

ISSN 1821-1046

UDK 630

INSTITUTE OF FORESTRY
BELGRADE



INSTITUT ZA ŠUMARSTVO
BEOGRAD

SUSTAINABLE FORESTRY ODRŽIVO ŠUMARSTVO

COLLECTION
TOM 67-68

ZBORNIK RADOVA
TOM 67-68



BELGRADE BEOGRAD
2013.

ISSN 1821-1046



9 771821 104000

ISSN 1821-1046
UDK 630

**INSTITUTE OF FORESTRY
BELGRADE**



**INSTITUT ZA ŠUMARSTVO
BEOGRAD**

SUSTAINABLE FORESTRY ODRŽIVO ŠUMARSTVO

COLLECTION
TOM 67-68

ZBORNİK RADOVA
TOM 67-68

**BELGRADE BEOGRAD
2013.**

INSTITUTE OF FORESTRY BELGRADE **INSTITUT ZA ŠUMARSTVO BEOGRAD**
PROCEEDINGS **ZBORNİK RADOVA**

Publisher

Institute of Forestry
Belgrade, Serbia

Izdavač

Institut za šumarstvo
Beograd, Srbija

For Publisher

Ljubinko Rakonjac, Ph.D.

Za izdavača

Dr Ljubinko Rakonjac

Editorial Board

Snežana Rajković, Ph.D.
Institute of Forestry, Belgrade
Dragana Dražić, Ph.D.
Institute of Forestry, Belgrade
Ljubinko Rakonjac, Ph.D.
Institute of Forestry, Belgrade
Mara Tabaković-Tošić, Ph.D.
Institute of Forestry, Belgrade
Miloš Koprivica, Ph.D.
Institute of Forestry, Belgrade
Radovan Nevenić, Ph.D.
Institute of Forestry, Belgrade
Mihailo Ratknić, Ph.D.
Institute of Forestry, Belgrade
Zoran Miletić, Ph.D.
Institute of Forestry, Belgrade
Milorad Veselinović, Ph.D.
Institute of Forestry, Belgrade
Biljana Nikolić, Ph.D.
Institute of Forestry, Belgrade
Vera Lavadinović, Ph.D.
Institute of Forestry, Belgrade
Vesna Golubović-Čurguz, Ph.D.
Institute of Forestry, Belgrade
Assoc. Prof. Iantcho Naidenov, Ph.D
Bulgaria
Prof. Nikola Hristovski, Ph.D.
Macedonia
Dr Kalliopi Radoglou, Ph.D.
Greece

Redakcioni odbor

Dr Snežana Rajković
Institut za šumarstvo, Beograd
Dr Dragana Dražić
Institut za šumarstvo, Beograd
Dr Ljubinko Rakonjac
Institut za šumarstvo, Beograd
Dr Mara Tabaković-Tošić
Institut za šumarstvo, Beograd
Dr Miloš Koprivica
Institut za šumarstvo, Beograd
Dr Radovan Nevenić
Institut za šumarstvo, Beograd
Dr Mihailo Ratknić
Institut za šumarstvo, Beograd
Dr Zoran Miletić
Institut za šumarstvo, Beograd
Dr Milorad Veselinović
Institut za šumarstvo, Beograd
Dr Biljana Nikolić
Institut za šumarstvo, Beograd
Dr Vera Lavadinović
Institut za šumarstvo, Beograd
Dr Vesna Golubović-Čurguz
Institut za šumarstvo, Beograd
Assoc. Prof. Dr Iantcho Naidenov
Bugarska
Prof. Dr Nikola Hristovski
Makedonija
Dr Kalliopi Radoglou
Grčka

Chief Editor

Snežana Rajković, Ph.D.

Glavni i odgovorni urednik

Dr Snežana Rajković

Technical Editor and Layout

Tatjana Ćirković-Mitrović, M.Sc.

Tehnički urednik i prelom teksta

Mr Tatjana Ćirković-Mitrović

Secretary

Tatjana Ćirković-Mitrović, M.Sc.

Sekretar Zbornika

Mr Tatjana Ćirković-Mitrović

Printed in

100 copies

Tiraž

100 primeraka

Printed by

Black and White
Beograd

Štampa

Black and White
Beograd

All rights reserved. No part of this publication might be reproduced by any means: electronic, mechanical, copying or otherwise, without prior written permission of the publisher.

Belgrade, 2013

Preuzimanje članaka ili pojedinih delova ove publikacije u bilo kom obliku nije dozvoljeno bez odobrenja

Beograd, 2013

Cover Page: Author of the Photos Tatjana Ćirković-Mitrović, M.Sc.
Naslovna strana: Autor fotografije mr Tatjana Ćirković-Mitrović

CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

630

SUSTAINABLE Forestry : collection =
Održivo šumarstvo = zbornik radova /
chief

editor = glavni i odgovorni urednik
Snežana

Rajković. - 2008, T. 57/58- . - Belgrade
(Kneza Višeslava 3) : Institute of forestry,
2008- (Beograd : Black and White). - 24
cm

Godišnje. - Je nastavak: Zbornik radova -
Institut za šumarstvo = ISSN 0354-1894
ISSN 1821-1046 = Sustainable Forestry
COBISS.SR-ID 157148172

CONTENT SADRŽAJ

TOM 67-68

| | |
|--|----|
| Ljiljana BRAŠANAC-BOSANAC, Tatjana ĆIRKOVIĆ-MITROVIĆ AIR TEMPERATURE CHANGES IN SERBIA IN PERIOD 1949-2010 IN VIEW OF GLOBAL CLIMATE CHANGES | 7 |
| Milorad VESELINOVIĆ, Suzana MITROVIĆ, Dragana DRAŽIĆ, Dragica STANKOVIĆ, Snežana RAJKOVIĆ, Biljana NIKOLIĆ, Nevena ČULE CERTAIN HISTOLOGICAL CHARACTERISTICS OF DOUGLAS- FIR NEEDLES IN DIFFERENT HABITATS | 15 |
| Vera LAVADINOVIĆ, Vladan POPOVIĆ, Emil POPOV, Vukan LAVADINOVIĆ TESTING OF CANADIAN DOUGLAS-FIR HEIGHT IN JUVENILE PHASE | 23 |
| Renata GAGIĆ SERDAR, Radovan NEVENIĆ, Goran ČEŠLJAR, Svetlana BILIBAJKIĆ, Tomislav STEFANOVIĆ, Zoran PODUŠKA, Ilija ĐORĐEVIĆ THE MOST COMMON FOREST PHYTOCOENOSIS ENDANGERED BY FALSE INDIGO SPREADING IN SERBIA | 33 |
| Miloš KOPRIVICA, Bratislav MATOVIĆ, Vlado ČOKEŠA, Snežana STAJIĆ STAND VOLUME TABLES FOR BEECH IN SERBIA | 45 |
| Snežana STAJIĆ, Vlado ČOKEŠA, Zoran MILETIĆ STAND CONDITION AND SILVICULTURAL NEEDS IN ARTIFICIALLY ESTABLISHED EASTERN WHITE PINE STAND (<i>Pinus strobus</i> L.) IN THE BOGOVAĐA REGION | 59 |
| Goran ČEŠLJAR, Radovan NEVENIĆ, Svetlana BILIBAJKIĆ, Tomislav STEFANOVIĆ, Renata GAGIĆ SERDAR, Ilija ĐORĐEVIĆ, Zoran PODUŠKA VIABILITY OF TREES ON BIO-INDICATOR PLOTS LEVEL -A 1 IN REPUBLIC OF SERBIA IN 2013 | 69 |
| Radovan NEVENIĆ, Svetlana BILIBAJKIĆ, Miroslava MARKOVIĆ, Goran ČEŠLJAR, Tomislav STEFANOVIĆ, Ilija ĐORĐEVIĆ, Zoran PODUŠKA TREE CROWN CONDITION AT LEVEL II SAMPLE PLOTS KOPAONIK, CRNI VRH AND MOKRA GORA IN 2013 | 79 |
| Tomislav STEFANOVIĆ, Svetlana BILIBAJKIĆ, Radovan NEVENIĆ, Ilija ĐORĐEVIĆ, Zoran PODUŠKA, Goran ČEŠLJAR, Renata GAGIĆ SERDAR RESULTS OF RESEARCH OF DEFOLIATION ON BIO-INDICATOR PLOTS IN REPUBLIC OF SERBIA IN 2013 | 95 |

| | |
|--|-----|
| Nevena ČULE, Dragana DRAŽIĆ, Milorad VESELINOVIĆ, Ljiljana BRAŠANAC-BOSANAC, Suzana MITROVIĆ, Marija NEŠIĆ BIOLOGICAL RECLAMATION OF LANDSCAPE DEGRADED BY SURFACE MINE EXPLOITATION - CASE STUDY OF COAL SURFACE MINE „TAMNAVA – ZAPADNO POLJE“ | 103 |
| Mihailo RATKNIC, Tatjana RATKNIC, Zoran MILETIC, Vlado COKESA, Snezana STAJIC, Sonja BRAUNOVIC, Tatjana CIRKOVIC-MITROVIC CHANGES OF FOREST HABITATS DESTROYED BY FIRE AND THE RATE OF NATURAL REVITALISATION OF DAMAGED ECOSYSTEMS | 117 |
| Svetlana BILIBAJKIĆ, Tomislav STEFANOVIĆ, Radovan NEVENIĆ, Goran ČEŠLJAR, Renata GAGIĆ SERDAR, Zoran PODUŠKA, Ilija ĐORĐEVIĆ ANALYSIS OF SILTATION SLOPE DEPENDENCE ON GRAIN SIZE COMPOSITION OF SEDIMENT IN TORRENT STREAMS OF TRGOVISKI TIMOK DRAINAGE BASIN | 133 |
| Mara TABAKOVIĆ-TOŠIĆ GYPSY MOTH (<i>Lymantria dispar</i> L.) OUTBREAK IN THE CENTRAL PART OF REPUBLIC OF SERBIA IN THE PERIOD 2010-2013 | 141 |
| Miroslava MARKOVIC, Snezana RAJKOVIC, Radovan NEVENIC, Aleksandar LUCIC IMPACT OF THE EDIBLE MUSHROOM ON DESTRUCTION OF OAK WOOD | 151 |
| Ilija ĐORĐEVIĆ, Zoran PODUŠKA, Radovan NEVENIĆ, Renata G. SERDAR, Svetlana BILIBAJKIĆ, Goran ČEŠLJAR, Tomislav STEFANOVIĆ ASSESSMENT OF THE SYSTEM OF FUNDING OF PROTECTED AREAS IN THE REPUBLIC OF SERBIA | 161 |
| Zoran PODUŠKA, Ilija ĐORĐEVIĆ, Radovan NEVENIĆ, Svetlana BILIBAJKIĆ, Renata GAGIĆ SERDAR, Goran ČEŠLJAR, Tomislav STEFANOVIĆ POSSIBILITIES FOR IMPROVEMENT OF THE MANAGEMENT OF PROTECTED NATURAL AREAS | 175 |
| Katarina MLADENOVIĆ, Bojan STOJNIĆ, Slobodan MILANOVIĆ, Vlado ČOKEŠA, Ivan MILENKOVIĆ SPECIES COMPOSITION OF SPIDER MITES AND PREDATORY MITES (<i>Acari: Tetranychidae, Phytoseiidae</i>) OCCURRING ON CRAB APPLE (<i>Malus silvestris</i> Mill) IN SERBIA | 187 |

UDK 630*174.75 Pseudotsuga menziesii (Mirb.) Franco:630*181.45=111
Original scientific paper

CERTAIN HISTOLOGICAL CHARACTERISTICS OF DOUGLAS-FIR NEEDLES IN DIFFERENT HABITATS

Milorad VESELINOVIĆ¹, Suzana MITROVIĆ¹, Dragana DRAŽIĆ¹,
Dragica STANKOVIĆ², Snežana RAJKOVIĆ¹,
Biljana NIKOLIĆ¹, Nevena ČULE¹

Abstract. *Opencast coal mines of the Kolubara Mining Basin (Rudarski basen Kolubara), with the accompanying power plants, are constantly exposed to air pollution. Attempts have been made to mitigate the adverse impact on environment by means of biological recultivation by afforestation of opencast mines' tailing disposal sites. Pseudotsuga menziesii Mirbel. Franco belongs to a group of species frequently used for afforestation of such areas. Our studies, focused on substantiating the species' resistance to air pollution, involved an analysis of this factor's effect on changes in needles. The paper outlines the results of histological studies, which consisted of an analysis of diameter of needle cross-section, along with an analysis of share of diameter of certain tissues in cross-section.*

Key words: needle tissues, air pollution, open pit coal mine

NEKE HISTOLOŠKE KARAKTERISTIKE ČETINA DUGLAZIJE NA RAZLIČITIM STANIŠTIMA

Izvod. *Površinski kopovi uglja Rudarskog basena „Kolubara“ sa pratećim energetskim postrojenjima su po stalnim uticajem aerozagađenja. Biološkom rekultivacijom odlagališta jalovine površinskih kopova čovek pokušava da ublaži negativne uticaje na životnu okolinu. Pseudotsuga menziesii Mirbel. Franco je jedna od često korišćenih vrsta u pošumljavanju ovih prostora. Naša straživanja su usmerena na*

¹ Institute of Forestry, Belgrade, Serbia

² Faculty of Forestry, Belgrade, Serbia

Translation: Dejan Arsenovski

potvrđivanje otpornosti ove vrste na aerozagađenje i u okviru njih istraživano je delovanje ovog faktora na promene na četinama. U radu su prikazani rezultati histoloških istraživanja koja su se sastojala u analizi dijametara poprečnog preseka četina kao i udela dijametra pojedinih tkiva u poprečnom preseku.

Ključne reči: tkiva četina, aerozagađenje, površinski kop uglja

INTRODUCTION

Works related to opencast coal mining, coal combustion for power generation, transport and treatment of lignite for the purpose of converting it into a more valuable combustible material represent the main activities conducted in the area of Kolubara Mining Basin. The result of these activities is a day-to-day pollution of the environment.

In order to mitigate the adverse impact of pollution, along with other measures, reclamation has been conducted of the terrain created by the disposal of coal overburden layers. The problem of degradation of over 1,300 ha of tailing disposal sites has been addressed by means of biological reclamation – afforestation. For that purpose, a species frequently used in this process - *Pseudotsuga menziesii* Mirbel - has been introduced in Serbia for the first time (Šmit & Veselinović 1986). In addition to a land degradation caused by the opencast lignite mining, air pollution is particularly apparent in the Kolubara Basin mining-energy complex. It exerts an adverse impact on the living world in the immediate proximity of the mining-industrial complex.

A leaf zone represents a primary zone of impact of negative effects of gas pollutants on plant species. For that reason, the studies have been focused on investigation of changes in assimilation organs caused by air pollution, as an indicator of resistance to air pollutants. The investigations of species *Pseudotsuga menziesii* Mirbel. Franco are also important due to the fact that this plant is a fast-growing species widely used in afforestation, particularly in landscaping of peri-urban and industrial zones, on account of its decorative and other properties. As early as in the 1970s, Dassler et al (1972) and Mayer (1978) emphasised the importance of studies that would enable a selection of species resistant to air pollution and create an opportunity for establishing stable forest plantations in the zones exposed to a severe anthropogenic impact.

Various studies of extreme factors (stressors) proved that, contingent upon their intensity and exposure time, they could cause more or less intensive negative effects on plants (Wolff 1973, Goring 1982). Numerous authors have studied changes in assimilation organs caused by air pollutants (Hartig 1896, Sorauer 1908, Solberg et al 1955, Solberg & Adams 1956, Miller & Evans 1974, Smit & Davies 1978, Soikkeli 1981, Schoettle & Roshelle 2000, Kivimaenpaa et al. 2005, Haberer et al. 2006, Fares et al. 2010). The common conclusion was that air pollutants, by means of penetration into the inner part of leaf, effect changes in leaf structure. A leaf is a fundamental laboratory for the most important life processes of plants (assimilation, dissimilation, transpiration, etc.), therefore the morpho-anatomical and histological structure of assimilation organs is of importance for the

functioning of these processes. A disruption of their entire structure or individual segments impairs the basic life functions of a plant organism.

MATERIAL AND METHOD

The basic studies have been conducted among the *Pseudotsuga menziesii* Mirbel. Franco. cultures planted during the course of recultivation by afforestation in the Kolubara coal and energy basin. In this area, three sample plots under the influence of air pollution have been selected (Zs) in the forest cultures of the species *Pseudotsuga menziesii* Mirbel. Franco. aged over 30 years, whereas two sample plots, outside the air pollution zone, have been selected as control units—one containing cultures aged over 50 years, located in the Management Unit 'Jelova Gora' Forestry Office Užice – the control unit (K1), and the other containing cultures aged over 30 years, located in the Management Unit 'Juhor I' Forestry Office Jagodina – the control unit (K2).

For the purpose of our studies, one-year old and two-year old needles were taken in autumn (October-November) and spring (April) from each sample plot. The needle samples were taken from the central part of the crown, from the side exposed to the source of pollution. In the control areas, samples were also taken from the central part of crown. Only green needles from main branch axles were selected for the analysis. The samples from the sample plots in polluted environment were collected into a common group and analysed collectively.

For each age group, ten needles from ten trees were sampled. The needles from main branch axles, were placed into a cooled ($t = +4^{\circ}\text{C}$) fixative (2% glutaraldehyde in 0.1M phosphate buffer pH/7) immediately after the field collection and transported to the laboratory. Rinsing (by a 0.1M phosphate buffer pH7), postfixation (by a 1% osmium tetroxide solution in a 0.1 phosphate buffer (pH 7)) (Soikkeli, 1978) and dehydration (by exposure to a series of alcohols and submersion into propylene oxide) were performed in the laboratory. Following the fixation and dehydration, the tissue was permeated by araldite resins. Thus prepared samples were placed into moulds, which were previously covered by pure resin and dried in thermostat.

The material for histological analysis was cut by an ultramicrotome, equipped with a glass knife. Cross-sections of $1\mu\text{m}$ thickness, placed onto microscope slides and dyed by toluidine blue, were used for a light (optical) microscope analysis.

Histological analyses consisted of measurement of needle diameter, thickness of epidermis with hypodermis and mesophyll, followed by a measurement of the diameter of central cylinder and vascular bundles. The measurements have also been performed on 100 semi-thin cross sections for each needle age group, on samples from the polluted area and samples from the control units. Following the performed measurement, the results were statistically analysed.

RESULTS AND DISCUSSION

Histological studies consisted of measurement of a diameter of needle cross-sections, along with measurement of a share of certain tissues' diameter in a cross-section. The data on a needle cross-section diameter (Table 1) indicate that the diameter of one-year and two-year old needles of autumn samples Zs is larger in comparison to the control unit K2 and that the effect of pollution is statistically significant. The cross-section diameter of one-year and two-year old needles in the control unit K1 in older cultures in a less polluted environment is larger than the needle diameter in the control unit V and the polluted zone Zs, while the difference is statistically significant. That indicates that the age of culture also has an impact on increase in needle diameter (Apple et al. 2000). The spring samples of one-year and two-year old needles from the polluted zone Zs, which endured winter, have a significantly smaller diameter in comparison to samples in the control units K1 and K2.

The data indicate that in the period of metabolic activity pollution effected a significant increase in needle diameter, while in the period of less intense metabolic activity caused by pollution, a statistically significant decrease in needle diameter in the polluted environment occurred.

Table 11. *A diameter of cross-section of needles from the polluted environment Zs and the control units K1 and K2 in mm*

| Experimental field | Needle age | Mean value ± standard error | |
|--------------------|------------|------------------------------|------------------------------|
| | | Autumn | Spring |
| Zs | 1 | 0.4553 ± 0.0093 ^b | 0.3192 ± 0.0067 ^a |
| K 1 | 1 | 0.5840 ± 0.0080 ^c | 0.3744 ± 0.0068 ^b |
| K 2 | 1 | 0.3759 ± 0.0041 ^a | 0.4939 ± 0.1214 ^c |
| Zs | 2 | 0.4681 ± 0.0155 ^b | 0.3365 ± 0.0086 ^a |
| K 1 | 2 | 0.5840 ± 0.0086 ^c | 0.4294 ± 0.0061 ^b |
| K 2 | 2 | 0.4173 ± 0.0027 ^a | 0.5270 ± 0.0100 ^c |

A multiple interval test – the values marked by the same letter in the column, does not indicate a difference on the level of significance $p < 0.05$.

Mean values and standard error of the diameter of abaxial and adaxial epidermis are presented in Table 2. In one-year and two-year old needles of autumn samples, following the period of more intense metabolic activity under the influence of pollution, the diameter of abaxial and adaxial epidermis was increased in the polluted environment Zs and in the less polluted environment K1, in comparison to the control unit K2. The effect of pollution is statistically significant. The needle diameter in older cultures in the control unit K1 is approximately equal to the diameter of needles in the polluted environment (Apple et al. 2002), which indicates that needles in the polluted area exhibit signs of ageing.

Table 2. *The diameter of abaxial (A) and adaxial (B) epidermis of needles from the polluted environment Zs and the control units K1 and K2 in mm*

| Experimental field | Needle age | Mean value ± standard error | |
|--------------------|------------|------------------------------|------------------------------|
| | | Autumn | Spring |
| (A) Zs | 1 | 0.0217 ± 0.0008 ^b | 0.0144 ± 0.0003 ^a |
| (A) K 1 | 1 | 0.0198 ± 0.0007 ^b | 0.0200 ± 0.0007 ^b |
| (A) K 2 | 1 | 0.0152 ± 0.0002 ^a | 0.0157 ± 0.0042 ^a |

| Experimental field | Needle age | Mean value \pm standard error | |
|--------------------|------------|----------------------------------|-----------------------------------|
| | | Autumn | Spring |
| (A) Zs | 2 | 0.0211 \pm 0.0005 ^c | 0.0161 \pm 0.0004 ^a |
| (A) K 1 | 2 | 0.0265 \pm 0.0009 ^b | 0.0201 \pm 0.0001 ^b |
| (A) K 2 | 2 | 0.0137 \pm 0.0000 ^a | 0.0195 \pm 0.0004 ^b |
| (B) Zs | 1 | 0.0228 \pm 0.0008 ^b | 0.0163 \pm 0.0005 ^a |
| (B) K 1 | 1 | 0.0235 \pm 0.0004 ^b | 0.0196 \pm 0.0014 ^b |
| (B) K 2 | 1 | 0.0166 \pm 0.0003 ^a | 0.0188 \pm 0.0044 ^{ab} |
| (B) Zs | 2 | 0.0232 \pm 0.0008 ^b | 0.0173 \pm 0.0007 ^a |
| (B) K 1 | 2 | 0.0237 \pm 0.0003 ^b | 0.0219 \pm 0.0002 ^b |
| (B) K 2 | 2 | 0.0145 \pm 0.0000 ^a | 0.0245 \pm 0.0002 ^b |

A multiple interval test – the values marked by the same letter in the column, does not indicate a difference on the level of significance $p < 0.05$.

In spring samples of one-year and two-year old needles, following the period of a less intense metabolic activity, the diameter of abaxial and adaxial epidermis is smaller in the polluted environment in comparison to both control units, while the difference is statistically significant. The effect of pollution had an impact on a statistically significant decrease in diameter of abaxial and adaxial epidermis of needles from the polluted environment.

Table 32. *The diameter of abaxial (A) and adaxial (B) chlorenchyma of needles from the polluted environment Zs and the control units K1 and K2 in mm*

| Experimental field | Needle age | Mean value \pm standard error | |
|--------------------|------------|----------------------------------|----------------------------------|
| | | Autumn | Spring |
| A Zs | 1 | 0.1483 \pm 0.0068 ^a | 0.1103 \pm 0.0040 ^a |
| A K 1 | 1 | 0.2086 \pm 0.0031 ^c | 0.1072 \pm 0.0041 ^a |
| A K 2 | 1 | 0.1255 \pm 0.0008 ^a | 0.1629 \pm 0.0426 ^b |
| A Zs | 2 | 0.1468 \pm 0.0081 ^b | 0.1105 \pm 0.0054 ^a |
| A K 1 | 2 | 0.1913 \pm 0.0038 ^b | 0.1326 \pm 0.0029 ^b |
| A K 2 | 2 | 0.1492 \pm 0.0002 ^a | 0.1627 \pm 0.0037 ^c |
| B Zs | 1 | 0.0908 \pm 0.0033 ^b | 0.0569 \pm 0.0028 ^a |
| B K 1 | 1 | 0.1081 \pm 0.0020 ^c | 0.0655 \pm 0.0015 ^b |
| B K 2 | 1 | 0.0706 \pm 0.0013 ^a | 0.0998 \pm 0.0249 ^c |
| B Zs | 2 | 0.1002 \pm 0.0060 ^b | 0.0686 \pm 0.0038 ^b |
| B K 1 | 2 | 0.1154 \pm 0.0032 ^c | 0.0875 \pm 0.0008 ^b |
| B K 2 | 2 | 0.0841 \pm 0.0012 ^a | 0.0947 \pm 0.0028 ^b |

A multiple interval test – the values marked by the same letter in the column, does not indicate a difference on the level of significance $p < 0.05$.

The diameter of abaxial chlorenchyma (Table 3) in one-year old needle samples taken in autumn, following the period of a more intense metabolic activity, is equal to the diameter of needles in the control unit K2, while it is smaller in comparison to the control unit K1, where the difference is statistically significant. In two-year old needles, the diameter of needles in the polluted environment and the control unit K1 is approximately equal, while the difference in diameter in comparison to the control unit K2 is statistically significant. The diameter of abaxial chlorenchyma in one-year and two-year old needles is the largest in the control unit K1, followed by the needles from polluted environment Zs, while it is the smallest in the control unit K2. In both cases, the difference is statistically significant. That indicates that both air pollution and the age of cultures had an impact on changes in size of abaxial and adaxial chlorenchyma.

The diameter of abaxial chlorenchyma in one-year and two-year needles sampled in spring is the smallest in needles from the polluted environment, while the difference is significant in comparison to both control units. That indicates that

an independent effect of air pollution is significant. The diameter of adaxial chlorenchyma is the smallest in one-year old needles only, while in two-year old needles the diameter is of an approximately equal size in all three sample sources. That indicates that the impact of air pollution on adaxial chlorenchyma is negligible.

The diameter of central cylinder (Table 4) in samples of one-year and two-year old needles taken from the polluted environment Zs in autumn, following the period of more intense metabolic activity, is larger in comparison to the control unit K2, and smaller in comparison to the control unit K1. That indicates that both pollution and the age of culture had an impact on the size of diameter, and that both factors are statistically significant. In spring needle samples from the polluted zone Zs, taken after a less intensive metabolic activity, the central cylinder diameter is smaller in comparison to one-year and two-year old needles in both control units. The changes occurred solely as a result of pollution and are statistically significant.

Table 43. *The diameter of central cylinder of needles from the polluted environment Zs and the control units K1 and K2 in mm*

| Experimental field | Needle age | Mean value ± standard error | |
|--------------------|------------|------------------------------|------------------------------|
| | | Autumn | Spring |
| Zs | 1 | 0.1657 ± 0.0039 ^b | 0.1250 ± 0.0030 ^a |
| K 1 | 1 | 0.2196 ± 0.0024 ^c | 0.1494 ± 0.0019 ^b |
| K 2 | 1 | 0.1471 ± 0.0007 ^a | 0.1948 ± 0.0467 ^c |
| Zs | 2 | 0.1822 ± 0.0055 ^b | 0.1254 ± 0.0028 ^a |
| K 1 | 2 | 0.2251 ± 0.0039 ^c | 0.1327 ± 0.0021 ^a |
| K 2 | 2 | 0.1519 ± 0.0030 ^a | 0.2241 ± 0.0084 ^b |

A multiple interval test – the values marked by the same letter in the column, does not indicate a difference on the level of significance $p < 0.05$.

The diameter of vascular bundles (Table 5) in samples taken from the polluted environment Zs in autumn, following a more intensive metabolic activity, is larger in one-year old needles in comparison to the control unit K2, but smaller in comparison to the control unit K1. The differences in diameter size are statistically significant in both cases. In two-year old needles from the polluted environment Zs, the size of vascular bundles is approximately equal to those in the control unit K2, but in comparison to the control unit K1 the difference in size remained significant. In samples taken from the polluted environment in spring following a less intense metabolic activity, the size of vascular bundles is smaller in comparison to both control units. The changes in diameter of vascular bundles occurred solely as a result of air pollution, where the differences in size are statistically significant.

Table 5. *The diameter of vascular bundles of needles from the polluted environment Zs and the control units K1 and K2 in mm*

| Experimental field | Needle age | Mean value ± standard error | |
|--------------------|------------|------------------------------|------------------------------|
| | | Autumn | Spring |
| Zs | 1 | 0.0828 ± 0.0030 ^b | 0.0630 ± 0.0022 ^a |
| K 1 | 1 | 0.0906 ± 0.0017 ^c | 0.0825 ± 0.0027 ^b |
| K 2 | 1 | 0.0727 ± 0.0008 ^a | 0.1010 ± 0.0246 ^c |
| Zs | 2 | 0.0805 ± 0.0018 ^a | 0.0650 ± 0.0013 ^a |
| K 1 | 2 | 0.1024 ± 0.0042 ^c | 0.1084 ± 0.0026 ^b |
| K 2 | 2 | 0.0805 ± 0.0007 ^a | 0.1221 ± 0.0055 ^c |

A multiple interval test – the values marked by the same letter in the column, does not indicate a difference on the level of significance $p < 0.05$.

CONCLUSIONS

Based on the analysis of the study results, it can be concluded:

- that the air pollution most frequently influenced the increase of diameter of all tissues, following a more intense metabolic activity, in samples taken in polluted environment in autumn.
- in samples taken in polluted environment in spring, following a less intense metabolic activity, the diameter of nearly all tissues was reduced in comparison to the control unit Juhor and that reduction, caused by air pollution, was statistically significant.
- the age of culture in the control unit Jelova Gora influenced an increase in size of cross-sections, when compared to the control unit Juhor.
- the diameter of needles from the polluted environment is approximately equal to the diameter of needles in the control unit Jelova Gora, which indicates that needles from the polluted environment exhibit signs of rapid ageing.

Acknowledgements

The research was partly financed by the Ministry of Education and Science, Republic of Serbia, within the Project „The study of climate change on the environment: monitoring impacts, adaption and mitigation“ III 43007

REFERENCES

- Apple, M., Bind, B., Young, J., McCready, D. (2000): Element analysis of old-growth Douglas-fir trees. *Interfacial Chemistry and Engineering, Annual Report*.
- Apple, M., Tiekotter, K., Snow, M., Young, J., Soeldner, A., Phillips, D., Tingey, D., Bond B.J. (2002): Needle anatomy changes with increasing tree age in Douglas-fir. *Tree Physiology* 22, p 129-136.
- Dassler, Hg., Ranft, H., Rehn, H. (1972): Zur Widerstandstohigrect von Geholzen gagen Uber fluoroerbindingen und Schwriteldioxid. *Tlorg*, 161: p.p. 289-302.
- Fares S, Goldstein A, Loreto F. (2010): Determination of ozone fluxes and metrics for ozone risk assessment in plants. *J Exp Bot*; 61: 629-33.
- Goring, H. (1982): Reaktionen der Pflanzen auf extreme physikalische and chemische Umweltbedingungen. In: *Umwelt-Stress, Wiss. Beitr. Martin-Luther-Univ, Halle-Wittenberg*, 1982/35 (P17), 152-160.
- Haberer K, Jaeger L, Rennenberg H. (2006): Seasonal patterns of ascorbate in the needles of Scots Pine (*Pinus sylvestris* L.) trees: Correlation analyses with atmospheric O₃ and NO₂ gas mixing ratios and meteorological parameters. *Environ Pollut*; 139: 224-31
- Hartig, R. (1896): Uber die Entwicklung schwefliger Saure auf die Gesundheit der Fichte. *Forstl. Naturwiss. Z.*, 5, 65-69.

Kivimaenpaa M, Sellden G, Sutinen S. (2005): Ozoneinduced change in the chloroplast structure of conifer needles, and their use in ozone diagnostics. *Environ Pollut*; 137: 466-75

Mayer, F.H. (1978): *Baumen der Stadt*. Ulmer, Stuttgart.

Miller, P. r. and Evans, L. S. (1974): Histopatology of oxidant injury and winter flack injury on needles of western pines. *Phytopathology* 64: p.p. 801-806.

Schoettle, A.W. and Rochelle S.G. (2000): Morphological variation of *Pinus flexilis* (Pinaceae), a bird-dispersed pine, across a range of evaluations. *Am. J. Bot.* 87:1797-1806

Smith, H.J., Davies, D.D., (1978): Histological changes induced in Scotch pine needles by sulphur dioxide. *Phytopathology* 68: 1711-1716.

Soikkeli, S. (1978): Seasonal changes in mesophyll of needles of Norway spruce (*Picea abies* L. Carst.). *Canad. J. Bot.* 56:1932-1940.

Soikkeli, S. (1981): Comparasion of cytological injuries in conifer needles from several polluted industrial en.v.ironments in Findland. *Ann. Bot. Fennici* 18: 47-61.

Soikkeli, S. (1981): The effects of chronic urban pollution on the inner structure of Norway spruce needles. *Savonia*, Vol 4, p. 1-10.

Soikkeli, S. (1981): The types of ultrastructural injuries in conifer needles of northern industrial en.v.ironments. *Silva fennica* Vol. 15(4), p. 399-404.

Soikkeli, S. (1981): A review of the structural effects of air pollution on mesophyll tissue of plants at light and transmission electron microscope level. *Savonia* 4: p.p. 11-34.

Sorauer, P. (1908): Beitrag zur anatomischen Analyse rauchgeschadigter Pflanzenll handwirtsch, Jahrb., 37: p.p. 673-710.

Solberg, R.A., Adams, D.F. and Ferchan, H.A. (1955): Some effects of hydrogen fluoride on internal structure of *Pinus ponderosa* needles. *Proc. 3rd. Nat. Air. Poll. Symp.* p.p. 164-176.

Solberg, R.A., Adams, D.F. (1956): Histological response of some plant leaves to hydrogen fluoride and sulfur dioxide. *Amer.J. Bot.* 43: p.p. 755-760.

Wolff, G. (1973): Untersuchungen zur chronischen Rauchschadifunf eines Fichten-Kiefernreviers unter Verwendung von Spektrozonalluftbildern, *Beitr., Forstwirtschaft, Berlin*, 7, 4, 181-185.

Šmit, S., Veselinović, N. (1996): Rekultivacija pošumljavanjem odlagališta površinskih kopova rudnika lignita "Kolubara". *Monografija*. Beograd, 111 p.