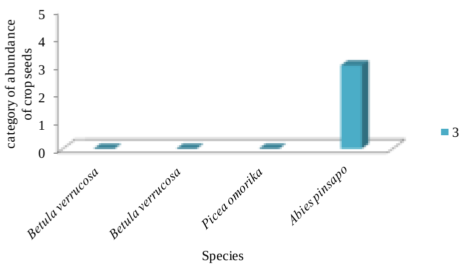


Visual evaluation the health status 2

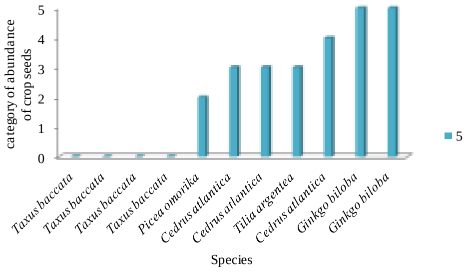


Visual evaluation the health status 5

c) Banovo Brdo Park

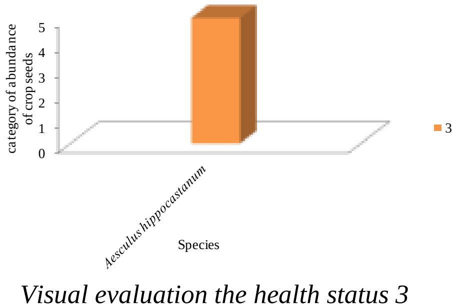


Visual evaluation the health status 3

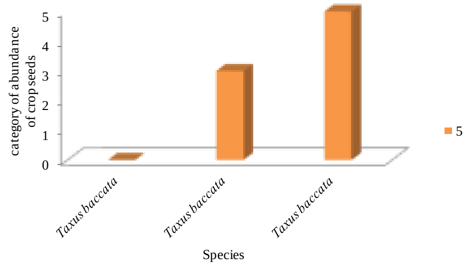


Visual evaluation the health status 5

d) SIV Park



Visual evaluation the health status 3



Visual evaluation the health status 5

e) Topčider Park

Graph 2(a-e). *Seed yield of trees with different health status scores*

In Banovo Brdo Park two trees in health status category 2 bore not fruits, while in SIV Park two birch trees and one Serbian spruce in health status category 3 had no yield, while a single Spanish fir scored 3 for seed yield (medium yield). In Topčider Park a chestnut tree with score 3 for the health status had very good seed yield.

Of all healthy trees assessed, in Pioneer Park two European yew trees scored 4 for seed yield and two paulownias and one Douglas fir had very good yield (score 5). Other trees (white firs, Atlas cedars, gingko and European yew trees) were not fruit-bearing. In Academic Park, a healthy Himalayan cedar bore no fruits, while an Atlas cedar had very good yield (score 5). In Banovo Brdo Park European yew trees bore no fruits, Atlas cedars had very poor and firs had medium seed yield. One Atlas cedar and three Douglas firs had good seed yield. In SIV Park European yew trees bore no fruits, while a Serbian spruce had poor yield. Somewhat better yield was recorded in two Atlas cedars and a small-leaved lime. Another Atlas cedar had good, while two gingko trees had very good yield. The three European yew trees selected for analysis in Topčider Park were all assigned different scores for see yield – one bore no fruits, and the other two had medium and very good seed yield volume.

4. CONCLUSIONS

According to the seed yield volume (abundance) the lowest score was achieved by the trees selected in SIV Park, the second lowest were those in Banovo Brdo, third highest seed yield volume was recorded in Pioneer Park, second in Topčider, and the highest was recorded in Academic Park (average seed yield score of 3.4).

As per visual assessment of the health status, trees in Pioneer Park displayed the best health although this park is located in a zone with very high air pollution. Trees in SIV Park (a zone with air pollution present) had the second best health status, then came the trees in Topčider Park and Banovo Brdo, while the lowest average score per health status criterion was achieved by the trees in Academic Park.

The green areas analyzed differ in the number of trees observed and environmental conditions, yet it can be remarked that their general condition is **largely dependent on the protection and care measures implemented in parks**. This is supported by the high scores achieved by trees in the downtown Belgrade, although the downtown area is exposed to the high traffic flow and frequency. Good examples are Pioneer Park, which is located in a zone with high air pollution and Academic Park, categorized as a significant natural asset with third degree protection regime set up since 2007.

ACKNOWLEDGMENTS

This paper is a result of research carried out within the Project "Development of Technological Methods in Forestry in order to Attain Optimal Forest Cover" (TR 31070, led by Dr. Ljubinko Rakonjac) financed by the Ministry of Education, Science and Technological Development of the Republic of Serbia and "Morphological-Anatomic and

Physiological Changes in Dendrological Species in Belgrade Parks as Indicators of the State of the Environment" (led by Dr. Ljubinko Rakonjac, coordinated by Dr. Baranislava Batos), financed by the City of Belgrade, City Administration, Secretariat for Environmental Protection.

REFERENCES

Anonymus (2006): Visual assessment of crown condition – Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests, International Co-operative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests, Hamburg

Anonymus (2010): Visual assessment of crown condition and damaging agents -Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests, Part IV, International Co-operative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests, Hamburg

Biddulph, M. (1999): Bringing Vitality to a Campus Environment. Urban Design Int., 4(3&4), 153-166

Isajev, V., Čomić, M., Mančić, A., Mataruga, M. (1998): Priručnik za proizvodnju šumskog semena u prirodnim semenskim objektima, Banja Luka 3-64 Stilinović, S. (1985): Semenarstvo šumskog i ukrasnog drveća i žbunja, Šumarski fakultet Beograd

Aničić Urošević, M. et al. (2015): Biomonitoring teških metala u vazduhu / edukacija o uticaju saobraćaja na kvalitet vazduha, Izveštaj, Institut za fiziku, Beograd.

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UDK **630*272+632(497.11)=111**
UDK **635.054+632(497.11)=111**
Original scientific paper

EVALUATION OF THE CONDITION OF DENDROLOGICAL SPECIES IN ACADEMIC PARK IN BELGRADE

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Abstract: *This paper presents the results of the conducted evaluation of the health condition and seed yield of the dendrological species in Academic Park in Belgrade. Both scores for each individual tree and average scores for all trees within each plant genus under observation were analyzed. The health condition of 126 trees belonging 19 genera was examined while the seed yield was assessed for the total of 132 trees. The best as-is health and physiological condition was observed in the following species: nettle trees, honey locusts, pagoda trees, cedars and individual ginkgo and tulip poplar trees. Horse chestnuts, eastern black walnuts and birch trees proved less resilient to biotic and abiotic damages. Japanese pagoda trees had the best seed yield. There were no significant differences in fruit bearing between the two years of research, although there were different scores at the individual level. Of all deciduous species recorded, which were prevailing, about 60% had very good seed yield in both years of monitoring, while some 20% of trees bore no fruits. Coniferous trees had higher fruit-bearing score in 2015 (47.4%) than in 2016 (43.0%), whereas about 10% of all conifers bore no fruit at all.*

Key words: damages, dendrological species, fungi, insects, mites, seed yield, park, Belgrade.

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OCENA STANJA DRVENASTIH BILJNIH VRSTA U AKADEMSKOM PARKU U BEOGRADU

Izvod: *U radu je prikazan rezultat izvršenog ocenjivanja zdravstvenog stanja i uroda semena drvenastih biljnih vrsta u Akademskom parku u Beogradu. Analizirane su ocene za svako pojedinačno stablo kao i srednje ocene svih stabala za svaki posmatrani biljni rod. Pregled zdravstvenog stanja je obuhvatio 126 stabala iz 19 rodova, a ocenjen je urod na 132 stabla. Utvrđeno je da su najboljeg zatečenog zdravstvenog stanja i fiziološke kondicije sledeće vrste: koprivić, gledičija, sofore i kedrovi i pojedinačna stabla ginka i liriodendrona. Manje otporna na biotička i abiotička oštećenja pokazala su se stabla: divljeg kestena, crnog oraha i breze. Najbolji urod imala su stabla sofore. Plodonošenje u obe godine istraživanja nije se bitno razlikovalo, mada je bilo individualnih razlika u oceni plodonošenja. Kod najviše zastupljenih svih evidentiranih lišćarskih vrsta, oko 60%, urod u bio vrlo dobar u obe godine praćenja ove pojave, a nije plodonosilo oko 20% stabala.. Kod četinarskih vrsta stabala sa najvišom ocenom plodonošenja bilo je 2015. godine 47,4%, a 2016. godine 43,0%. Nije plodonosilo oko 10% stabala četinarskih vrsta.*

Ključne reči: oštećenja, drvenaste biljne vrste, gljive, insekti, grinje, urod semena, park, Beograd.

1. INTRODUCTION

There are 65 public parks in Belgrade and they are mostly situated in the city's most beautiful parts. The total area of Belgrade's parks covers about 385 hectares. In comparison to the developed urban areas, the parks in Belgrade are small and unevenly distributed. Academic (Student) Park is located in the old Belgrade downtown area, in front of the Belgrade University Rectorate, at Student Square, between Vasina Street and the square. The area of Academic Park covers 1.45 hectares. Since 2007 the park has been categorized as a significant natural asset with third degree protection regime set up.

Predominant among the tree species in the park are older chestnut, ginkgo, plane and English oak trees. There is a protected small-leaved lime tree as well.

Changes in the environmental habitat factors have adverse impact on the physiological and hence health condition of the dendrological plant species. Due to the reduced general resilience, plants are more susceptible to the attacks of fungal phytopathogens causing rot and plant diseases and harmful insects and mites. In urban areas, where tree species are more exposed to effects of numerous both abiotic and biotic factors (higher air temperatures, lower soil moisture, air pollution, higher soil salinity, human influences, fungi, insects, mites, etc.), crown condition enables assessment of their overall condition and represents a valid measure for their health evaluation. Crown condition, as an indicator of biotic and anthropogenic impacts on the condition of trees, is viewed through different classes of defoliation and discoloration.

Damages may be various and often species-specific or specific for groups of fungi, insects and mites, although they are most commonly non-specific and resulting from several different causes (Agrios 2005; Karadžić 2010). Proper identification of the causes of damage to the urban greenery is of the outmost significance for prevention of symptom spread and preservation of its longevity and aesthetic value. In addition to mechanical damages, pests and fungal pathogens may produce toxic effects that will be manifest both in foliage and other plant organs, which results in reduced fitness and more or less reduced decorativeness. Attacked leaves display damaged stomatal complex, higher transpiration activity, loss of chlorophyll and the like, which may give rise to early defoliation, discoloration and even desiccation and early foliage fall (Agrios 2005). Foliage damage is manifest through changes in color, gallfly and blister mite infestations, leaf curls, bud hypertrophy and other malformations (Karadžić 2010; Mihajlović 2008). Due to the synergic or simultaneous attack of harmful insects and fungal pathogen infections, shoots are slow in growth and die out, branches rot and die out, and crowns become more transparent and show a typical “dieback” degradation.

Park trees on the other hand can have more favorable growth and development owing to more frequent inspections and better care and protection undertaken by the competent institutions. Such trees have larger crowns and are exposed to more light, and, as they are supplied larger quantities of nutrients, they have more frequent and plentiful yield. Time needed for fruit maturation in forest tree and shrub species depends on the genus or species, and within the same species on the habitat, in particular microclimatic characteristics of the habitat during fruit maturation.

2. MATERIALS AND METHODS

During vegetation in the years 2015/16 all trees in Academic Park in Belgrade were examined in order to evaluate the general condition of the tree species. The examination of the health of trees involved detection of mechanical, phytopathological, entomological and acarological damages to the tree crowns, tree trunks and root collar zone.

Fieldwork was conducted twice during a single vegetation period, in spring and in summer. Biotic and abiotic damages were identified in all trees. For evaluation of the as-is health condition of trees and identification of any health impairing factors, visual assessments of health condition and of assimilation area loss and discoloration were made for the trees under observation. In June and July defoliation was assessed, while discoloration was inspected in the observed trees in August, applying ICP Forests methodology (Anonymous, 2006; 2010).

Visual assessment of the health of trees was provided for all trees under observation according to the following scale:

Score **5** – Healthy tree (without visible symptoms of damage to the foliage, trunk and branches, or with insignificant damage);

Score **4** – Tree with minor damage (rare and random damage to the foliage, trunk and branches, with a small number of dry branches);

Score **3** – Tree with significant damage (presence of damage to the foliage, trunk and branches with possibility of recovery, tip burns, rot in trunk and/or branches);

Score **2** – Tree dying out (significantly reduced leaf assimilation area, progressive rot in trees and branches, poses a public safety issue)

Score **1** – Dead tree.

Young, newly planted trees were exempt from the evaluation of the health condition, with remarks recorded on any abiotic and/or biotic damages present.

The recorded harmful causes of decay were determined directly during fieldwork wherever possible. Samples of leaves, conifer needles, shoots necrotic tissues, rotten tree parts as well as those of wood-rotting fungus fruiting bodies were collected and processed in the Phytopathological and Entomological Laboratory of the Institute of Forestry.

Leaf samples were observed in the laboratory under binocular and light microscopes to determine the presence of pathogen fungus fruiting bodies and spore-bearing structures, causes of leaf flecking and spotting and other changes in leaves. Samples of conifer needles, shoots and tree branches were treated in the laboratory as follows: they were first sterilized on the surface in 70% ethyl alcohol or 4% sodium hypochlorite solution, then rinsed in sterile distilled water and thereafter dried on sterile paper tissue. Parts thereof were then dissected using a scalpel sterilized in 70% ethyl alcohol and open flame, and then placed on the malt extract agar (MEA) and potato dextrose agar (PDA) media prepared according to the recipe by Booth (1971). Culture incubation was conducted in daylight or in dark, as appropriate, at temperatures ranging from 22 to 25°C. The objective of isolation was to obtain pure cultures of pathogen fungi in order to properly identify and verify causes of damage and decay in trees. For identification of species observed in the preparations under the light microscope and in pure cultures after isolation, different publications containing identification keys and species characteristics were used (Agrios (2005); Alexopoulos et al., (1996); Barnett and Hunter (1998); Breitenbach and Kränzlin (1986); Černy (1989); Davidson et al., (1938); Gilbertson (1979); Hagara et al., (2012); Karadžić (2010); Karadžić et al., (2014); Karadžić and Milenković (2014, 2015); Murrill (1903, 1908); Overholts (1953); Pegler and Waterston (1968); Ryvarden and Johansen (1980); Sutton (1980); Stalpers (1978); Wagner and Fischer (2002) and others).

From the trees displaying symptoms typical for infections with the species from the genus *Phytophthora* (e.g. top-to-bottom die-out, reduced crown density, trunk and root collar necrosis, necrosis and damage to the larger roots and rot and loss of the fine roots) samples of necrotic tree tissues and of soil containing fine roots were collected. The tree tissue samples were rinsed in sterile distilled water and placed on selective nutrient medium prepared under the methodology of Jung et al., (1996, 2000) Jung (2009). Isolation from the soli was made using the baiting method (Jung et. al., 1996, 2000; Milenković 2015). Upon appearance of first hyphae from the inoculum of the tree and leaf tissues, these were transferred to the fresh carrot agar (CA) medium (Jung and Nechwatal 2008). The obtained isolates were identified and confirmed as belonging to the *Phytophthora* genus by developing both sexual and asexual structures in non-sterile soil solution under the methodology of Erwin and Ribeiro (1996) their observation under the light microscope with a magnification of ×400. For the same purposes morphological keys presented in Erwin and Ribeiro (1996), Stamps et al. (1990), and recently issued publications with descriptions of new species were used.

Plant materials were collected for identification of pests during vegetation by random sampling or based on the symptoms displayed. Leaves, buds, blossoms, twigs and the like were sampled and packed into polyethylene bags and later stored in the refrigerator at the temperature of 5°C until processing. Pests were identified microscopically or directly on the field based on the symptoms present and insects hunt out in different development stages. Insects were hunted out directly with fingers, using brushes, catchers or by means of an aspirator. Mites were separated from the plant material using a stereo microscope. After separation, eriophyid mites were directly immersed into Heinz medium whereas tetranychidae were immersed into the mixture of ethanol and lactic acid for light maceration (Evans & Browing 1955) so that they are ready for further preparation process. Petri dishes had been incubated in a heater at the temperature of 35°C for several days or held at the room temperature for up to a few months. Hoyer's medium (Baker & Wharton 1964) was used for preparation of the permanent tetranychidae specimens. The permanent specimens were observed through a phase-contrast light microscope using oil immersion technique (Leica DMLS). For insect and mite identification purposes appropriate taxonomy literature and keys were used (Amrine et al., 2003; Baker et al., 1996; Domes 1998; Keifer 1938-1979; Malandraki et al., 2004; Nalepa 1910; Petanović 1988a, b; Shi & Boczek 2000; Baker & Tuttle 1994; Mitrofanov et al., 1987; Prichard & Baker, 1955; Reeves, 1963; Rota, 1962; SmithMeyer 1987; Begljarov 1981; Chant 1959; DeMoraes et al., 1986; Demite et al., 2014; Karg 1993; Moraes et al., 2004; Alford 1995; Johnson & Lyon 1991; Maceljski 1986, 2002; Mihajlović 2007, 2008; Petrović-Obradović 2003; Tanasijević and Simova-Tošić 1987; Strous & Winter 2000).

In the course of the two-year field and laboratory research of the seed yield of dendrological species in Academic Park, the total of 132 trees were examined and scored. Individual trees were scored for seed yield for all deciduous and conifer species. Analyses of the seed yield and its volume were performed using the adapted Kaper scale for forecasting seed yield within a stand (Table 1) (Stilinović, 1985, Isajev et. al., 1998).

Table 1. *Yield scoring scale*

Category of yield volume – score		Quantitative yield volume parameters
0	**-**	No fruit
1	**Very poor**	Insignificant number of fruits in trees
2	**Poor**	Small number of fruits in trees
3	**Medium**	More observable fruits in trees
4	**Good**	Sufficient fruits in trees
5	**Very good**	High volume of fruits in trees

3. RESULTS AND DISCUSSION

3.1. Evaluation of health condition

The total of 126 trees belonging to 19 genera were examined. The largest in number is the park under observation were young pear trees (*Pirus* spp.), of which 22 were examined, then plane trees (*Platanus* spp.), of which 20 were examined and cedars (*Cedrus* spp.) and Japanese pagoda trees (*Sophora japonica*), of which 18 trees were examined per respective species. Other species had small number of trees in the park. All trees examined classified into genera are presented in Table 2.

Table 2. *Total number of trees examined in Academic Park*

Genus	No. of trees
Acer	1
Aesculus	12
Cedrus	18
Betula	1
Catalpa	1
Celtis	1
Fraxinus	1
Ginkgo	1
Gleditsia	7
Juglans	2
Koelreuteria	4
Liriodendron	1
Pinus	1
Pirus	22
Platanus	20
Prunus	3
Quercus	4
Sophora	18
Tilia	8
TOTAL	**126**

In a single *Acer pseudoplatanus* L. examined, the trunk displayed mechanical injuries, which were appropriately treated, and individual dry branches were identified so that the tree was assessed as a tree with minor damage without considerable defoliation and discoloration.

In twelve trees *Aesculus hippocastanum* L. mechanical injuries of the root collar and trunk were identified and open cancer wounds in certain cases, as well as necrosis with dark exudate, typical for *Phytophthora* spp. In addition, in certain instances, dry branches and carpophores of rot fungus *Phellinus* spp. were observed. Top-to-bottom drying was perceived as well as leaf flecks caused by *Guignardia aesculi* (Pk.) Stew. and the presence of horse chestnut leaf miner *Cameraria ochridella* Desch. & Dimić. The health condition of horse chestnut trees was assigned the average score of 3.4 – trees with significant damage. Medium discoloration and moderate defoliation were identified in the foliage. Three young trees were excluded from the assessment.

The young *Betula verrucosa* Erhr tree displayed mechanical injury of the root collar and trunk and dry branches. Its health condition was hence assigned score 3.0 – a tree with significant damage, low discoloration and severe defoliation.

In a single *Catalpa bignonioides* Walter tree random dry branches and mechanical damage to the root collar were observed so that it was assessed as a tree with minor damage (4.0) without defoliation and discoloration perceived.

Of eighteen *Cedrus atlantica* (Endl.) Mann. ex Carr. trees examined, some exhibited mechanical injuries, which were adequately treated. Some closed cancer wounds and sap exuding were also identified. The average score assigned for health condition of cedars in the park was 4.3 with no discoloration and weak defoliation observed.

A single *Celtis australis* L. tree received the highest score (5.0) with no defoliation or discoloration identified.

A single *Fraxinus ornus* L. tree had mechanical damage and was assigned score 4.0 as no discoloration or defoliation were identified.

A single *Ginkgo biloba* L. tree had random dry branches and was assigned score 4.0.

Seven *Gleditsia triacanthos* L. trees were examined. Some of them had mechanical injuries in the root collar area and trunk. The average score for the health condition of this group of trees was 4.4 as no defoliation or discoloration were observed.

In the two *Juglans nigra* L. trees mechanical injuries were recorded in the trunk and branches as well as random dry branches. The average score for black walnut trees equals 3.0 with no defoliation and low discoloration observed.

Four *Koelreuteria paniculata* Laxm. trees examined scored 4.0 on the average, showing slight defoliation and no discoloration.

In a single young *Liriodendron tulipifera* L. tree there were mechanical injuries in the trunk and it therefore scored 4.0.

Twenty-two young *Pirus* spp. trees were examined, some of them exhibiting mechanical injuries to the branches, which were adequately treated.

In a single *Pinus nigra* Arnold examined, random dry branches were observed with no defoliation and low discoloration identified, caused by fungus *Lophodermium pinastri* (Schrad) Chev. The score assigned for health condition was 4.0.

The examination covered 20 *Platanus×acerifolia* (Aiton) Willd. trees, 16 of which were young plants. In some of the older trees there were mechanical injuries in the root collar zone and branches. Presence of the fungal pathogen *Apiognomonia veneta* (Sacc. & Speg.) Höhn. causing leaf flecks along the nerves and anthracnose was observed, as well as of the sycamore lace bug *Corytucha ciliata* Say. The average score of 4.0 was assigned to the plane trees since slight defoliation and low to medium discoloration were perceived.

In the three *Prunus cerasifera* var. *pissardii* (Carr.) Koehne trees examined, foliage chlorosis and mechanical injuries treated and healed were perceived so that these scored 4.8 on the average for health condition given that no defoliation and low discoloration were identified.

In four oaks (*Quercus robur* L.) examined, two of them young, the presence of powdery mildew *Erysiphe alphitoides* (Grif. &Maubl.) Br. & Takam.

(sin. *Microsphaera alphitoides* Grif. & Maubl.), chlorosis and mechanical damage to the trunk and root collar were observed. Older trees scored 4.0 on the average given their slight defoliation and moderate discoloration.

Eighteen *Sophora japonica* (L.) trees were subject to examination. In certain trees, the root collar, trunk and branches showed mechanical damages. The average score for the health condition of this group of trees was 4.8 since no defoliation or discoloration were identified.

Seven *Tilia parvifolia* Ehrh. trees and one *T. tomentosa* Moench. tree were examined. In small-leaved lime trees, lime tree aphid *Eucallipterus tiliae* (L.), planthopper *Metcalfa pruinosa* (Say) and spider mite *Tetranychus urticae* Koch. were observed. In some instances, tree trunks and root collars display mechanical damages. This group of trees scored 4.2 on the average, with no defoliation and low discoloration identified.

The average health condition scores for all species examined in the park are provided in Table 3 below.

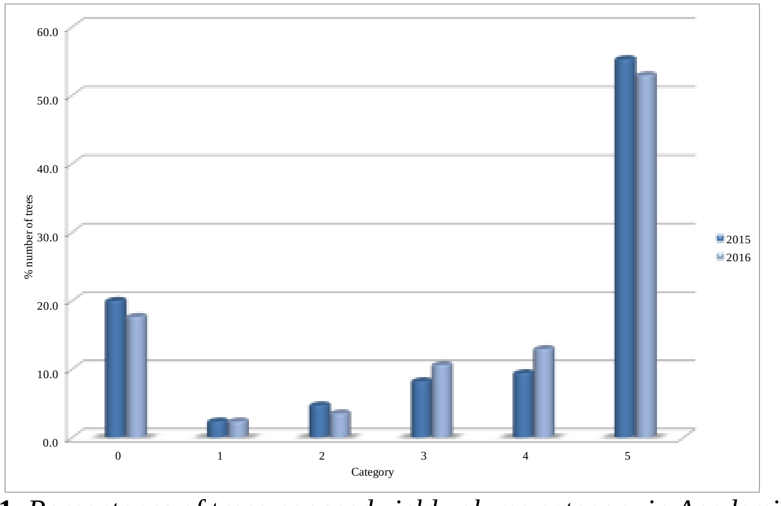
Table 3. *The average health condition scores for all trees in Academic Park*

Genus	Score
Acer	4.0
Aesculus	3.4
Betula	3.0
Catalpa	4.0
***Cedrus*.**	4.3
Celtis	5.0
Fraxinus	4.0
Ginkgo	4.0
Gleditsia	4.4
Juglans	3.0
Koelreuteria	4.0
Liriodendron	4.0
Pinus	4.0
Pirus	/
Platanus	4.0
Prunus	4.8
Quercus	4.0
Sophora	4.8
Tilia	4.2
TOTAL	**4.0**

Based on the examination performed on all the trees (Table 2) in the park under observation, it is clear that the species with the best as-is health state and physiological condition were: nettle trees, honey locusts, pagoda trees, cedars and individual ginkgo and tulip poplar trees. Horse chestnuts, eastern black walnuts and birch trees proved less resilient to biotic and abiotic damages.

3.2. Volume of seed yield

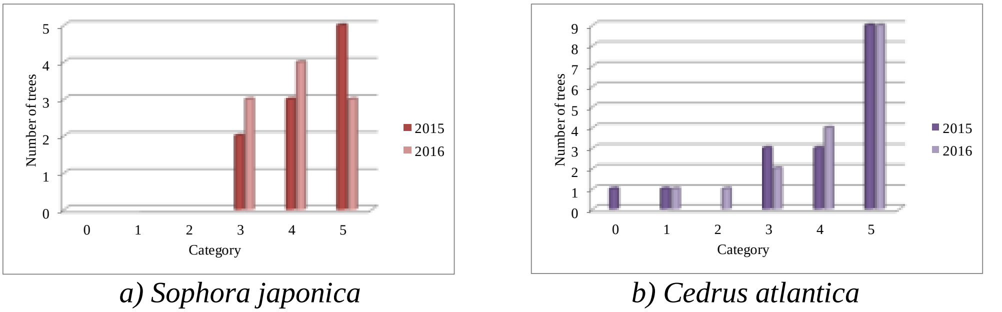
The total of 132 trees were recorded in Academic Park, of which 85 are fruit-bearing trees. The percentages of trees per seed yield volume category monitored over two years of research (2015-2016), are presented in Graph 1. There were no significant differences year on year in evaluation of seed yield volume.



Graph 1. *Percentages of trees per seed yield volume category in Academic Park*

Japanese pagoda tree (*Sophora japonica* L.) represents a deciduous species with the largest number of fruit-bearing trees – 18 – in the park. Of these 18 trees, 17 were ranked within the highest-score category, while only one scored 2 and 1 in 2015 and 2016, respectively, when it had a small/insignificant number of fruits (Graph 2a).

Among conifers, the Atlas cedars (*Cedrus atlantica* (Endl.) Manetti ex Carrière), were the largest in number with the total of 17 trees. In each year of research 9 trees had high volume yields, while score 4 was assigned to three trees in 2015 and thereafter to four trees of this species in 2016 (Graph 2b).



a) Sophora japonica *b) Cedrus atlantica*

Graph 2. *Percentages of the predominant (in number of trees) deciduous and conifer species per seed yield volume category*

Out of five plane trees (*Platanus x acerifolia* (Aiton) Willd.) four were fruit-bearing, three with high volume yield. Percentage of trees that scored 2 in 2015 decreased while that of trees with score 3 in 2016increased.

A single sycamore maple tree (*Acer pseudoplatanus* L.), had a high volume yield over the period under observation as well as a silver lime tree, so these two were classified into category 5 – very good.

A single black pine tree (*Pinus nigra* Arnold) scored 4 both in 2015 and 2016.

Table 4. *Percentages of all deciduous and conifer tree species per yield volume category*

	Category of yield volume – score											
	0	**1**	**2**	**3**	**4**	**5**	**0**	**1**	**2**	**3**	**4**	**5**
	% in 2015						**% in 2016**					
Deciduous	21.2	3.0	6.1	6.1	6.1	57.6	21.2	3.0	3.0	9.1	3.0	60.6
Conifer	10.5	5.3	0.0	15.8	21.1	47.4	10.5	0.0	5.3	10.5	31.6	42.1

For all deciduous species observed in terms of their yield volume, it may be deduced that for all deciduous species with large number of trees the yield was very good (category 5) – about 60% – in both years of research. About 21% of deciduous trees bore no fruits. In conifer species, 47.4% of trees had the highest score (category 5) in 2015, while in 2016 their share decreased to 43.0%. About 10% of conifer trees bore not fruits at all (Table 4).

4. CONCLUSIONS

Based on the phytopathological, entomological and acarological research performed, it was concluded that the species subject to analyses differ in health condition. Certain species such as nettle trees, honey locusts, pagoda trees, cedars, ginkgo and tulip poplar trees displayed rather high resilience, good health and physiological condition in contrast to horse chestnuts, eastern black walnuts and birch trees, which, in the park under observation, proved more sensitive to both biotic and abiotic agents. In Academic Park horse chestnut turned out to be the most sensitive species and hence most susceptible to the attacks of pathogens and insects.

Assessment and comparison of damages caused by biotic agents reveal that, in the park under observation, damages caused by fungal phytopathogens are more substantial than those caused by pest insects and mites.

Identified insect and mite species observed in larger populations during the research, had no significant impact on the development of the plant species assessed. They affected the aesthetics of the plants, caused physiological weakening of the plants, their discoloration defoliation, which, over prolonged periods, along with other adverse agents and influences within the urban environment, may result in plant drying.

A large number of trees with small or larger mechanical injuries were recorded in the park, with most of these injuries treated in adequate manner. However, in certain instances, wounds were direct entryway for penetration and further development of fungal pathogens, in particular wood rot fungi.

No significant differences were identified in the trees examined year on year and season on season (2015, 2016) in terms of their health. The environment, primarily through the impact of climatic factors, affects the presence of phytopathological and entomological causes of damage, yet several years of research may be required for more clarified conclusions on this matter.

Protection measures and care undertaken on a regular annual basis in Academic Park have contributed to decreased pest populations and pathogenicity of pathogens, resulting in the high average score for health condition of the entire park.

There were no significant differences in fruit bearing between the two years of research, although there were different scores at the individual level. For all deciduous species observed in terms of their yield volume, it may be deduced that for all deciduous species with large number of trees the yield was very good (category 5) – about 60% – in both years of research. About 21% of deciduous trees bore no fruits. In conifer species, 47.4% of trees had the highest score (category 5) in 2015, while in 2016 their share decreased to 43.0%. About 10% of conifer trees bore not fruits at all. Japanese pagoda tree (*Sophora japonica* L.) represents a species with the largest number of fruit-bearing trees in the park. Among conifers, the Atlas cedars (*Cedrus atlantica* (Endl.) Manetti ex Carrière). Evaluation of the fruit-bearing is largely dependent on the species and genus, so that the percentage share (number) of both trees and the species, i.e., diversity of the species, has had an effect on the evaluation of the fruit-bearing.

For proper interpretation of the results obtained regarding the impact of adverse factors (both biotic and abiotic) on the general health condition and defoliation and discoloration intensity, further observation and assessment of the health of tree species are necessary so that long-term prognoses can be made.

REFERENCES

Agrios G. N. (2005): *Plant Pathology (Fifth Edition).* Elsevier Academic Press, Burlington, San Diego, London: 1-922.

Alexopoulos C. J., Mims C. W., Blackwell M. (1996): *Introductory Mycology (Fourth Edition).* John Wiley and Sons, Inc., New York, Chichester, Brisbane, Toronto, Singapore, 1-868.

Alford, D., (1995): *A Colour Atlas of Ornamental Trees, Shrubs and Flowers.* Manson Publishing, London.

Amrine, J. W. JR., T. A. Stasny, C. H. W. Fletchmann (2003): *Revised keys to world genera of Eriophyoidea (Acari: Prostigmata).* Indira Publishing House, West Bloomfield, Michigan, USA, p 244.

Anonymus, (2010): *Visual assessment of crown condition and damaging agents -Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests,* Part IV, International Co-operative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests, Hamburg.

Anonymus, (2006): *Visual assessment of crown condition -Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests,* International Co-operative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests, Hamburg.

Baker, E.W., Kono, J., Amrine, J.W. Jr, Delfinado-Baker, M., Stasny, T. (1996): *Eriophyoid Mites of the United States.* Indira Publishing House. West Bloomfield, Michigan, USA.

Baker, E.W., Tuttle, D.M. (1994): *A guide to the spider mites (Tetranychidae) of the United States.* Indira Publishing House, pp. 347.

Barnett H. L., Hunter B. B. (1998): *Illustrated Genera of Imperfect Fungi* (Fourth Edition). APS Press, St. Paul, Minnesota: 1-218.

Begljarov, G.A. (1981): *Key for identification of the predacious mites Phytoseiidae (Parasitiformes, Phytoseiidae) in the fauna of the USSR.* Information Bulletin EPS IOBC, 3, pp. 141.

Booth C. (1971): *Methods in microbiology.* Vol. 4, Academic Press, London, 1-795.

Breitenbach J., Kränzlin F. (1986): *Champignons de Suisse.* Tome 2. Edition Mycologia, CH-6000 Lucerne 9, 1-412.

Chant D. A. (1959): *Phytoseiid mites (Acarina:Phytoseiidae*). Part I. Bionomics of seven species in Southeastern England. 1-44 pp.

Černy A. (1989): *Parazitické Drevokazné houby.* Vydalo ministerstvo lesniho a vodniho hospodárstvi a drevozpracujiciho prumyslu ČSR ve Statnim zemedelskem nakladatelstvi v Praze, 1-100.

Davidson R.W., Campbell W.A., Blaisdell J.D. (1938): *Differentiation of wood-decaying fungi by their reaction on gallic or tannic acid medium.* Journal of Agricultural Research, Vol.57, no.9, Washington, 683-695.

Demite, P.R., de Moraes, G.J., McMurtry, J.A., Denmark, H.A., Castilho, R. de C. (2016.): *Phytoseiidae Database.* www.lea.esalq.usp.br/phytoseiidae.

De Moraes G. J., McMurtry J. A., Denmark H. A., Campos C. B. (2004): *A revised catalog of the mite family Phytoseiidae.* Zootaxa 434: 1-494.

De Moraes, G. J., J. A. McMurtry, H. A. Denmark (1986): *A catalog of the family Phytoseiidae.* References to taxonomy, synonymy, distribution and habitat. EMBRAPA, Brasilia, Brazil. 353 pp.

Domes, R., (1998): *A new species of the genus Anthocoptes (Phyllocoptinae: Eriophyidae) on Juglans regia L.* Acarologia 39 (1): 69-71.

Erwin D. C., Ribeiro O.K. (1996): *Phytophthora diseases worldwide*. APS Press, American Phytopathological Society, St. Paul, Minnesota.

Evans, G.O., Browning, E, (1955): *Techniques for the preparatión of mites for study.* Ann. Mag, Nat. Hist., 8(12): 631-635.

Gilbertson R. L. (1979): *The Genus Phellinus (Aphyllophorales: Hymenochaetaceae) in Western North America.* Mycotaxon 9, 51-89, 51-89.

Hagara L., Antonin V., Baier J. (2012): *Velký Atlas Hub.* Vydalo Ottovo Nakladatelstvi, Praha, 1-432.

Johnson, W. T., H. Lyon, (1991*): Insects that feed on trees and shrubs.* Cornell University Press.

Jung T., Orlikowski L., Henricot B., Abad-Campos P., Aday A. G., Aguín Casal O., Bakonyi J., Cacciola S. O., Cech T., Chavarriaga D., Corcobado T., Cravador A., Decourcelle T., Denton G., Diamandis S., Doğmuş-Lehtijärvi H. T., Franceschini A., Ginetti, B., Green S., Glavendekić M., Hantula J., Hartmann G., Herrero M., Ivic D., Horta Jung M., Lilja A., Keca N., Kramarets V., Lyubenova A., Machado H., Magnano di San Lio G., Mansilla Vázquez P. J., Marçais B., Matsiakh I., Milenkovic I., Moricca S., Nagy Z. Á., Nechwatal J., Olsson C., Oszako T., Pane A., Paplomatas E. J., Pintos Varela C., Prospero S., Rial Martínez C., Rigling D., Robin C., Rytkönen A., Sánchez M. E., Sanz Ros A. V., Scanu B., Schlenzig A., Schumacher J., Slavov S., Solla A., Sousa E., Stenlid J., Talgø V., Tomic Z., Tsopelas P., Vannini A., Vettraino A. M., Wenneker M., Woodward S., Peréz-Sierra A. (2015): *Widespread Phytophthora infestations in European nurseries put forest, semi-natural and horticultural ecosystems at high risk of Phytophthora diseases*. Forest Pathology 46: 134-163.

Jung T. (2009): *Beech decline in Central Europe driven by the interaction between Phytophthora infections and climatic extremes.* Forest Pathology 39: 73–94.

Jung T., Nechwatal J. (2008): *Phytophthora gallica sp. nov., a new species from rhizosphere soil of declining oak and reed stands in France and Germany*. Mycological Research 112: 1195–1205.

Jung T., Blaschke H., Oßwald W. (2000): *Involvement of soilborne Phytophthora species in Central European oak decline and the effect of site factors on the disease.* Plant Pathology 49: 706–718.

Jung T., Blaschke H., Neumann P. (1996): *Isolation, identification and pathogenicity of Phytophthora species from declining oak stands.* European Journal of Forest Pathology 26: 253–272.

Karadžić D. (2010): *Šumska fitopatologija.* Univerzitet u Beogradu Šumarski fakultet, Beograd, 1-774.

Karadžić D., Milenković I. (2015): *Prilog poznavanju parazitne gljive Inonotus nidus-pici Pilát uzročnika rak.rana na stablima lišćara*. Šumarstvo br. 1-2, 15-29.

Karadžić D., Milenković I. (2014): *Najčešće Inonotus vrste u šumama Srbije i Crne Gore.* Šumarstvo br. 3-4, Beograd, 1-18.

Karadžić D., Radulović Z., Milenković I. (2014): *Ganoderma vrste u šumama Srbije i Crne Gore*. Šumarstvo br. 1-2, Beograd, 1-19

Karg, W. (1993). *Raubmilben. Acari (Acarina), Milben Parasitiformes (Anactinochaeta). Cohors Gamasina Leach*. 524 pp. Gustav Fischer Verlag, Jena, Stuttgart, New York

Keifer, H.H. (1979*): Eriophyid studies C-11*. ARS-USDA, 24 pp.

Keifer, H.H. (1975): *Eriophyoidea Nalepa. Injurious eriophyoid mites*. In: Jeppson LR, Keifer HH, Baker EW (eds) Mites injurious to economic plants. University of California Press, Berkeley, pp 327–533.

Keifer, H.H. (1952): *The Eriophyid mites of California (Acarina: Eriophyidae)*. Bull Calif Insect Surv 2 (1): 1–123.

Keifer, H.H. (1946). *A review of the North American economic Eriophyid mites*. J. Econ. Entomol. 39: 563-570.

Keifer, H.H. (1944): *Eriophyid studies XIV BCDA*, 33: 18-38.

Keifer, H.H. (1940): *Eriophyid studies VIIII*. BCDA, 29: 21-46.

Keifer, H.H. (1938*): Eriophyid studies I*. BCDA, 27: 181-206.

Maceljski, M. (2002): *Poljoprivredna entomologija*. Čakovec: Zrinjski, II dopunjeno izdanje

Maceljski, M, (1986): *Current status of Corythuca* ciliata in Europe. Bulletin OEPP/EPPO Bulletin 16: 621-624.

Malandraki, E., Petanovic, R., Nikolaos, (2004*): Description of Two New Species of Eriophyid Mites (Acari: Prostigmata: Eriophyide) Common in Greece and Serbia*, Agricultural University of Athens, Laboratory for Agricultural Zoology and Entomology, Iera Odos 75, 118 55 Athens, Greece.

Mihajlović Lj. (2008): *Šumarska entomologija*, Univerzitet u BeograduŠumarski fakultet, Beograd.

Mihajlović, L. (2007): *Metcalfa pruinosa (Say) (Homoptera: Auchenorrhyncha) nova štetna vrsta za entomofaunu Srbije*. Glasnik Šumarskog fakulteta, br. 95, str. 127-134.

Milenković I. (2015): *Diverzitet vrsta roda Phytophthora i njihova uloga u propadanju stabala u lišćarskim šumama u Srbiji.* Univerzitet u Beogradu-Šumarski fakultet, doktorska disertacija u rukopisu, 1-240.

Mitrofanov, V.I., Strunkova, Z.I., Livshits, I.Z., (1987): *Keys to the tetranychid mites (Tetranychidae, Bryobiidae) fauna of the USSR and adjacent countries*. *SSR*, I.o.Z.a.P.E.N.P.T., Dushanbe, Donish: 224 p.

Murrill W.A., Burlingham G.S., Pennington L.H., Barnhart J.H. (1908): *North American Flora, (Agaricales) Polyporaceae-Agaricaceae.* The New York Botanical Garden, Volume 9, Part 2: 73-132.

Murrill W.A. (1903): *A Historical Review of the Genera of the Polyporaceae*. The Journal of Mycology 9 (2): 87-102.

Nalepa, A. (1910): *Eriophyiden Gallmilben*, Zoologica, 24 (61): 167-293.

Overholts L. O. (1953): *The Polyporaceae of the United States, Alaska and Canada*. University of Michigan Press. Ann. Arbor, Michigan, 1-466.

Pegler D.N., Waterston J.M. (1968): *Descriptopons of Pathogenic Fungi and Bacteria*. Set 20, No. 194-197, Commonwealth Mycological Institute, Kew, Surrey, England.

Petanović, R. (1988a): *Rhinotergum, a new genus, family Diptilomiopidae (Acari: Eriophyoidea*). Acarologia (Paris) 29, 4, 319-323.

Petanović, R. (1988b): *Eriofidne grinje u Jugoslaviji*, 159 pp. Naučna Knjiga, Beograd.

Petrović-Obradović, O. (2003): Biljne vaši (Aphididae, Homoptera) Srbije. Poljoprivredni fakultet Univerziteta u Beogradu.

Pritchard, A.E., Baker, E.W., (1955) *A revision of the spider mite family Tetranychidae*.

Reeves, R.M. (1963): *Tetranychidae infesting woody plants in New York State, and a life history study of the elm mite Eotetranychus matthyssei n.sp*. Cornell University Agricultural Station Mem.: 99.

Rota, P.(1962): *Osservazioni sugli Acari Tetranychidi dannosi alle piante coltivate ed ornamentali in Italia*. Bollettino di Zoologia Agraria e di Bachicoltura, 4: 31-136.

Ryvarden L., Johansen I. (1980): *A preliminary polypore flora of East Africa.* Fungiflora, Oslo-Norway, 1-636.

Shi, A., Boczek, J. (2000): *Studies on Eriophyoid mites (Acari: Eriophyoidea). XXXV*. Bulletin of the polish Academy of Siences, Biological Siences. Vol. 48, No. 3. 241-254.

SmithMeyer M.K.P.S., (1987): *African Tetranychidae (Acari: Prostigmata) - with reference to the world genera*. Entomology Memoir, Department of Agriculture and Water Supply, Republic of South Africa, 69: 1-175.

Stalpers J.A. (1978): *Identification of Wood-inhabiting Aphyllophorales in pure culture*. Studies in Mycology, No. 16, Baarn, 1- 248.

Stamps D. J., Waterhouse G. M., Newhook F. J., Hall G. S. (1990): *Revised tabularkey to the species of Phytophthora*. CAB International Mycological Institute, Kew, Surrey, Mycol Pap 162: 28.

Stilinović, S. (1985): *Semenarstvo šumskog i ukrasnog drveća i žbunja*, Šumarski fakultet Beograd.

Strouts, R. G., T. G. Winter (2000): *Diagnosis of ill-health in trees*. Forestry Comission.

Tanasijević, N., Simova-Tošić, D. (1987): *Posebna entomologija*. Beograd: Naučna knjiga

Wagner T., Fischer M. (2002): *Proceedings towards a natural classification of the worldwide taxa Phellinus s.l. and Inonotus s.l. and phylogenetic relationships of allied genera*. Mycologia 94 (6), 998-1016.

OCENA STANJA DRVENASTIH BILJNIH VRSTA U AKADEMSKOM PARKU U BEOGRADU

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Rezime

U Akademskom parku u Beogradu tokom 2015/16 godine ocenjeno je zdravstveno stanje i urod semena drvenastih biljnih vrsta. Analizirane su ocene za svako pojedinačno stablo kao i srednje ocene svih stabala za svaki posmatrani biljni rod. Pregled zdravstvenog stanja je obuhvatio 126 stabala iz 19 rodova, a ocenjen je urod na 132 stabla.

Na terenu, tokom proleća i leta, obavljen je pregled krošnje, debla i korenovog vrata kako bi se utvrdilo prisustvo mehaničkih, fitopatoloških, entomoloških i akaroloških oštećenja. Izvršeno je vizuelna ocena zatečenog zdravstvenog stanja prema skali 1 do 5, kao i ocena gubitka asimilacione površine i obezbojavanja za posmatrana stabla. U junu i julu izvršeno je ocenjivanje defolijacije a u avgustu dekolorizacija proučavanih stabala prema metodologiji ICP Forests

Analiza obilnosti uroda i semena je rađena na osnovu prilagođene Kaperove skale za predviđanje uroda semena u sastojini

Najvišu ocenu zdravstvenog stanja dobilo je pregledano stablo koprivića na kome nije utvrđena defolijacija i dekolorizacija. Nešto nižu ocenu (4,8) ponela su stabla ukrasne šljive i sofore bez uočene defolijacije i dekolorizacije. Stabla gledičije su ocenjena sa 4,4 bez uočene defolijacije i dekolorizacije, kedra sa 4,3 bez dekolorizacije sa slabom defolijacijom, lipe sa 4,2 na kojoj nije utvrđena defolijacije već samo slaba dekolorizacija. Stabla javora, katalpe, jasena, ginka, koelreuterie, liriodendrona, borova, platana i hrasta su ocenjena sa 4,0. Stabla sa izraženim oštećenjima abiotičke i biotičke prirode su stabla kestena, breze, i crnog oraha. Prosečna ocena za sva ispitivana stabla u Akademskom parku je 4,0.

Determinisani su sledeći uzročnici oštećenja: *Phytophthora* spp., *Phellinus* spp. *Guignardia aesculi, Cameraria ochridella* na kestenu. *Lophodermium pinastri* na crnom boru. *Apiognomonia veneta* i *Corytucha ciliata* na platanu. *Erysiphe alphitoides* na lužnjaku. Na stablima sitnolisne lipe *Eucallipterus tiliae, Metcalfa pruinosa* i *Tetranychus urticae*. Utvrđeno je da su štete od fitopatogenih gljiva značajnije u odnosu na oštećenja do kojih dovode prisutni insekte i grinje. Na većem broju ispitivanih stabala uočena su mehanička oštećenja koja su na adekvatan način sanirana.

Zdravstveno stanja pregledanih stabala drvenastih biljnih vrsta je bez utvrđenih značajnijih razlika tokom obe godine istraživanja.

Prilikom ocene obilnosti uroda utvrđeno je da od pregledanih 132 stabala 85 plodonosi. Plodonošenje u obe godine istraživanja nije se bitno razlikovalo, mada je bilo individualnih razlika u oceni plodonošenja. U najvišu kategoriju obilnosti uroda svrstano je 17 stabala sofore dok je jedno stablo ocenjeno je ocenom 2 u 2015 odnosno ocenom 1 u 2016. Od četinarskih vrsta, od ukupno 17 stabla atlaskog kedra, u obe istraživačke godine, 9 stabala je imalo obilan urod dok su u kategoriju 4 u 2015. godini svrstana tri odnosno u 2016. četiri stabla ove vrste. Od pet stabala platana samo četiri plodonose od toga tri obilno. Za jedno stablo javora i srebrne lipe urod je ocenjen najvišom ocenom 5, dok je stablo crnog bora ocenjeno sa ocenom 4 u obe godine istraživanja. Udeo lišćarskih vrasta koje su plodonosile a čiji je urod bio vrlo dobar, u obe godine istraživanja, je 60% dok su sa 21% zastupljene vrste kod kojih je izostalo plodonošenje. Kod četinarskih vrsta najvišu ocenu plodonošenja je dobilo 47,4% u 2015. odnosno 43,0%. u 2016. godini dok je urod izostao kod 10% stabala.

Visoka prosečna ocena zdravstvenog stanja Akademskog parka je rezultat adekvatnih i redovnih mera nege i zaštite.

EVALUATION OF THE CONDITION OF DENDROLOGICAL SPECIES IN ACADEMIC PARK IN BELGRADE

Summary

In 2015/2016 health condition and seed yield of the dendrological species in Academic Park in Belgrade. Both scores for each individual tree and average scores for all trees within each plant genus under observation were analyzed. The health condition of 126 trees belonging 19 genera was examined while the seed yield was assessed for the total of 132 trees.

In spring and summer crowns, trunks and root collars were examined in order to identify mechanical, phytopathological, entomological and acarological damages, Visual assessments of the health condition as is were made as well as assessments of assimilation area loss and discoloration in the trees under observation. In June and July defoliation was assessed, while discoloration was inspected in the observed trees in August, applying ICP Forests methodology.

Analyses of the seed yield and its volume were performed using the adapted Kaper scale for forecasting seed yield within a stand.

The highest score was assigned to the single nettle tree examined, with no defoliation and discoloration identified. Slightly lower score (4.8) was assigned to the ornamental plum and Japanese pagoda trees, where no defoliation and discoloration were identified. Honey locust trees displayed no defoliation and discoloration and achieved a score of 4.4., cedar trees achieved a score of 4.3 and showed slight defoliation but no discoloration and lime trees received a score of 4.2 with no defoliation and low discoloration identified. Sycamore maples, catalpas, ash and gingko trees, golden raintrees, tulip poplar, pine, plane and oak trees scored 4.0. Horse chestnut, black walnut and birch trees displayed visible damage of both biotic and abiotic nature and origin. The overall average score for all trees examined in Academic Park equals 4.0.

The following causes of damage in injuries were determined: *Phytophthora* spp., *Phellinus* spp. *Guignardia aesculi*, and *Cameraria ochridella* in the chestnut trees; *Lophodermium pinastri* in the black pines; *Apiognomonia veneta* and *Corytucha ciliata* in the plane trees; *Erysiphe alphitoides* in English oaks; *Eucallipterus tiliae*, *Metcalfa pruinosa* and *Tetranychus urticae in small-leaved lime trees*. It was established that the damages caused by fungal pathogens are more significant than those caused by the present insects and mites. In a large number of trees examined, mechanical injuries were observed, which were adequately treated.

There were no significant differences in the health condition of the dendrological species examined during the two years of research.

Upon assessment of the seed yield volume, it was found that out of the total of 132 trees examined, 85 trees were fruit-bearing. There were no significant differences in fruit bearing between the two years of research, although there were different scores at the individual level. Seventeen Japanese pagoda trees were ranked within the highest-score category, while only one scored 2 and 1 in 2015 and 2016, respectively. Among conifers, the Atlas cedars were the largest in number with the total of 17 trees. In each year of research 9 trees had high volume yields, while score 4 was assigned to three trees in 2015 and thereafter to four trees of this species in 2016. Out of five plane trees four were fruit-bearing, three with high volume yield. A single sycamore maple tree had a high volume

yield over the period under observation as well as a silver lime tree, so these two were classified into category 5 – very good. A single black pine tree scored 4 both in 2015 and 2016. For all deciduous species with large number of trees the yield was very good – about 60% – in both years of research. About 21% of deciduous trees bore no fruits. In conifer species, 47.4% of trees had the highest score in 2015, while in 2016 their share decreased to 43.0%. About 10% of conifer trees bore not fruits at all.

The high overall average score for health condition of Academic Park was a result of the adequate care and protection measures taken on an ongoing basis.

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EFFECTS OF *Coniophora puteana* (Schumach.) P. Karst. FUNGUS ON THE DECOMPOSITION OF SESSILE OAK WOOD

Miroslava MARKOVIĆ, Snežana RAJKOVIĆ[1]

Abstract: *The paper examines the effects of a brown rot agent - Coniophora puteana (Schumach.) P. Karst on the mass loss and compression strength of sessile oak (Q. petraea agg) wood. The wood mass loss of Q. petraea agg., caused by C. puteana amounted to 1.5, 2.12 and 2.23 after 2, 4 and 6 months respectively. The obtained values indicate that the biggest mass loss of wood occurred in the first two months. Compression strength also decreased under the influence of C. puteana. In comparison to its initial value (100%), it amounted to 92.13, 90.72 and 76.25 after 2, 4 and 6 months. The analysis of the correlation between the sessile oak mass loss - G_m and compression strength decrease - σ_p (dependent variables) and the incubation time (T-independent variable) revealed a strong correlation between the variables and the following regression equations were obtained:*

$$G_m = 0.0638492 + 0.954107 \times \sqrt{T}$$
$$\sigma_p = 96.328 - 2.666 \times T$$

Key words: Coniophora puteana, mass loss, compression strength

DEJSTVO GLJIVE *Coniophora puteana* (Schumach.) P. Karst. NA RAZLAGANJE DRVETA HRASTA KITNJAKA

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Izvod: *Ispitan je uticaj prouzrokovača mrke prizmatične truleži Coniophora puteana (Schumach.) P. Karst., na gubitak mase i smanjenje pritisne čvrstoće kitnjaka (Quercus petraea agg.). Gubitak mase drveta Q. petraea agg., pod dejstvom gljive C. puteana, posle 2, 4 i 6 meseci inkubacije iznosio je 1.5, 2.12 i 2.23, što znači da je najveći gubitak mase drveta nastupa u prva dva meseca. Utvrđeno je da se pritisna čvrstoća drveta Q. petraea agg. pod dejstvom gljive C. puteana posle 2, 4 i 6 meseci smanjila u odnosu na početnu (100%) i iznosila 92.13, 90.72 i 76.25. Korelacionom analizom gubitka mase - G_m i smanjenja pritisne čvrstoće drveta kitnjaka - σ_p (zavisno promenljive) u odnosu na vreme dejstva gljive C. puteana (T - nezavisno promenljiva), konstatovana je jaka veza između promenljivih i dobijene su regresione jednačine :*

$$G_m = 0{,}0638492 + 0{,}954107 \times \sqrt{T}$$

$$\sigma_p = 96{,}328 - 2{,}666 \times T$$

Ključne reči: *Coniophora puteana, gubitak mase, pritisna čvrstoća*

1. INTRODUCTION

During their development, wood-decaying fungi feed on the basic constituents of wood and thus change not only its chemical composition but also the entire inner structure, which results in the change *i.e.* reduction of its mechanical, physical, aesthetic and other properties (Uščuplić, 1996). If we want to determine how wood-decaying fungi affect wood properties, it is necessary to analyze their nutrition requirements and the changes that their activity produces in the structure of wood. Brown rot agents are more destructive to wood than white rot agents (Muntañola-Cvetković, 1987) due to their intensive degradation of cellulose, which is one of the most important constituents of wood cell walls, Petrović (1980). This process, depending on the conditions and the time of fungal activity, degrades cell walls and reduces or completely destroys wood properties, Rypáček (1957). The growth of mycelia simultaneously gives rise to the decay process, leading wood mass to the state in which the natural properties (color, structure, composition) are changed under the influence of microorganisms which use enzymes from hypha cells to enforce this transformation.

As a host tree, oak is colonized by a large number of microorganisms, Čeremesinov *et al.*, (1970) and the effects of the fungi, particularly of the species that attack the heartwood as the most valuable portion of a tree, is a topic of special importance in the research of oakwood destructors. Oak is one of the most significant tree species in our country and thus 'the preservation and sustainability of its wood and the products made of it are directly related to the preservation of its mechanical, physical, chemical, aesthetic and other properties. Therefore, monitoring of the changes in the above-stated properties under the influence of fungi is imposed as logical and necessary' (Mirić and Popović, 1993). The importance of oak wood, primarily of its heartwood, for the industry in general and the significant role of *C. puteana* in its decomposition and degradation were the key factors in determining the direction of the research into the reduction of physical and mechanical properties of oak heartwood under the influence of the fungus. The results of these investigations will provide a deeper insight into the course as well as the causes and effects of *C. puteana* activity on the most important properties that characterize oak wood in terms of its usability and ease of processing as one of our noblest broadleaves.

2. MATERIAL AND METHODS

The test samples were taken from a healthy sessile oak tree, aged 115 years, 18.9 m in height and 34 cm in diameter at breast height. The tree was felled in *Quercetum montanum* (Čer. et Jov., 1953, according to T o m i ć , Z . 1992) association at a southern aspect and an altitude of 550 *m*. A 3.5 m long butt log (from the butt end to the first live branch) was taken for the purpose of the study. It was cut into 4 central planks which were further divided into 10 sections and each section was then cut into 2 x 2 x 32 cm test specimens. All the sides of the test specimens were processed at an angle of 90^0 to two parallel sides. Having eliminated the test specimens with defects, knots and damage, 3 completely healthy specimens with approximately parallel grain were taken from each section for the analysis.Thus we obtained a total of 120 test specimens, 60 of which were control specimens and 30 specimens were used for the fungus and for each period of incubation (2, 4 and 6 months). This number of samples is sufficient for statistical analysis, considering that 20 is considered to be the minimum number of samples (Š o š k i ć, 1994).

Before exposing them to the activity of the fungus, test specimens were measured with an accuracy of 0.01 g, then dried to the oven dry state (in an oven at a temperature 103 ± 1^{o}C) and measured again (all the measurements of properties were done with the oven dry wood), Immediately upon drying to the oven dry state, the control test specimens had 2 x 2 x 4 cm test specimens cut from their both ends and they were used for the measurements of the compressive strength parallel to the grain (JUS D.A1.045 and JUS D. A1. O58 (1971). All the other test specimens were dried using the standard method of drying and then conditioned to approximately 12% moisture content. The optimum moisture content for the attack of *Coniophora puteana* is 50-60% (Josifović, 1951). Therefore, we put 3 petri dishes with 5% aqueous solution of boric acid in sterilized containers and thus increased the relative air humidity in the containers. The ends of the samples were sealed with an antiseptic toothpaste to prevent penetration of the fungus hyphae from that direction. We applied 0.09 g (dry weight) of the paste to each end surface of the test specimens. The test specimens were UV sterilized before the experiment.

The test specimens were exposed to the fungal activity by the method proposed by Mirić, M. (pers. com.). Plastic containers with lids, measuring 9 x 22 x 35 cm were used in the experiment. They were also sterilized using UV light. Each container had 10 plastic petri dishes arranged in two rows. They contained fully-developed mycelia of the tested fungus on the standard medium of malt agar. Petri dishes also acted as carriers that prevented the test specimens from coming into the direct contact with the substrate and absorbing moisture. A total of 10 sessile oak test specimens were put in each container, *i.e*. 5 test specimens in each row, thus there was a row of 5 petri dishes with mycelia below each of them. At the top of the stack, we placed Petri dishes with a 5% aqueous solution of boric acid in order to maintain the relative air humidity. The containers were kept in a closed sterile chamber in complete darkness and the temperature was measured using a thermograph for the entire duration of the experiment. The temperature recorded in the chamber during the experiment was mostly around 20^0C, with shorter intervals of around 28^0C, which is about the optimum temperature for the growth of the investigated fungus species. After the appropriate incubation time, the test specimens were removed from the containers, cleaned of surface mycelia and dried in a classic oven at a temperature 103 ± 1^0C.

In order to determine the difference between the mass of healthy wood and the wood that had been exposed to the activity of the fungus for 2, 4 and 6 months, the test specimens were measured in the oven dry state before and after the activity of the fungus, with an accuracy of 0.01 g. The dry weight of wood before and after the activity of the fungus was used to determine the percent wood mass loss by the formula:

$$Gm = \frac{m_1 - m_2}{m_1} \times 100\%$$

wherein:

G_m - wood mass loss (%)

m_1 - mass of oven dry wood before it was exposed to the fungus (g)

m_2 - mass of oven dry wood after it was exposed to the fungus (g)

Compressive strength was calculated as the maximum stress produced in the wood of a particular cross section under the pushing force applied to change the original shape by compression (Šoškić, 1994). Since the compressive strength was measured on the cross-section of the test specimens, we first measured the cross diameter of the 2x2x4 cm test specimens using a micrometer with an accuracy of 0.01mm. It was measured using 120/291 Amsler testing machine with mechanical transmission and the speed of pusher movement amounting to 4 mm/min. The maximum tension (breakage) of the test specimens was achieved in approximately 2 min. Compressive strength was calculated using the formula:

$$\sigma_p = \frac{F}{A}\left[N/mm^2\right]$$

wherein:

σ_p - compressive strength parallel to grain (N/mm^2)

A - cross-sectional area of the test specimen (mm^2)

F - maximum force (N)

3. RESULTS AND DISCUSSION

3.1. Loss of Wood Mass

Samples of *Q. petraea agg*. wood that were exposed to *C. puteana* show a significant dispersion of data in all three study periods (2, 4, and 6 months) as shown in Table 1.

Table 1. *Mass loss (%) of Q. petraea agg. wood affected by C. puteana depending on the incubation time (basic parameters)*

	0 mon.	2 mon.	4 mon.	6 mon.
Number of measurements	30	30	30	30
Minimum amount	0.0	0.60	0.86	1.06
Maximum amount	0.0	4.81	5.43	9.28
Arithmetic mean	**0.0**	**1.50**	**2.12**	**2.23**
Standard deviation	0.0	0.85	1.60	1.74
Coefficient of variation	0.0	56.35	75.86	78.14

Mass loss ranged from 0.60 to 4.81% in the first 2 months, from 0.86 to 5.43% after 4 months and from 1.06 to 9.28% in the last study period (6 months). The coefficient of variation was 56.35 for 2 months, 75.86 for 4 months and 78.14 for 6 months, which means that data dispersion increased with the length of *C. puteana* incubation.

The average mass loss caused by *C. puteana* was the greatest in the first 2 months and amounted to 1.50%, and then almost stagnated amounting only to 2.12% after 4 months and 2.23% after 6 months. After the initial intense degradation of wood of 1.50% in the first 2 months, the differences in the mass loss decreased, so that the difference in the mass loss between the period of 2 and 4 months was 0.62% and between 4 and 6 months only 0.11%. In other words, the total mass loss between the periods of 2 and 6 months was only 0.73%, which was less than half the loss in the first two months. This means that the early decomposition of wood by *C. puteana* (in the first 2 months) was very intense, which is reflected in the mass loss, while it was much slower in the subsequent period (between 2 and 6 months). For this reason, future investigations should cover a longer period of time and thus study the further rate of destruction.

The results of the least significant difference test (T-test) are shown in Table 2. They are expressed in absolute amounts because relative amounts (%) are not suitable for statistical analysis.

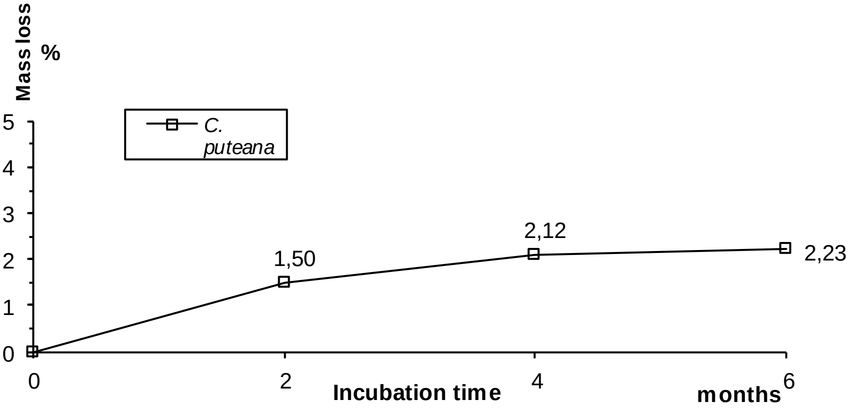
Table 2. *Mass loss of Q. petraea agg. wood affected by C. puteana depending on the incubation time - T-test results (difference +/-)*

	0 month	2 month	4 month	6 month
0 month	x	- 1.32667	- 1.87800	- 1.91100
2 month		x	- 0.55133	- 0.58433
4 month			x	- 0.03300
6 month				x

[grey box] - significant difference at 0.05

The results of T-test show that there are significant differences between all the investigated groups of samples, except between 2 and 4months and between 4 and 6 months of the *C. puteana* incubation. It can be also seen from the data presented in the tables that these chance differences are the result of slower and uneven destruction of wood in the period between 2 and 6 months.

Graph 1 shows the mass loss of the samples of *Q. petraea agg*. wood that were exposed to *C. puteana* for 2, 4 and 6 months compared to the control wood (wood that was not exposed to the action of the fungus).



Graph 1. *Wood mass loss (%) of Q. petraea agg. caused by C. puteana depending on the incubation time*

To sum up, the destruction of *Q. petraea agg*. wood affected by *C. puteana*, which was manifested in the loss of wood mass, was the most intense in the first two months after which it slowed down (between 2 and 6 months).

3.2. Reduction of compressive strength parallel to the grain

According to data provided by Š o š k i ć (1994), the compressive strength of healthy sessile oak wood parallel to the grain and with the standard moisture content of 12% amounts to a minimum of 48.0, an average of 650 and a maximum of 70.0 N/mm^2. The author states that compressive strength decreases by 4% per one percent increase in the moisture content and vice versa, the lower the moisture in the wood, the higher the compressive strength. According to the results shown in Table 3, the compressive strength of the oven dry *Q. petraea agg*. wood which was not exposed to the activity of the fungus amounted to the minimum of 75.77, an average of 93.22 and a maximum of 108.92 N/mm^2.

Table 3. *Reduction in the compressive strength of Q. petraea agg. wood (N/mm^2) affected by C. puteana (basic parameters)*

	0 month	2 month	4 month	6 month
Number of measurements	30	29	28	26
Minimum amount	75.77	57.18	62.34	41.50
Maximum amount	108.92	114.47	115.52	96.62
Arithmetic mean	**93.22**	**92.13**	**90.72**	**76.25**
Standard deviation	10.51	15.31	12.03	14.74
Coefficient of variation	11.28	16.61	13.26	19.32

The results presented in Table 3 show that the compressive strength in the control group of samples averaged 93.22. It was 92.13 after 2 months of *C. puteana* activity, 90.72 after 4 months and 76.25 N/mm^2 after 6 months when the more intensive destruction occurred.

All the groups of samples expressed similar variability of data, with slightly higher variation after 2 and 6 months of *C. puteana* activity (coefficient of variation was 16.61 and 19.32 respectively).

The greatest reduction in compressive strength within the investigated incubation periods occurred in the period between 4 and 6 months - the difference was 15.52%, which was almost 6 times greater than in the first 4 months. This does not mean that the decrease in the compressive strength was dramatic in the period between 4 and 6 months. It rather means it was insignificantly small in the first 4 months, *i.e.* the process of destruction was very slow in this period. This was further confirmed by the results of T-test (Table 4). Significant differences were found only for the group of samples after 6 months of fungal activity (control and 6 months, 2 and 6 months, 4 and 6 months).

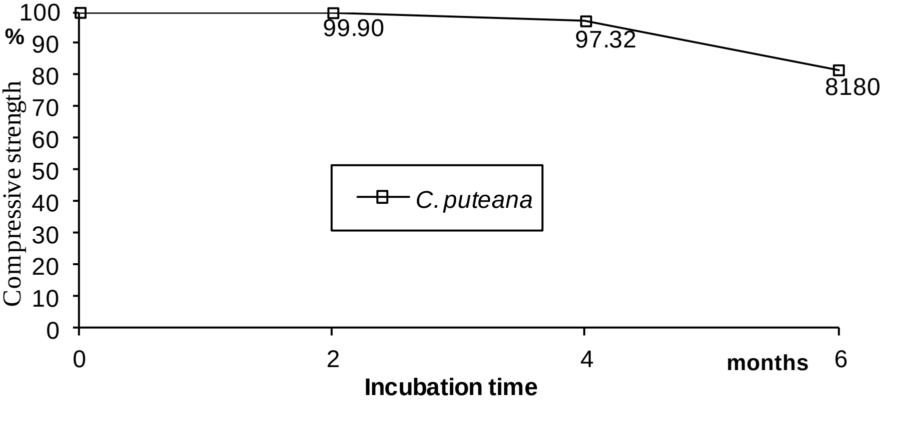
Table 4. *Reduction in the compressive strength of Q. petraea agg. wood (N/mm^2) affected by C. puteana depending on the incubation time, T-test results (difference +/-)*

	0 month	2 month	4 month	6 month
0 month	x	1.09258	2.50417	16.9757
2 month		x	1.41159	15.8831
4 month			x	14.4715
6 month				x

- significant difference at 0.05

It can be said that a significant reduction in the compressive strength of *Q. petraea agg*. wood affected by *C. puteana* occurred between 4 and 6 months of fungal activity.

Graph 2 shows the reduction in the compressive strength of *Q. petraea agg*. wood affected by *C. puteana* expressed as a percentage of the control which was designated as 100% - no change in the strength (wood that was not exposed to fungal activity).



Graph 2. *Reduction in the compressive strength of Q. petraea agg. wood (N/mm^2) affected by C. puteana depending on the incubation time*

Graph 2 shows that the reduction in the compressive strength caused by *C. puteana* is negligible in the first 4 months. In the period between 4 and 6 months of the incubation, the reduction in the compressive strength is more rapid.

Table 5 shows the loss in the investigated mechanical properties of wood in relation to the mass loss after 2, 4 and 6 months of incubation. The loss in the mechanical properties is presented as the difference from the control (100%).

Table 5. *Difference in the loss of mechanical properties (%) of Q. petraea agg.wood affected by C. puteana*

Wood property	***Incubation of C. puteana***		
	2 month	**4 month**	**6 month**
Mass loss	1.50	2.12	2.23
Compressive strength	0.10	2.68	18.20

The table shows the percent decrease in the investigated mechanical property relative to the mass loss, after a period of incubation, which is important in the practical application of the research results.

For the purpose of determining the correlation between the investigated properties of *Q. petraea agg.* and the incubation time, we conducted a correlation analysis (Table 6).

Table 6. *Overview of data of the correlation analysis of the incubation time of C. puteana and investigated properties of Q. petraea agg.wood*

Investigated property	Model type	Coefficient of correlation (r)	Regression equation
Mass loss (G_m)	The quadratic function (x)	0.990032	$G_m = 0.0638492 + 0.954107 \times \sqrt{T}$
Compressive strength (σ_p)	Linear model	-0.84605	$\sigma_p = 96.328 - 2.666 \times T$

The correlation analysis of the changes in the mechanical and physical properties of *Q. petraea agg.* wood in relation to the time of *C. puteana* incubation shows a strong correlation between the variables. The presented regression equations open the possibility of forecasting changes in the properties of wood in certain periods of fungal activity under the same environmental conditions. These findings can have important practical benefits in taking measures of protection and increasing the usability of wood.

4. CONCLUSIONS

The samples of *Q. petraea agg.* wood were used to test the effects of *C. puteana* on the mass loss and compressive strength parallel to the grain in the incubation periods of 2, 4 and 6 months. The performed investigations produced the following conclusions:

The mass loss of *Q. petraea agg.* wood affected by *C. puteana* after 2, 4 and 6 months of incubation was 1.50%, 2.12% and 2.23% respectively, which means that the greatest mass loss of the wood affected by *C. puteana* occurred in the first two months.

Compressive strength of *Q. petraea agg*. wood affected by *C. puteana* decreased after 2, 4 and 6 months of incubation and amounted to 99.90%, 97.32% and 81.80%, compared to the control (100 %). This means that the greatest reduction in compressive strength of the wood affected by *C. puteana* occurred in the period between 4 and 6 months.

Correlation analysis pointed to a strong correlation between the properties of *Q. petraea agg*. wood and the time of incubation. These findings have opened up the possibility of forecasting changes in the properties of wood in certain periods of fungal activity under the same environmental conditions. The obtained regression equations can be used to determine the reduction of mechanical properties of wood in a given period of fungal activity.

Future studies should include similar experiments performed with the most important wood species in our country and the most dangerous wood destructors, but with a greater number of monitoring periods, which would form a solid basis for the development of adequate tables (standards). Bearing in mind the wood-fungus interaction and the impact of the environment, if we want the results to have broader application (in areas with different climates), parallel experiments should be set up with the isolates of a fungus and the samples of a tree species from different geographical areas (the ones in which the fungus most frequently occurs and which are within the area of distribution of the investigated tree species). A comparative analysis of the obtained data and their statistical processing would provide the most accurate data that could be classified in the appropriate tables and applied in practice.

REFERENCES

Čeremesinov, N.A., Negruckij, S.F., Leškovceva, I.I. (1970: *Gribi i gribnie bolezni derevjev i kustarnikov*, Lesnaja promišlenost, Moscow

Josifović, M. (1951): *Forest Phytopathology*, Scientific Book, Belgrade

Mirić, M., Popović, Z. (1993): *The effect of Pleurotus ostreatus (Jacq.) Fr. and Trametes versicolor (L. ex Fr.) Pilat on the loss of hardness, compressive strength and mass of beech wood*, Lumber Bullettin, no. 6-7, Belgrade, 36-40

Muntañola-Cvetković, M. (1987): *General mycology*, NIRO Književne novine, Belgrade

Petrović, M. (1980): *Protection of wood 2*, Scientific Book, Belgrade

Rypáček, V. (1957): *Biologie drevokaznych hub*, Nakladestivi československe Akademie Ved, Praha

Tomic, Z. (1992): *Forests phytocenoses of Serbia*, Faculty of Forestry, Belgrade, 26

Šoškić, B. (1994): *Properties of wood*, Faculty of Forestry, University of Belgrade, Belgrade

Uščuplić, M. (1996): *Pathology of forest and ornamental trees*, Faculty of Forestry, University of Sarajevo, Sarajevo, 297

JUS D. A1. O45 (1957): *Examination of wood, COMPRESSIVE STRENGTH PARALLEL TO GRAIN*

JUS D. A1. O58 (1971): *Examination of the resistance to fungi*, Moscow

EFFECTS OF *Coniophora puteana* (Schumach.) P. Karst. FUNGUS ON THE DECOMPOSITION OF SESSILE OAK WOOD

Miroslava MARKOVIĆ, Snežana RAJKOVIĆ

Summary

The test samples were taken from the heartwood of a healthy *Quercus petraea agg.* tree from *Quercetum montanum* (Čer. et Jov., 1953) association. The wood samples were exposed to the mycelia of the fungus that causes brown cubical rot of oak wood - *Coniophora puteana* (Schumm. ex Fr.) Karst. (cellar fungus) for 2, 4 and 6 months. It was performed according to the method proposed by Mirić, M. (pers.com.). In order to assess the impact of *C. puteana* on the reduction in the properties of *Q. petraea agg.* wood, we investigated the mass loss of wood and the compressive strength parallel to the grain. It was found that the mass loss of *Q. petraea agg* wood after 2, 4 and 6 months of *Coniophora puteana* incubation amounted to 1.50%, 2.12% and 2.23% respectively. The compressive strength parallel to the grain of *Q. petraea agg*. wood affected by *C. puteana* decreased to 99.90%, 97.32% and 81.80%. Besides the individual loss values of the stated properties of wood, the paper presents a comparative overview of the correlation between the decrease in the mechanical properties and the mass loss, depending on the time of *C. puteana* incubation, on the basis of which we determined the percent reduction in the compressive strength of *Q. petraea agg*. wood for the determined mass loss values after 2, 4 and 6 months. In the conclusions, we stressed that the future studies should include similar experiments performed with the most important wood species in our country and the most dangerous wood destructors, but with a greater number of monitoring periods, which would form a solid basis for the development of adequate tables (standards). Bearing in mind the fungus-wood interaction and the impact of the environment, the obtained results could have broader application (in areas with different climates) and parallel experiments could be set up with the isolates of a fungus and the samples of a tree species from different geographical areas (the ones in which the fungus most frequently occurs and which are within the area of distribution of the investigated tree species). A comparative analysis of the obtained data and their statistical processing would provide the most accurate data that could be classified in the appropriate tables and applied in practice.

DEJSTVO GLJIVE *Coniophora puteana* (Schumach.) P. Karst. NA RAZLAGANJE DRVETA HRASTA KITNJAKA

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Rezime

Uzorci za ispitivanja uzeti su iz srčike zdravog stabla *Quercus petraea agg*., iz asocojacije *Quercetum montanum* (Čer. et Jov., 1953). Uzorci drveta su 2, 4 i 6 meseci izlagani dejstvu micelije gljive koja izaziva mrku prizmatičnu trulež hrastovog drveta *Coniophora puteana* (Schumm. ex Fr.) Karst. (podrumska gljiva), po metodu koji je predložio M i r i ć , M.

(pers.com.). U cilju utvrđivanja uticaja vrste *C. puteana* na smanjenje svojstava drveta *Q. petraea agg.*, ispitivan je gubitak mase drveta, i čvrstoće na pritisak paralelno sa vlakancima. Utvrđeno je da je gubitak mase drveta *Q. petraea agg.* pod dejstvom gljive *C. puteana* posle 2, 4 i 6 meseci iznosi 1,50%, 2,12% i 2,23%. Čvrstoća na pritisak paralelno sa vlakancima, drveta *Q. petraea agg.* pod dejstvom gljive *C. puteana* smanjila se na 99,90%, 97,32% i 81,80%. U radu je pored pojedinačnih prikaza gubitka pomenutih svojstava drveta, dat i uporedni prikaz gubitka mehaničkih svojstava u odnosu na gubitak mase, zavisno od vremena dejstva gljive *C. puteana*, na osnovu koga je za utvrđene gubitke mase određen procenat smanjenja čvrstoće na pritisak drveta *Q. petraea agg.* posle 2, 4 i 6 meseci. U zaključnim razmatranjima konstatovano je da bi u budućim istraživanjima trebalo slične oglede trebalo sprovesti sa našim najvažnijim vrstama drveta i najznačajnijim i najopasnijim destruktorima drveta, sa većim brojem perioda praćenja, na osnovu kojih bi se mogle formirati odgovarajuće tablice (standardi). Imajući u vidu interakciju gljiva - drvo i niz uticaja spoljne sredine, ovako dobijeni rezultati bi imali širu primenu (u različitim klimatskim područjima), a postoji i mogućnost paralelnog postavljanja ogleda sa izolatima jedne gljive i uzorcima jedne vrste drveta, ali sa različitih geografskih područja (i to onih u kojima se gljiva najčešće javlja, a koja pripadaju arealu te vrste drveta). Ukrštanjem dobijenih podataka i njihovom statističkom obradom, dobile bi se najpribližnije vrednosti koje bi se mogle svrstati u odgovarajuće tablice i praktično primenjivati.

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THE CONIFEROUS ANTHROPOGENIC AND NATURAL FORESTS DECLINE IN SERBIA DRIVEN BY DIFFERENT ABIOTIC AND BIOTIC FACTORS

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Abstract: *The epidemic dieback of conifer forest, as the modern phenomenon, is present in the central part of the Republic of Serbia as well as in other countries of Southeastern Europe. Affected forest area increased in the period 2011-2014. It was most intense in forest stands dominated by spruce and silver fir, and about eight-fold less intense in Austrian and Scots pine. Change in climate conditions is supposed to be one of the main possible causes of coniferous forests dieback.*

The climate change initiated the increased activity of fungi Armillaria spp. and Heterobasidion annosum which led to the decay of individual trees and spreading in groups of trees. In pine and spruce monocultures afforested within the broadleaved habitats, massive dieback of trees was also a consequence of these two fungi.

Spatial and temporal scales of insect outbreaks increase due to dry summers and mild winters in high elevations. In the last decade, in the coniferous plantation and natural forests in the central part of Serbia, intense outbreaks of bark beetles on spruce and silver fir were recorded. Spruce forests were heavily attacked by Ips typographus and Pityogenes chalcographus, and Austrian and Scots pine forests have been mostly affected by forest fires followed by outbreaks of Ips sexdentatus and other bark beetles. Insufficient silvicultural measures and inappropriate forest management in silver fir forests contribute to mistletoe infestations.

Key words: coniferous, anthropogenic and natural forests, decline, harmful factors

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PROPADANJE ČETINARSKIH ANTROPOGENIH I PRIRODNIH ŠUMA U SRBIJI, UZROKOVANO RAZLIČITIM BIOTIČKIM I ABIOTIČKIM FAKTORIMA

Izvod: *Epidemijsko sušenje četinarskih šuma, kao savremeni fenomen, kao i u drugim zemljama jugoistočne Evrope, prisutno je i centralnom delu Republike Srbije, gde je u periodu od 2011. do 2014. godine došlo do značajnijeG povećanja ugroženog šumskog područja. Najizraženije je u šumskim sastojinama gde dominira smrča i jela, dok je oko osam puta slabijeg intenziteta u antropogenim i prirodnim šumama belog i crnog bora. Promenjeni klimatski uslovi su jedan od glavnih mogućih uzročnika sušenja prethodno navedenih vrsta drveća.*

Klimatske promene inicirale su pojačanu aktivnost gljiva Armillaria spp. i Heterobasidion annosum, a one su dovele do propadanja pojedinačnih i grupa stabala. Sušenje stabala smrče i borova u monokulturama podignutim na lišćarskim staništima, takođe je uzrokovano navedenim vrstama gljiva.

Pojave prenamnoženja gradogenih vrsta insekata, te širenje površina pod napadom, intenzivirane su sušnim letima i blagim zimama na višim nadmorskim visinama. U području centralne Srbije, poslednje decenije, u četinarskim antropogenim i prirodnim sastojinama smrče i jele, došlo je do gradacije potkornjaka. Smrčeve šume su napadnute od strane dve najznačajnije ekonoski štetne vrste Ips typographus i Pityogenes chalcographus, a sastojinama crnog I belog bora, pogođenim šumskim požarima i ledolomima, preti opasnost od, za njih najznačajnije vrste potkornjaka, Ips sexdentatus, kao i drugih ksilofagih insekata. Kada je u pitanju jela, u pojedinim područjima centralne Srbije, usled nedovoljnih uzgojnih mera i nepravilnog gazdovanja, najviše je ugrožena poluparazitnom cvetnicom – imelom.

Ključne reči: četinari, antropogene i prirodne šume, sušenje, štetni faktori

1. INTRODUCTION

Forests, by their structure, as well as by connections and relations among some members, belong to the category of the most complex ecosystems on the Planet. The stability of the forest ecosystems to a great extent depends on the impact, i.e. presence of the different harmful abiotic and biotic factors at the global and local levels. At the local level, it refers to the plant diseases, economically harmful living organisms, climate factors, local environment pollution, whereas at the global level it refers to the climate change, reflected in the global warming which is the result of the ozone layer depletion.

The climate is regarded as the main ecological abiotic factor and it is inextricably bound to some ecosystems, i.e. their presence depends upon climate, and, therefore, it is of special importance to their development and stability. The climate parameters influence the soil fertility, vitality of plants, aggressiveness and pathogenicity of fungi which inhabit certain tissues of host plant, and population dynamics of so-called "useful and harmful" forest insects.

About 90% of all natural disasters, which occurred since 1980 have been directly or indirectly attributed to the weather and climate. About 95% of the economic losses caused by the catastrophical events are the result of the climate-related disasters. The annual number of the disasters caused by the weather and climate in Europe increased by about 65 % over the period 1998-2007 in the comparison with the annual average value for 1980. It is estimated that in the next decades the losses caused by the natural disasters will be dominant, and that in the second half of the next century the effects of the climate change on the economy will be more expressed (Rosenzweig et al., 2001).

Forest productivity and species diversity typically increase with increasing temperature, precipitation and nutrient availability, although species may differ in terms of their tolerance (Das, 2004). The impacts of elevated temperatures on trees and plants will vary throughout the year since warming may relieve plant stress during colder periods but increase it during hotter periods (Garrett et al., 2006). Moisture availability in forests will be strongly influenced by changes in both temperature and precipitation. Warmer temperatures lead to increased water losses from evaporation and evapotranspiration and can also result in reduced water use efficiency of plants (Mortsch, 2006). Longer, warmer growing seasons can intensify these effects resulting in severe moisture stress and drought. Moisture stress and drought can also impact forest health by enhancing susceptibility to disturbances such as insect pests and pathogens and forest fires.

The impact of the climate change on the ecosystems, which mainly refers to the warming caused by the anthropogenic increase of the glass house gases (C, CH4, N2O, O3, HCFCs, CFCs), which will initiate the numerous adverse effects on the forest ecosystems, has been elaborated in the domestic and foreign literature. For instance, Willmott and Legates (1991) report that the increase of temperature ensured the sufficient energy for the increased transpiration and evaporation, and owning to the limited capacity of the atmosphere to absorb the moisture, all these phenomena have been globally reflected in the increase of the precipitation (Quoted by Liovic and Zupanic, 2005). The increased precipitation are not uniformly distributed, so in some regions the floods and soil erosion can be expected, whereas the decrease in precipitation and accelerated forest desiccation (Bradley et al., 1987).

2. RESULTATES AND DISCUSION

Each species has well-defined ecological amplitude, which can be either narrow or broad, depending on the effects of certain abiotic and biotic factors. If the values of certain parameters are outside the limits, they directly affect the survival of the species in a given area, *i.e.* they become a limiting factor. In the forests area in Southeastern Europe change in climate conditions is on the first places of the possible causes of desiccation.

Change in climate conditions is supposed to be one of the main possible causes of coniferous forests dieback in forest area of Southeastern Europe. At the global level, the year of 2013 was together with the year of 2003 the fourth hottest year since the beginning of measurements in 1880. The average global temperature was by 0.62°C above the average (13.9°C) for the period 1981-2010. The hottest year was 2010, and nine out of ten hottest years in a 134 year-long measurement series occurred in the period from 2000 to today. Furthermore, the year of 2013 was the thirty-seventh consecutive year with the temperatures above the average.

These data indicate a significant change in climate and a steady increase in global temperature.

A severe ice storm accompanied by heavy rainfall hit the area of central Serbia (State Enterprise Srbijašume: Forest Estates Niš, Timočke šume Boljevac, Južni Kučaj Despotovac, Rasina Kruševac, Severni Kučaj Kučevo; 18,500 ha of state forests) in late November and early December 2014 and caused unprecedented ice breakages in artificially-established conifer stands, mostly of spruce and Austrian pine. The most vulnerable area was the Forest Estate Timočke šume Boljevac with 10,060.72 hectares (Srbijašume estimate: 979,682 m^3 of damaged or dead trees) (Tabaković-Tošić & Milosavljević, 2015).

The population density of the four of bark beetle species [*Ips typographus* (Linnaeus, 1758), *I. acuminatus* (Gyllenhaal, 1827), *Ips sexdentatus* (Börner, 1767) and *Pityogenes chalcographus* (Linnaeus, 1761)] in artificially-established conifer stands damaged by ice-breaks in 2014, in the area of Central Serbia was managed using traps with specific pheromone dispensers – synthetically produced aggregation pheromones. The obtained results, with the above-stated exceptions, generally do not indicate an increase in their abundance. However, in the future, weather conditions favourable for their development (mild winters) in the absence of urgent control measures may turn these species into a calamity of bigger proportions (Tabaković-Tošić & Milosavljević, 2015).

The epidemic dieback of conifer forest, as the modern phenomenon, is present in the most countries of Southeastern Europe. Affected forest area increased in the period 2011-2014. For example, the massive desiccation of individual or groups of trees in 2013 was reported in all areas of Serbia. It was most intense in the spruce and fir, and about eight-fold less intense in the Austrian and Scots pines. The intensity of desiccation is expressed by the timber volume marked for the sanitation felling and in the case of spruce and fir it is 103,239 m^3, and in the case of pines it is 13,051 m^3 (Tabaković-Tošić, 2014).

Mediterranean pluviometric precipitation regime, which is unfavourable to the forest due to the spring and autumn maximum, is ideal for the development of the parasite fungi. Therefore, there are great possibilities for the occurrence of the fungal diseases, which will be multiplied every year.In the regions with moderate climate the most frequent plant pathogens decrease their activity during the winter and in the early spring due to the low temperatures. Although there are some diseases which have been favoured over the cold period, many species favour the higher temperatures. The increase of temperature causes the change of the physiology of plant host, which can be reflected in the increase of the sensitivity or the resistance to the plant pathogens. The resistance to the pathogens becomes effective due to the increased defence of plants, which are the results of the changes in physiology, nutrition status and water ability.

The most important abiotic cause is the climate change that has been highly expressed in the last ten years. Conditions for plant growth and development are completely different between individual years, but one thing is common in this entire period is unevenly distributed rainfall. It is especially expressed during the vegetation period, which adversely affects the vitality and the health of the plants. Moisture, as well as temperature, is the most important climatic factor with strong impact on plant pathogens and their interactions (Agrios, 2005). It is particularly important that these two factors have a strong influence on the development, reproduction, survival and dispersal of pathogenic fungi. Their relatively short generations, which are characterized by high mobility and reproductive power, are able to react more quickly to climate change than long-lived organisms such as higher plants and mammals (Menéndez, 2007). In addition to the impact of the changes in the development of host plant and pathogen development, climate changes have an impact on the interaction between the pathogen and the host, which increases the risk of infections, but the resistance power can also be increased. (Coakley et al., 1999; Garrett et al., 2006).

However, strong decline of different forest stands was recorded on the entire area of Serbia, and all the tree species were affected with the decline. Particularly, decline of different coniferous plantations was recorded after the year 2011, and the most affected were artificially established stands of Scots pine (*Pinus sylvestris* L.), Austrian pine (*Pinus nigra* Arnold), spruce (*Picea abies* (L.) Karst.), Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco), and Silver fir (*Abies alba* Mill.). Decline of the other coniferous plantations was also recorded, but the established and affected areas are not so significant, comparing to previously listed hosts.

Intensive field studies on the diagnostic of the main causes of the decline of different coniferous plantations in Serbia were performed between the years 2011 and 2015. In most of the cases, root and but rots of the trees were recorded and different pathogenic fungi were registered and isolated. However, in the plantations of Scots pine, the most often and most aggressive fungi were *Heterobasidion annosum* (Fr.) Bref. and *Armillaria* spp., causing root and stem rot of the trees, and *Naemacyclus minor* on the needles. In the plantations of Austrian pine, *Armillaria* spp. was recorded on the roots and stem bases of the trees, and *Mycosphaerella pini* Rostrup apud Munk, *Sphaeropsis sapinea* (Fr.) Dyko &Sutton, *Lophodermium* spp., *Naemacyclus niveus* (Pers.) Sacc. were the most often parasitic fungi recorded on needles and shoots. In some places, *Cenangium ferruginosum* Fr. and *Gremmeniella abietina* (Lagerb.) Morelet, causing the decline of Austrian pine trees, were previously recorded (Karadžić *et al.* 2011). In the plantations of spruce, the biggest damages and the declines were recorded by *Heterobasidion parviporum* Niem. & Korh., as well as by *Armillaria* spp. Also, different parasitic fungi on needles, including some rusty fungi were recorded on spruce trees in plantations. In the plantations of Douglas fir, the biggest damages were recorded by *Armillaria* spp., and in some places by needle diseases *Phaeocryptopus gaeumannii* (Rohde) Petrak and *Rhabdocline pseudotsugae* Syd.

From the other coniferous species in plantations in Serbia, we could point out European larch (*Larix decidua* Mill.), that was affected by larch canker disease (*Lachnellula willkommii* (Hartig) Dennis), as well as white pine (*Pinus strobus* L.), that was also affected with the decline in some places. In the plantations of silver fir, *Heterobasidion abietinum* Niem. & Korh. And *Armillaria ostoyae* (Romagn.) Herink were the most destructive pathogens, following the development of mistletoe (*Viscum album* subsp. *abietis* (Wiesb.) Abromeit.), particularly in older artificially established stands.

Fungal pathogens attacking secondarily thickened roots of trees are amongst the most destructive agents known in forestry. The genera with serious impacts in this category in Souteast European forestry are *Heterobasidion* and *Armillaria* (Woodward et al., 1998; Kile & Shaw, 1991; Fox, 2000; Karadžić & Milijašević 2008). Three species of *Heterobasidion* are present in Europe, and cause serious damage: *H. annosum*, *H parviporum* and *H. abietinum*, of which *H. annosum* is arguably the most aggressive species (Woodward et al., 1998; Asiegbu et al., 2005). Amongst the seven species of *Armillaria* known in Europe, only two, *A. mellea* and *A. ostoyae* are serious pathogens. The most affected are stands of European silver fir, Norway spruce, Scotch and Austrian pine in both natural and semi-natural stands. It was shown in several national and international studies that stability of different conifer stands and ecosystems are strongly disturbed without control of fungi from *Heterobasidion* genus (Woodward *et al.* 1998). Apart of ecological loss, there are significant economic losses, since the most valuable part of the trees are completely deteriorated by the fungus activity. Also, *Armillaria* species were recorded as dangerous pathogens to different conifer stands in SE Europe (Keča et al., 2004). Due to evident climatic extremes, recorded over the last decades, infections with *Armillaria* species are driven with these changes and weak trees without resistance mechanisms are easily colonized with this opportunistic fungus. In many cases, damages by both *Heterobasidion* and *Armillaria* were recorded in the same stands, and even on the same trees.

On the basis of long term research on causes of the acute dieback of *Picea, Abies, Pinus* and *Pseudotsuga*, in some areas of Southeastern Europe, the conclusion was made that the climate change initiated the increased activity of fungi *Armillaria* spp. and *H. annosum* which led to the decay of individual trees and spreading in groups of trees. In pine and spruce monocultures afforested within the broadleaved habitats, massive dieback of trees was also a consequence of these two fungi.

The main factors affecting insects distribution are the temperature and habitat requirements specific to each insect herbivore species. Climate can influence ihe geografical distribution of insect species. Moreover, depending on the local climate the same species can present one or more generations per year. The bark beetle, Ips sexdentatus, has one to five generations per year depending on the climatic codition (EPPO, 1997).

Spatial and temporal scales of insect outbreaks increase due to dry summers and mild winters at high elevations. In the last decade, in the Southeastern Europe, intense outbreaks of bark beetles (Coleoptera: Curculionidae, Scolytinae) on spruce and silver fir were recorded.

Ips typographus is mostly a secondary biotic agents, affecting trees that are already weakened. As a result, it is possible to assess the level of risk of forest infestation for this species, according to the combination of environmental traits that are present, and on the management aims. However, *I. typographus* is currently expanding its range, and interestingly, outbreak risks are similarly high outside its natural range than in non-managed, old-growth spruce stands. Spruce forests on the territory of Central Serbia have been heavily attacked by *I. typographus* and *Pityogenes chalcographus,* and Austrian and Scots pine forests have been mostly affected by forest fires followed by outbreaks of *Ips sexdentatus* and other bark beetles.

Intensive degradation of coniferous tree species has been present for many years in Serbia. Nearly all conifer species are endangered in plantations, in urban areas and in nurseries. The drying causes are very complex and involve a large number of biotic and abiotic factors.

Many plantations are built on an inadequate site. In afforestation and reclamation of degraded forests not enough attention was paid to the ecology of the species which were entered. That's how mesophilic conifers were massively entered in drier broadleaf forests, while they were in middle-aged stage of their development, when they have higher demands for water, where they were stuck by a physiological drought. This has caused the decline of many trees in the cultures of Douglas fir and pine bred on such sites (Lazarev & Golubović Ćurguz, 2000, 2004). If bred at such, inappropriate sites, due to the specific structure and composition of the soil, where the runoff of excess water is prevented and retained in the rhysosphere, allowing the development of a number of anaerobic pathogens. Excess moisture in plantations of Weymouth pine and larch causes physiological weakening of the trees and they become susceptible to massive development of pathogenic fungi and pests.

As a result of lack of care and improper management of the plantations of the conifer species in Serbia damages were caused by many causes of biotic origin that were developed in different intensity. In older untended silver fir plantations a massive development of mistletoe was recorded, which also causes damaging and decay of trees. By removing these fir trees the circuit is opened and favorable conditions for further development of the mistletoe are made, which causes continued deterioration of fir trees.

Pathogenic fungi *Armillaria* spp. and *H. annosum* are a frequent cause of deterioration of conifer plantations raised on the habitats of broadleaves species, especially oaks. The consequence of the development of the fungus is that it leads to a massive degradation of coniferous trees. If contemporaneous plantations are raised in these large areas, it enables easy transfer of fungal diseases.

3. CONCLUSION

Forest decline, insect outbreaks, forest fires and other negative impacts are driven and intensified by climatic changes. All these phenomena are more frequent in the recent years, threatening different natural and semi-natural ecosystems, including coniferous plantations. Also, these phenomena have catastrophic character in some cases, and they are followed by process of chaining of damages.

Apart of all the negative biotic and abiotic causes, many plantations were established on inadequate sites in the past, what makes them more vulnerable for different stress and declining factors. Particularly, this situation is pointed out in the cases of mesophilic conifers that were introduced in drier broadleaf forests. During the first years of development, they did not have high demands for water supply and remained healthy. Later, during the middle-aged stages of their development, they have higher demands for water, and they suffered from the physiological drought, what caused the decline of many trees, or made them more vulnerable for the infections of opportunistic pathogens and pests attacks. In opposite, introduced species that are not tolerated on excess moisture and water in the soil, are also under physiological weakening of the trees in plantations, and they became susceptible on the attacks of pests and opportunistic pathogens.

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REFERENCES

Agrios, G.N. (2005): Plant Pathology, 5th ed. San Diego, CA, USA: Elsevier-Academic Press.

Asiegbu, F.O., Adomas, A. & Stenlid, J. (2005): Conifer root and butt rot caused by Heterobasidion annosum (Fr.) *Bref. s.l, Molecular Plant Pathology*, 6: 395-409.

Coakley, S.M., Scherm, H. & Chakraborty, S. (1999): Climate change and plant disease management. *Annu. Rev. Phytopathol.*, 37: 399–426.

Bradley, R.S., Diaz, H.F., Eischeid, J.K., Jones, P.D., Kelley, P.M. & Goodess, C.M. (1987): Precipitation fluctuations over Northern Hemisphere land areas since mid 19th century. *Science*, 237: 171–175.

Das, H.P. (2004): Adaptation strategies required to reduce vulnerability in agriculture and forestry to climate change, climate variability and climate extremes. *In* World Meteorological Organization (WMO). *Management Strategies in Agriculture and Forestry for Mitigation of Greenhouse Gas Emissions and Adaptation to Climate Variability and Climate Change*, Report of CAgM Working Group. Technical Note No. 202, WMO No. 969, Geneva, WMO, pp. 41–92.

EPPO (1997): Pest risk assessment scheme – *EPPO Bull*, 27: 281-305

Fox, R.T.V. (2000): Armillaria Root Rot: Biology and Control of Honey Fungus. Intercept Press, Andover, UK.

Garrett, K.A., Dendy, S.P., Frank, E.E., Rouse, M.N. & Travers, S.E. (2006): Climate change effects on plant disease: genomes to ecosystems. *Annual Review of Phytopathology*, 44: 489–509.

Karadžić D. & Milijašević T. (2008): The most important parasitic and saprophytic fungi in Austrian pine and scots pine plantations in Serbia. *Bulletin of the Faculty of Forestry*, 97: 147-170.

Keča, N., Bodles, W.A.J., Woodward, S. & Karadžić, D. (2004): Identification of Armillaria spp. in Serbia, Proccedings of the 11th. International Conference on ”Root and Butt Rots of Forest Trees”. Poznań and Bialowezy, Poland, august 16-22, 35-41.

Kile, G.A. & Shaw C.G. (1991): Armillaria Root Disease. USDA Forest Service, Agriculture Handbook No. 691.

Lazarev, V. & Golubović-Ćurguz, V. (2000): *Rabdocline pseudotsugae* Syd. - nova bolest četina duglazije u Srbiji, *Šumarstvo* (Beograd), 2-3: 79-86.

Lazarev, V. & Golubović-Ćurguz, V. (2004): Nalaz *Rhizosphaera kalkoffii* Bubak - izazivača osipanja četina na *Picea omorika* (Pančić) Purkyne, *Šumarstvo* (Beograd), 1-2: 81-87.

Liovic, B. & Zupanic, M. (2005). Forest Pests in National Parks of Croatia and Ecologically Acceptable Protective Measures. *Forests institute Works* (Jastrebarsko), 40(1): 101–112,.

Menéndez, R. (2007). How are insects responding to global warming? *Tijdschrift voor Entomologie*, 150: 355–365.

Mortsch, L.D. (2006): Impact of climate change on agriculture, forestry and wetlands. In Bhatti, J., Lal, R., Apps, M. & Price, M., eds. Climate change and managed ecosystems, pp. 45–67. Taylor and Francis, CRC Press, Boca Raton, FL, US.

Rosenzweig, C., Iglesias, A., Yang, X.B., Epstein, PR. & Chivian, E. (2001): Climate change and extreme weather events, Implications for food production, plant diseases, and pests, Global change & human health, 2(2): 90-104.

Tabaković-Tošić, M. (2014): The condition of tree crowns at the sample plots of level I-reliable or unreliable indicators of the vitality of main conifer species in Serbian forests. 3rd ICP Forests Scientific Conference "Impact of nitrogen deposition and ozone on the climate change mitigation potential and sustainability of European forests". Athens, Greece, May 26-28, 27.

Tabaković-Tošić, M. & Milosavljević, M. (2015): Impact of extreme weather conditions on the population dynamics of bark beetles in the forests of eastern Serbia. *Suistainable Forestry*, 71-72: 27-37.

Willmott, C. J. & Legates, D. R. (1991): Rising estimates of terrestrial and global precipitation. *Climate Research*, 1: 179–186.

Woodward S., Stenlid J., Karjalainen R. & Hüttermann A. (1998): *Heterobasidion annosum*: Biology, ecology, impact and control. Wallingford, UK: Cab International.

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Original scientific paper

THE CORRELATION BETWEEN THE CHANGES IN CLIMATE, THE INTENSITY OF SPRUCE DECLINE AND THE ABUNDANCE OF SPRUCE BARK BEETLES IN `GOLIJA` NATURE PARK

Mara TABAKOVIĆ-TOŠIĆ[1], Marija MILOSAVLJEVIĆ[2]

Abstract: *The paper presents the results of the research on the correlation between changes in microclimate, the intensity of spruce decline and active abundance of its two economically most significant harmful insects – eight-toothed (Ips typographus) and six-toothed (Pityogenes chalcographus) spruce bark beetles (Coleoptera: Curculionidae) in `Golija` Nature Park whose pure and mixed conifer stands are dominated by spruce. The route method and ocular inspection were applied to study the presence and determine the intensity of spruce decline – both of individual trees and groups of trees in the management units of Dajićke planine, Kolješnica, Golija and Brusničke šume. Population dynamics of the two species of bark beetles and their active abundance were monitored by the method of trapping with barrier traps and the use of combined pheromone dispensers - PCIT Ecolure. Although the decline of individual conifer trees, primarily of spruce, had already been present in certain areas of these management units for several decades, it reached epidemic proportions due to extreme adverse climatic conditions in the period between 2011 and 2012 and culminated in 2015. A large number of physiologically-weakened trees raised the population levels of secondary harmful insect and the number or the active abundance of the two investigated species of insects reached a peak in 2016. The inability to take appropriate and timely remedial measures in the areas under stricter protection regimes greatly contributed to this situation.*

Keywords: air temperature, precipitation, spruce decline, *Ips typographus, Pityogenes chalcographus*

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KORELACIJA IZMEĐU KLIMATSKIH PROMENA, INTENZITETA SUŠENJA SMRČE I BROJNOSTI POTKORNJAKA U PARKU PRIRODE GOLIJA

Izvod: *U radu su prikazani rezultati istraživanja korelacije između mikroklimatskih promena, intenziteta sušenja smrče i aktivne abundancije dve njene, ekonomski najznačajnije, štetne vrste insekata – osmozubog (Ips typographus) i šestozubog (Pityogenes chalcographus) smrčinog potkornjaka (Coleoptera: Curculionidae) u području Parka prirode Golija, gde u četinarskim, čistim i mešovitim, sastojinama dominira smrča. U gazdinskim jedinicama Dajićke planine, Kolješnica, Golija i Brusničke šume, maršrutnim metodom, okularnim pregledom, istraženo je prisustvo i određen intenzitet sušenja pojedinačnih i grupe stabala, a populaciona dinamika navedene dve vrste potkornjaka, odnosno njihova aktivna abundancija, praćena je metodom lova pomoću barijernih klopki, uz korišćenje kombinovanog feromonskog dispenzera – PCIT Ecolure. Iako je sušenje pojedinih stabala četinarskih vrsta drveća, prvenstveno smrče, u pojedinim područjima navedenih gazdinskih jedinica, prisutno već nekoliko decenija, ono, posle vrlo nepovoljnih, ekstremnih klimatskih uslova u periodu 2011-2012. godine, poprima epidemijski karakter, sa kulminacijom u 2015. Velika količina fiziološki oslabelih stabala, pozitivno je uticala na povećanje populacionih nivoa sekundarnih štetnih vrsta insekata, pa je u 2016. godini došlo do kulminacije brojnosti, odnosno aktivne abundancije istraživane dve vrste potkornjaka. Na ovakvo stanje dosta je uticala i nemogućnost i neblagovremenost preduzimanja odgovarajućih sanacionih mera u područjima pod strožijim režimima zaštite.*

Ključne reči: temperatura vazduha, padavine, sušenje smrče, *Ips typographus, Pityogenes chalcographus*

1. INTRODUCTION

The epidemic decline of mainly coniferous indigenous forest tree species, as a recent phenomenon that most countries of Eastern and Central Europe are faced with, has reached unprecedented proportions in the Republic of Serbia. Numerous multidisciplinary research studies of this process have all proved that it is affected by a range of abiotic and biotic factors, one or several of which can become the most important ones at a certain time and space.

It has long been known that the stress caused by unfavorable climatic conditions has a major impact on the health status of forest stands. In some parts of the world, these impacts have led to sporadic, territorially-limited decline of the most vulnerable species. Therefore, many environmentalists have considered it to be normal, natural succession within the forest ecosystem (Auclair, 1993; Ciesla and Donaubauer, 1994; Swetnam and Betancourt, 1998). However, the situation has suddenly and dramatically changed in the last decade. Due to global warming and insufficient or irregular precipitation, a great number of countries have faced an epidemic decline of primarily coniferous tree species. Globally, the year of 2013 has been the fourth warmest year on record (1880), together with 2003. For instance, the average global temperature for the period of 1981-2010 was 0.62°C above the average (13.9°C). Annual precipitation sums were generally at the same level, but their temporal patterns were substantially changed, with a notable lack of rain during the growing period.

The interaction between insects and plants accounts for half of all relationships in nature, but natural conditions, such as extreme temperatures and excessive or poor rainfall, can also lead to a rapid increase in the number of some sensitive species.

When it comes to bark beetles, insects that would be the first to attack the trees weakened by different stress factors, the studies that have been conducted worldwide point to a variety of factors that can affect the high rate of their outbreak and attack. Some authors (Waring and Pitman, 1983; Christiansen and Bakke, 1988; Dutilleul et al., 2000; Økland and Christiansen, 2001; Wermelinger, 2004; Schumacher and Bugmann, 2006; Aukema et al., 2008, Tabaković-Tošić, 2014; Tabaković-Tošić and Milosavljević 2015, 2016) have listed the following factors as the most important causes of spruce bark beetle attack: prolonged drought and high daytime temperatures, excess and lack of rainfall, stand age and vitality of trees, tree aspect, UV radiation, ozone, lack of sanitary fellings and forest law, as well as elevation, excessive nitrogen, magnesium and phosphorus in the soil.

The large-scale decline of individual or groups of spruce trees, as the most common coniferous tree species in the growing stock of Serbia (Banković et al., 2009), has been recorded in all areas but its pure or mixed stands under special protection regime within the national parks of Kopaonik (Tabaković-Tošić, 2014; Tabaković-Tošić and Milosavljević, 2015) and Tara and in the nature parks of Stara Planina (Tabaković-Tošić, 2006) and Golija seem to be most affected. The epidemic decline of spruce forests in `Golija` Nature Park has been going on for many years, but it reached massive proportions in the period from 2014 to 2016.

The paper presents the results of the research on the correlation between the changes in microclimate, an increasingly intensive decline of mostly spruce trees in `Golija` Nature Park and the active abundance of two economically-important harmful insect species – eight-toothed, *Ips typographus* (Linnaeus, 1758) and six-toothed, *Pityogenes chalcographus* (Linnaeus, 1761) (Coleoptera, Curculionidae, Scolytinae) bark beetles.

2. MAIN CHARACTERISCTICS OF THE STUDY AREA

Golija Mountain belongs to the extensive area of Stari Vlah-Raška Mountain Range or the inner zone of the Dinaric mountain range. It stretches from east to west, surrounded by the mountains of Jelica (north), Kopaonik, Čemerno, Radočelo (east), Javor (west), Zlatar, Jadovnik and Pešter plateau (south). There are three clearly distinguishable climate zones in the area: the mountain-valley zone (700 m a.s.l.) with a humid continental climate modified under the influence of the surrounding mountains, the transition zone (700-1300 m a.s.l.) with long, cold winters and short, cool summers, and the mountainous zone (over 1300 m a.s.l.) with harsh and cold winters and short and cool summers.

Mt. Golija, with a nature park of the same name (75,183 ha) and `Golija-Studenica` Biosphere Reserve (53,804 ha), is one of forest-richest mountains of Serbia (total of 89,000 ha; forest cover by municipalities: Ivanjica 49%, Raška 46%, Novi Pazar 48% Kraljevo 49% and Sjenica 20%). According to the Spatial Plan of the special purpose area of `Golija` Nature Park (2004), broadleaved species outnumber coniferous species, dominated by beech (accounting for 63.3% of the volume and 54.0% of the total volume increment), spruce (accounting for 19.5% of the total volume and 23.0% of the total increment), and with much lower shares of fir, Austrian pine, sessile oak and Turkey oak (from 1 to 7%). Other tree species are represented by less than 1%, but they also contribute to the biodiversity of the forest ecosystems.

The correlation between the intensity of the decline of individual trees and groups of trees and the active abundance of the two most important species of spruce bark beetles was studied in the forest stands of the following forest management units: Dajićke planine, Kolješnica, Golija and Brusničke šume (SE` Srbijašume`, `Golija Ivanjica` Forest estate, `Ivanjica` Forest Administration).

3. MATERIAL AND METHODS

In the management units Dajićke planine, Kolješnica, Golija and Brusničke šume the route method and ocular inspection were applied to study the presence and determine the intensity of spruce decline – both of individual trees and groups of trees. The population dynamics of the eight-toothed, *Ips typographus* and six-toothed, *Pityogenes chalcographus* bark beetles and their active abundance were monitored by the method of trapping with barrier traps and the use of combined pheromone dispensers - PCIT Ecolure (Figure 1).

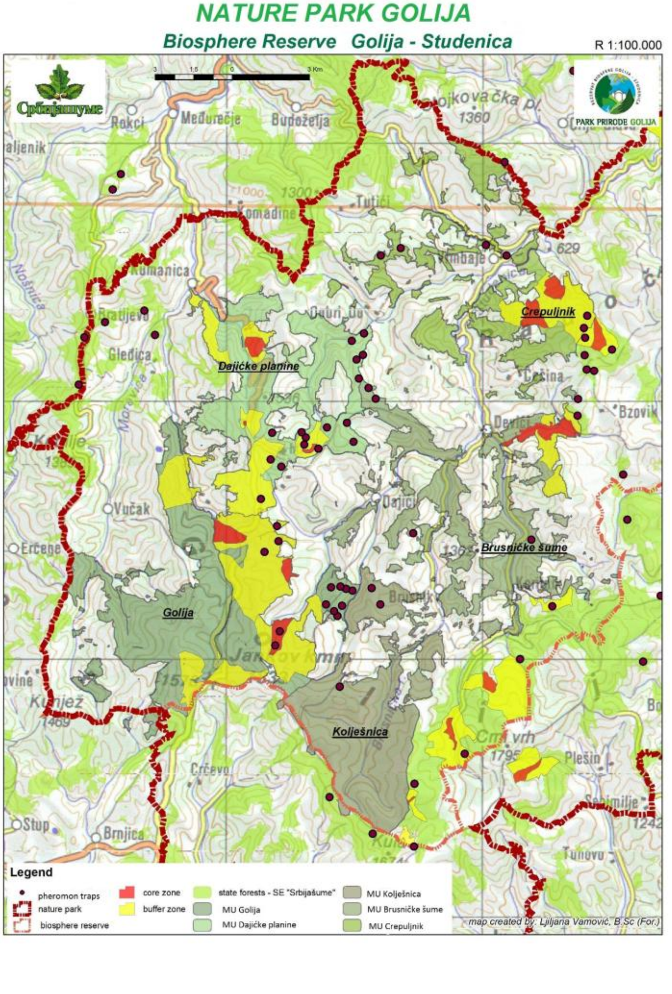


Figure 1. *Distribution of pheromone traps in `Golija` Nature Park with its `Golija-Studenica` Biosphere Reserve.*

4. RESULTS AND DISCUSSION

The sporadic and modest decline of individual and small groups of trees of coniferous tree species, primarily spruce, has been present in the forest complexes of Mt. Golija for decades. The decline has been monitored within regular annual activities of SE `Srbijašume`, `Golija Ivanjica` Forest Estate and the Department of Forest Protection of the Institute of Forestry in Belgrade. Since a part of this area was declared nature park and biosphere reserve and put under special protection regime, monitoring of the health state of the forest stands has been intensified, with special emphasis on the process of their decline.

In the FE `Golija Ivanjica`, especially in the FA `Golijska reka` (Management units: Dajićke planine, Kolješnica, Golija and Brusničke šume), *i.e.* in the part of the nature park with conifer stands under the protection regime I, intensive decline of spruce trees began in 2012 and reached the strongest intensity in 2015 (sanitary felling of declined trees in 2014 – 12.579 m^3, 2015 – 18.502 m^3). In 2016, despite sanitary measures, the decline was not stopped, but according to the wood volume marked for sanitary felling, (13,000 m^3), its intensity was somewhat lower compared to the previous two years (Graph 1).

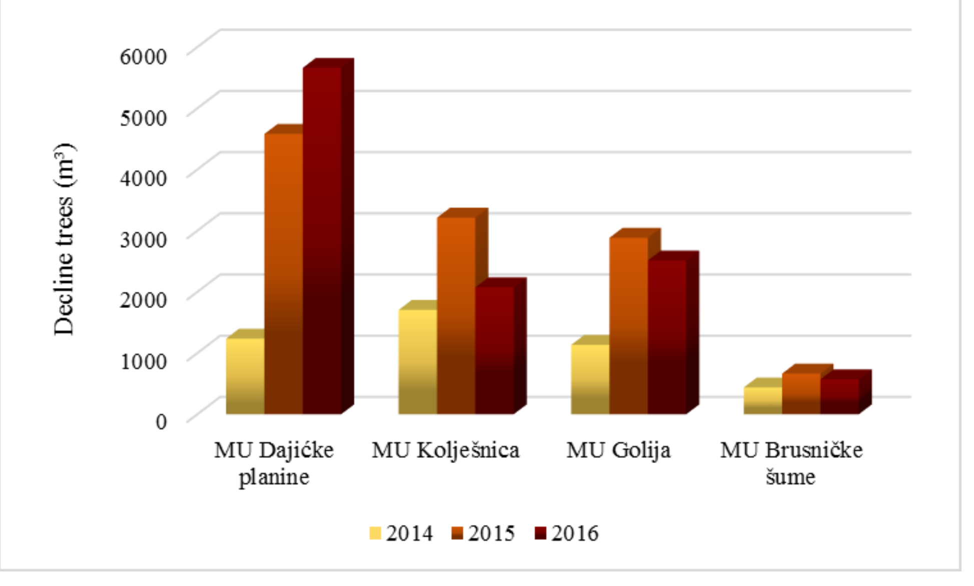


Figure 2. *Spruce decline expressed as wood volume marked for sanitary felling in the period 2014-2016 in the study area of `Golija` Nature Park.*

Spruce decline reached a peak value in MU Dajićke planine (with 11,749 m^3 of volume marked for felling in the period between 2014 and 2016), in 2016 (5, 661 m^3) and in MU Kolješnica and MU Golija (with the volume marked for felling in the period between 2014 and 2016 of 6,994 and 6,532 m^3 respectively) in 2015 (3,213 and 2,885 m^3). The lowest values were found in MU Brusničke šume (the total volume marked for sanitary felling amounted to 1,674 m^3) (Figure 2).

Drought-induced changes in trees, such as transpiration reduction and carbon assimilation, significantly reduce their natural, mostly chemical defense against attacks of various xylophagous species of insects and thus lower the threshold limit values.

To confirm the initial hypothesis of the research – a positive correlation between the changes in the microclimate, the decline of spruce trees and abundance of bark beetles, we thoroughly analyzed the climate - mean monthly air temperatures and monthly precipitation for the period 2006-2015. As there is not a main meteorological station on Mt. Golija, we used data of the main meteorological station on Zlatibor (Figure 3).

Figure 3. *Monthly values of air temperature and precipitation for Zlatibor Meteorological Station (α: 43°44′ N; δ: 19°43′ E; the altitude of 1028 m) for the period 2006-2015*

In the ten-year study period, the year of 2012 shows the greatest deviations - significantly higher mean monthly air temperatures in the growing period when the insects exert the most intense adverse effects on the coniferous species with shallow root plate system as in spruce. The onset of spruce forest decline in `Golija` Nature Park was thus recorded in the year with the climate outside its optimum values (Figures 2, 3). The year of 2013 also recorded the smallest amounts of precipitation again in the growing period (April: the ten-year monthly average of 78 mm, but only 31 mm in 2013; July: the ten-year monthly average of 89 mm, but only 23 mm in 2013) (Figure 3).

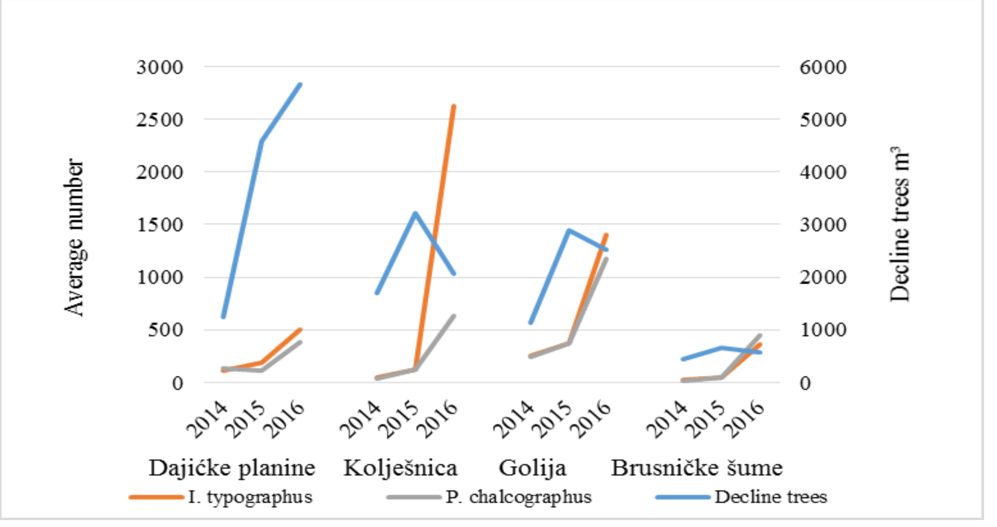
A comparison of the results presented in Figures 2 and 3 clearly leads to the conclusion that there is a positive correlation between the intensified process of spruce decline and marked deviations of the two main meteorological parameters - air temperature and precipitation in the growing period in the forest complexes of `Golija` Nature Park.

Table 1. *The number of beetle adults of one generation caught in one pheromone trap*

Management unit	Year	Trapped adults (N/pheromone trap)					
		Ips typographus			*Pityogenes chalcographus*		
		minimum	maximum	average	minimum	maximum	average
Dajićke planine	2014	15	316	110	21	369	130
	2015	54	499	184	37	299	112
	2016	21	1500	500	100	1150	383
Kolješnica	2014	13	137	50	19	106	42
	2015	19	359	126	21	360	127
	2016	303	7874	2625	54	1896	632
Golija	2014	31	742	258	15	710	242
	2015	27	1103	377	18	1110	376
	2016	38	4196	1398	406	3522	1174
Brusničke šume	2014	10	73	28	9	37	15
	2015	3	126	43	15	125	47
	2016	25	1085	362	116	1360	453

In all the investigated management units in `Golija` Nature Park, the active abundance of the two most important species of spruce bark beetles, *I. typographus* and *P. chalcographus* has had a positive upward trend since 2014, with the maximum in 2016. The largest increase was recorded in the management units of Kolješnica and Golija (*I. typographus* 50:2625, 258:1398; *P. chalographus* 106:1896, 710: 3522) (Table 1). It should be noted that this trend will continue in 2017, unless we take all available measures of suppression aimed at reducing their abundance to normal, natural numbers.

Figure 4. *The ratio of the average number of bark beetles caught in a trap to the volume of declined trees marked for felling*



Dajićke planine management unit has a noticeable positive correlation between the spruce decline and the active abundance of *I. typographus* and *P. chalcographus*, *i.e.* in the three-year research period this management unit recorded an increase in the volume of declined trees marked for felling and in the abundance of the two species of bark beetles, which was not the case with the other three (Kolješnica, Golija and Brusničke šume), where the volume of declined trees marked for felling decreased, while the number of bark beetles increased dramatically (Figure 4). However, it is known that bark beetles attack living but severely physiologically-weakened trees, so it can be assumed that a positive correlation between these two parameters will be established in these management units, too.

5. CONCLUSIONS

The three-year study of the correlation between the changes in microclimate, the epidemic spruce decline and the increasing abundance of the two most important species of bark beetles, *I. typographus* and *P. chalographus* clearly points to a causal connection between them. Changes in microclimate, increasing average monthly air temperatures and a significant decrease in precipitation in the growing period contributed to the physiological weakening of spruce trees and initiated the process of their decline, thus increasing their susceptibility to the attack of the two species of bark beetles. The end result of this joint operation is the continuation of the epidemic decline of spruce stands in `Golija` Nature Park.

6. ACKNOWLEDGEMENTS

These investigations were carried out as part of activities of public interest in the field of diagnostics of harmful organism and protection of the health of forest plants on the territory of the Republic of Serbia, excluding the territory of the Autonomous Province of Vojvodina in the period 2015-2019, financed by the Republic of Serbia through the Forest Directorate of the Ministry of Agriculture and Environmental Protection. The authors would particularly like to thank the colleagues from `Srbijašume` General Directorate and Golija Ivanjica Forest Estate on their the participation in the performance of the aforementioned tasks.

REFERENCES

Auclair, A.N.D. (1993): Extreme climatic fluctuations as a cause of forest dieback in the Pacific Rim. *Water, Air and Soil Pollution*, 66(3–4): 207–229.

Aukema, B.H., Carroll, A.L., Zheng, Y., Zhu, J., Raffa, K.F., Moore, D., Stahl, K., Taylor, S.W. (2008): Movement and outbreak populations of mountain pine beetle: influences of spatiotemporal patterns and climate. *Ecography*, 31: 348–358.

Banković, S., Medarević, M., Pantić, D., Petrović, N. (2009): National Forest Inventory of the Republic of Serbia - Forests of the Republic of Serbia. Ministry of Agriculture, Forestry and Water Management - Forest Directorate, Belgrade, Serbia, 1-244.

Bentz, B.J., Régnière, J., Fettig, C.J., Hansen, M., Hayes, J.L., Hicke, J.A., Rick, G., Kelsey, RG., Negrón, J., Seybold, S.J. (2010): Climate Change and Bark Beetles of the Western United States and Canada: Direct and Indirect Effects. *BioScience*, 60: 602-613.

Christiansen, E., A. Bakke, Eds. (1988): The spruce bark beetle of Eurasia. Dynamics of forest insect populations. Plenum Publishing Corporation.

Christensen, J.H., Hewitson, B., Busuioc, A., Chen, A., Gao, X., Held, I., Jones, R., Kolli, R.K., Kwon, W.-T., Laprise, R., Magaña Rueda, V., Mearns, L., Menéndez, C.G., Räisänen, J., Rinke, A., Sarr, A., Whetton, P. (2007): Regional climate projections. In Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK & New York, USA, Cambridge University Press.

Ciesla, W.M., Donaubauer, M.E. (1994): *Decline and dieback of trees and forests: a global overview*. FAO Forestry Paper No. 120. Rome, FAO.

Dutilleul, P., Stockwell, J.D., Frigon, D., Legendre, P. (2000): The Mantel test versus Pearson's correlation analysis: Assessment of the differences for biological and environmental studies. *J. Agri. Biol. Env. Stat.*, 5: 131-150.

Dutilleul, P., Stockwell, J.D., Frigon, D., Legendre, P. (2000): The Mantel test versus Pearson's correlation analysis: assessment of the differences for biological and environmental studies. *J Agric Biol Environ Stat*., 5:131–150.

Jönsson, M.A., Harding, S., Bärring, L., Ravn, H.P. (2007): Impact of climate change on the population dynamics of Ips typographus in southern Sweden. *Agricultural and Forest Meteorology*, 146: 70-81.

Lindner, M., Garcia-Gonzalo, J., Kolström, M., Geen, T., Reguera, R., Maroschek, M., Seidl, R., Lexer, M.J., Netherer, S., Schopf, A., Kremer, A., Delzon, S., Barbati, A., Marchetti, M., Corona, P. (2008): Impacts of climate change on European forests and options for adaptation. Report to the European Commission Directorate-General for Agriculture and Rural Development. AGRI-2007-G4-06. Brussels, Belgium.

Økland, B., Christiansen, E. (2001): 22 years of spruce bark beetle records from southeastern Norway. Poster presentation at IUFRO-meeting Dynamics of Forest Insect Populations, Aberdeen 9-14 September.

Schumacher, S., Bugmann, H. (2006): The relative importance of climatic effects, wildfires and management for future forest landscape dynamics in the Swiss Alps. *Global Change Biology*, 12: 1435-1450.

Swetnam, T.W., Betancourt, J.L. (1998): Mesoscale disturbance and ecological response to decadal climatic variability in the American Southwest. *Journal of Climate*, 11: 3128–3147.

Tabaković-Tošić, M. (2006): Managament possibilities of Gypsy moth multiplication in forest ecosystems of protected areas. Proceedings of International Scientific Conference - Management of forest ecosystems in national parks and other protected areas, p. 373-379, Jahorina-Tjentište, Bosnia and Herzegovina.

Tabaković-Tošić, M. (2014). The condition of tree crowns at the sample plots of level I-reliable or unreliable indicators of the vitality of main conifer species in Serbian forests. 3rd ICP Forests Scientific Conference "Impact of nitrogen deposition and ozone on the climate change mitigation potential and sustainability of European forests". Athens, Greece, May 26-28, 27.

Tabaković-Tošić, M., Milosavljević M. (2015): Impact of extreme weather conditions on the population dynamics of bark beetles in the forests of eastern Serbia. *Sustainable Forestry*, 71-72: 27-38.

Tabaković-Tošić, M., Milosavljević M. (2016): Spruce decline and an outbreak of spruce bark beetles in the natural forest stands of Kopaonik National Park. Proceedings of the XV Symposium of Plant Protection, Zlatibor, 28.11-02.12. 2016., pp.

Wermelinger, B. (2004): Ecology and management of the spruce bark beetle Ips typographus--a review of recent research. *Forest Ecology and Management*, 202(1-3): 67-82.

Waring, R.H., Pitman, G.B. (1983) Physiological stress in lodgepole pine as a precursor for mountain pine beetle attack. *Zeitschrift fur angewandte Entomologie* 96: 265-270.

Spatial plan of Golija Special Purpose Nature Park - Strategy for the Protection and Development (2004). (Republic Agency for Spatial Planning of the Ministry of Tourism, Trade and Services, Eds.)

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Within this chapter there can be subtitles of first and second line. In the description of material it should be given enough information to allow another researchers to repeat the experiment at a different location. It is necessary to provide information on the material, subject of the study that precisely defines its origin, physical characteristics etc. If a device or instrument is used to obtain experimental results should be specified: name of the device or instrument, model, manufacturer's name and country of origin. If a scientifically recognized method is used it has to be cited in the References, without the explanation of the steps of the used method. If changes were made in a scientifically recognized method should be provided the original literature references that will support –justify those changes.

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Within this chapter there can be subtitles of first and second line. The paper results should be presented in the form of text, tables, pictures (diagrams) and, rarely, photographs. From the results should be clear whether the hypotheses have been confirmed or disproved and whether the aim and tasks have been achieved. It should not be avoided the presentation of the negative results or disproving the hypotheses.

DISCUSSION (**bold**), centered on the page, Font Size 11. Tekst normal, Font Size 11, Justify, with single line spacing below the title.

Discussion should not be the simple repeating of obtained results. The results should be discussed by comparing them with the research results of other authors with compulsory citing of literature sources. It is very important to give discussion of the results and the opinion of the authors. Interpretation of perceived ambiguities and illogicalities should be correctly stated.

CONCLUSION (**bold**), centered on the page, Font Size 11. Tekst normal, Font Size 11, Justify, with single line spacing below the title.

Conclusions of the paper should be carefully carried out and shown clearly to the reader. Conclusions can be significantly connected with the result discussion, but in them should be given freer and wider interpretation of the paper subject and results. The special quality is the defining of suggestions for future work and identifying the issues need to be resolved.

11

LITERATURE 11points, bold

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Janković, Lj. (1958): Contribution to the knowledge of gypsy moth host plants in nature during the last outbreak, 1953-1957, Plant protection, 49-50: 36-39 (In original: *Janković, Lj. (1958): Prilog poznavanju biljaka hraniteljki gubara u prirodi u toku poslednje gradacije*, *1953-1957. god. Zaštita bilja*, *49-50: 36-39*)

10

Roberts, G., Parrotta, J. and Wreford, A. (2009): *Current Adaptation Measures and Policies.* In: Risto Seppälä, Alexander Buck and Pia Katila. (eds.). Adaptation of Forests and People to Climate Change - A Global Assessment Report. IUFRO World Series Volume 22. Helsinki. 123-13311

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In this text is given a detailed structured instruction for writing papers. Papers that do not meet the propositions of this guide will not be forwarded for review and will be returned to the author.

Categorization of papers (suggested by the author – determined by Editorial board taking into account the opinion of the reviewer):

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1. Review paper (paper that contains original, detailed and critical review of the research issue or field in which the author made a contribution, visible on the basis of auto-citations);
2. Original scientific paper (paper which presents previously published results of author's researches by scientific method);
3. Preliminary communication (Original scientific paper of full format, but small-scale or preliminary character).
4. Other known forms: scientific review, case study and others, if Editorial board finds that such paper contributes to the improvement of scientific thought.

Professional articles

1. Professional paper (annex in which are offered the experiences for improving professional practice, but which are not necessarily based on scientific method).

This guide, as well as an example of correctly printed paper in the journal Sustainable Forestry, can be found on the web-site of Institute of Forestry **(*http://www.forest.org.rs*).**

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