UDK 630*164+272 (001)
https://doi.org/10.31298/sl.147.11-12.4

Izvorni znanstveni članci – Original scientific papers
Šumarski list, 11–12 (2023): 535–546

INFLUENCE OF CROWN EXPOSURE ON THE MORPHOLOGICAL NEEDLE TRAITS OF NINE CONIFERS

UTJECAJ EKSPOZICIJE KROŠNJE NA MORFOLOŠKA SVOJSTVA IGLICA DEVET ČETINJAČA

Biljana M. NIKOLIĆ[1]*, Katarina MLADENOVIĆ[1], Ljubinko RAKONJAC[1], Slobodan MILANOVIĆ[2,3], Marija M. MARKOVIĆ[1], Srdjan BOJOVIĆ[4], Nevena ČULE[1]

SUMMARY

The aim of this research was to investigate if the crown exposure of some conifers influenced to needle properties. The leaf morphological traits of sixty-six trees of nine conifers: Atlas cedar, Austrian pine, Blue spruce, Douglas fir, European spruce, European yew, Serbian spruce, Silver fir, and White fir, from six Belgrade parks, were analyzed. Five needles were measured from each of the four main crown exposures. Length, width, area and perimeter of needles were investigated. Species, parks in which they were found, as well as crown exposures, differed mostly in needle length and needle width. Correlations between measured needle traits were determined by linear regression analysis. Strong positive correlations were found between the length, perimeter, and area of needles. The differences among the species in terms of light requirement determine species for individual planting as light-loving or partial shade species (Atlas cedar, European spruce, Serbian spruce, Blue spruce, Austrian pine and Douglas fir), or for group planting as shade-loving species (Silver fir, White fir and European yew).

KEY WORDS: conifers, correlations, exposure, needle morphology, parks.

INTRODUCTION
UVOD

The influence of light exposure on the tree crown, among other ecological factors is very important for the successful development of a species. In parks, where crowns are almost open, it is relevant whether a species is light or shade-loving. Other habitat conditions such as habitat exposition, geological substratum, soil, assemblage, air pollution, etc. also influence tree growth (e.g. Hällgren and Fredriksson 1982; Donovan et al. 2005; Freer-Smith et al. 2005).

Silver fir (*Abies alba* Mill.) is a tall, European high-mountain species, growing on silicate and limestone. As it tolerates dry air, arid soil, and polluted air of urban city very poorly, it is rarely used in parks. White fir (*Abies concolor* / Gordon/ Lind. ex Hildebr.) is a tall, high-mountain species though sometimes it can be found below 1000 MSL. It in-

[1] Dr Biljana M. Nikolić, Principal Research Fellow, Institute of Forestry, Kneza Višeslava 3, Belgrade, Serbia, e-mail: smikitis2@gmail.com; corresponding author, Dr Katarina Mladenović, Senior Research Associate, Institute of Forestry, Kneza Višeslava 3, Belgrade, Serbia, e-mail: katarina.mladenovic@gmail.com; Dr Ljubinko Rakonjac, Principal Research Fellow, Institute of Forestry, Kneza Višeslava 3, Belgrade, Serbia, e-mail: ljrakonjac@yahoo.com; Dr Marija S. Marković, Senior Research Associate, Institute Institute of Forestry, Kneza Višeslava 3, Belgrade, Serbia, e-mail:markovicsmarija9@gmail.com; Dr Nevena Čule, Senior Research Associate, Institute of Forestry, Kneza Višeslava 3, Belgrade, Serbia, e-mail: nevena.cule@yahoo.com;
[2] Dr Slobodan Milanović, Full Professor, University of Belgrade, Faculty of Forestry, Kneza Višeslava 1, Belgrade, Serbia, e-mail: slobodan.milanovic@sfb.bg.ac.rs;
[3] Dr Slobodan Milanović, Assistant Professor, Mendel University in Brno, Faculty of Forestry and Wood Technology, Zemědělská 3, Brno, Czech Republic, e-mail: slobodan.milanovic@mendelu.cz;
[4] Dr Srdjan Bojović, Principal Research Fellow, University of Belgrade, Institute for Biological Research "Siniša Stanković", Boulevard Despota Stefana 142, 11060 Belgrade, Serbia, e-mail: bojosbios@gmail.com.

habits the Western USA. It is resistant to frost, wind and drought, as well as dust and harmful gases in the air and has modest soil requirements. Atlas cedar (*Cedrus atlantica* /Endl./ Mann. ex Carrière) is a tall, high-mountain fast-growing conifer native to Algeria and Morocco. It is resistant to climate extremes and can grow near the sea, as well as in mountainous regions at low elevations. It is an alkalophilic and heliophilic species. European spruce (*Picea abies* /L./ Karst.) is a tall, European mountain species that requires plenty of humidity both in the air and the soil. It grows on silicate substrate and acidic soil, though some plant communities also grow on serpentinite or limestone substrate. It has poor tolerance for polluted urban area and industrial air. Serbian spruce (*Picea omorika* /Panč./ Purkyně) is a tall, high-mountain species, tertiary relict and endemite of the Balkan Peninsula (Bosnia and Herzegovina and Serbia, Europe). Grows mostly on limestone, as well as silicate and swampy soil. Because of its resistance to city conditions, it is very common in parks. Blue spruce (*Picea pungens* Engelm.) is a tall, North American high-mountain species, growing on humid podzolic, acidic and carbonated soils. It tolerates severe frost, as well as dry air and summer droughts, and urban area conditions. Austrian pine (*Pinus nigra* J. F. Arnold) is a medium-height mountain species spreading from east Spain to Asia Minor and Crimea. It is a pioneer species, heliophilic, widely used for the afforestation of arid stony areas. It grows on steep limestone, dolomite and serpentinite cliffs. It is resistant to drought, and wind, it tolerates urban area conditions. Douglas fir (*Pseudotsuga menziesii* /Mirb./ Franco), is a tall species, native to the Pacific zone of North America and requires enough relative air humidity and acidic soil. It is widely cultivated in Serbian parks and forest cultures. European yew (*Taxus baccata* L.) is slow-growing but long-living species, often shrubby and naturally distributed from North and South Europe to the Mediterranean, Algeria, Morocco, Asia and the Caucasus. It can grow in shade, as well as in open positions, on shallow and poor or deep and rich soils. It is widely cultivated in parks (Vukićević 1982).

Up to now, examinations of the interacting effects of drought and light intensity (e.g. Holmgren, 2000; Aranda et al. 2005; Dutilleul et al. 2015) were performed almost exclusively on seedling growth. Gebauer et al. (2019) examined the impact of drought stress on the growth of one-year needles of *Picea abies* and ascertained that drought stress was correlated with tree assemblage and needle morphological traits. They also discovered that the differences in needle shape cross-section correlated to light intensity i.e. that the cross-section of needles exposed to light was quadrangular, while for the ones in the shade was ellipsoid.

To date, research has focused on the influence of crown light exposure on tree growth i.e. tree height and diameter (Wyckoff and Clarck 2005; Osada 2012; etc.), as well as tree mortality (Shenkin et al. 2018). The correlation of air polution with morphoanatomical traits of the needles of conifers living in urban areas had been previously examined (Nikolić et al. 2019 and refs. cited therein).

The aim of present paper is to examine the influence of crown exposure on the needle morphology of nine conifer species from different genera found in the parks of Belgrade, Serbia. To our knowledge, there has been no similar research conducted in Serbia with adult trees published to date.

MATERIALS AND METHODS
MATERIJALI I METODE

Geographic and geologic characteristics of the study parks and their position in town were presented in Table 1 and Figure 1, respectively). Sixty-six trees of nine conifer species: *Abies alba* (3 trees), *Abies concolor* (5 trees), *Cedrus atlantica* (14 trees), *Picea abies* (3 trees), *P. omorika* (7 rees), *P. pungens* (6 trees), *Pinus nigra* (10 trees), *Pseudotsuga menziesii* (6 trees), and *Taxus baccata* (12 trees) (Table 2) were analyzed. One to four trees of every species per park were analyzed, as was indicated in Table 2. One-year old needles were collected from the tips of lower third of the crown of solitary trees. Five needles (ca. 20 needles per tree) were analyzed from each of the four crown exposures (E, N, S, W). Four morphological needle properties (length, width, area, and perimeter) were measured using *SigmaScan Pro*

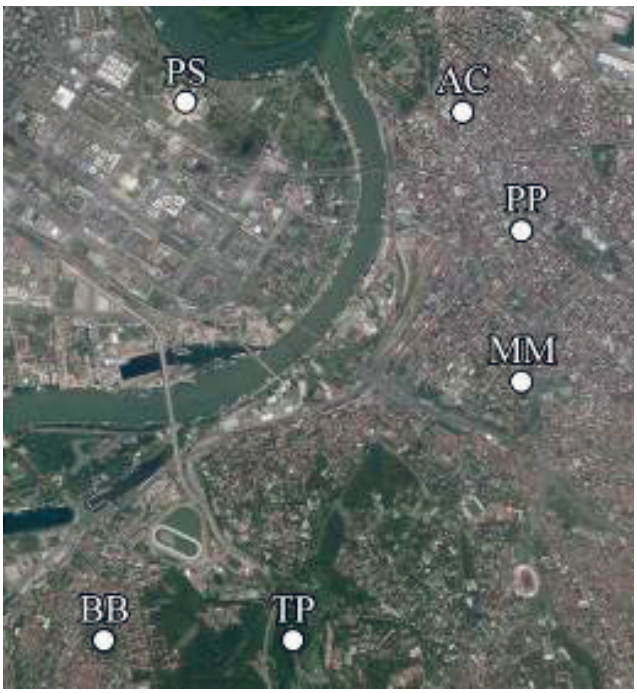

Figure 1. Position of analyzed Belgrade parks: PS – palace 'Serbia' park, AC – Academic park, PP – Pioneer park, MM – Milutin Milanković park; TP – Topčider park, and BB – park at Banovo Brdo.
Slika 1. Položaj analiziranih beogradskih parkova: PS – park palate 'Srbija', AC – Akademski park, PP – Pionirski park, MM – park Milutina Milankovića; TP – Topčiderski park i BB – park na Banovom Brdu.

Table 1. Geographic and geologic characteristics of the study parks
Tablica 1. Geografske i geološke značajke proučavanih parkova

Park	Area (ha)	Latitude (N)	Longitude (E)	Pollution	Substratum	
					Geologic	Pedologic
Park	*Površina* (ha)	*Zemljopisna širina* (N)	*Zemljopisna dužina* (E)	Onečišćenje	Supstrat	
					geološki	pedološki
AC	1.45	44° 49′ 10.33″	20° 27′ 28.17″	moderate	limestone	loam/hortisol
BB	10.90	44° 46′ 43.72″	20° 25′ 07.16″	moderate	serpentinite	loam/hortisol
MM	0.01	44° 47′ 55.84″	20° 27′ 52.97″	excessive	limestone	loam
PP	3.02	44° 48′ 37.39″	20° 27′ 51.96″	excessive	limestone	loam
PS	41.95	44° 49′ 12.16″	20° 25′ 39.05″	excessive	limestone	loam/clay loam
TP	13.00	44° 46′ 51.55″	20° 26′ 25.31″	slight	limestone	loam

Legend: AC – Academic park; BB – park at Banovo Brdo; MM – Milutin Milanković park; PP – Pioneer park ; PS – Palace 'Serbia' park; TP – Topčider park. Pollution: moderate, excessive, slight; Geologic substrate: limestone, serpentinite; Pedologic substratum: loam/hortisol, loam, loam/clay loam.

Legenda: AC – Akademski park; BB – park na Banovom Brdu; MM – park Milutina Milankovića; PP – Pionirski park; PS – Park palate 'Srbija'; TP – Topčiderski park. Onečišćenje: umjereno, prekomjerno, malo; Geološki supstrat: vapnenac, serpentinit; Pedološki supstrat: ilovača/hortizol, ilovača, ilovača/ilovača.

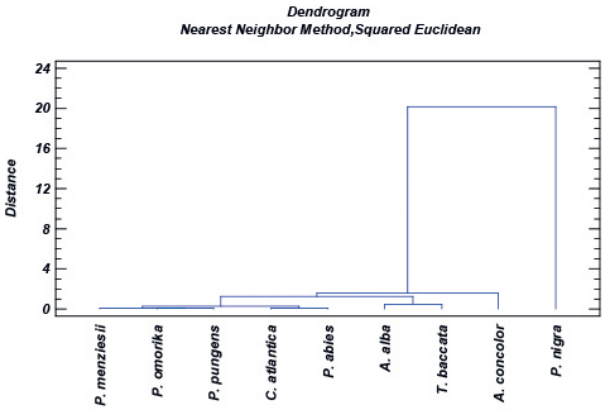

Figure 2. Cluster analysis of nine conifer species based on four morphological traits of needles (length, width, area and perimeter).
Slika 2. Klasterska analiza devet vrsta četinjača temeljena na četiri morfološka svojstva iglica (duljina, širina, površina i opseg).

5.0 image analysis software (Systat Software, Inc., San Jose, CA, USA).

Mean values and differences between the species' needle morphology were examined using the Cluster Analysis (Nearest Neighbor Method, Squared Euclidean Distance, Figure 2), while differences between parks and exposures were examined by ANOVA and LSD test at 95% level, using *Statgraphics Centurion* XVI, Version 16.1.11., (USA) statistical program (Figures 3 and 4; Table 2; Table 3). Correlations between the four measured needle traits of nine conifer species were determined by linear regression analyses (presented as text in Results section).

RESULTS
REZULTATI

Geographic and geologic characteristics of the study parks were presented in Table 1. For TP park slight air pollution was found. AC and BB parks had moderate, but MM, PS and PP parks excessive air pollution (according to distance from trafic). Geologic substrata also differ between parks, but pedologic substrata were almost same (limestones), with the exception of BB park (serpentinite).

Mean values of four morphological needle traits (length, width, area and perimeter) influenced by the crown exposure of all nine investigated species were presented in Tables 2,3 and 4 and Figures 2,3 and 4. The mean values of all quoted morphological traits were almost published before (Nikolić et al. 2019) (all histograms which were marked as "Mean" in Figures 3 and 4, and in Table 2).

Pinus nigra possessed the highest needle trait values (Table 2, Figure 2). *Abies concolor*, *Taxus baccata* and *Abies alba* also had larger needles in comparison to other investigated conifers.

Strong positive linear correlations were found between length and perimeter (r = 0.94 – 1.00), length and area (r = 0.82 – 0.96), and area and perimeter (r = 0.84 – 0.97) (results were not presented). Predominantly weak positive correlations were found between width and area (r = 0.10 – 0.80). Negative correlations between width and length and width and perimeter (r = -0.37 and r = -0.29, resp.) were found for *C. atlantica*. There were strong positive correlations (r > 0.75) between almost all four traits of *P. pungens*.

Means for each analyzed park were presented in Table 2. Mean values for four main exposures (E, N, S, W) had been presented in Table 2 too, as well as for every of analyzed park (Figure 3 a-i and Figure 4 a-i). Statistical signification was presented in Table 3.

In *Abies alba* needles, the mean values of the four measured traits (length, width, area and perimeter) were presented (Table 2, Figure 3a, Figure 4a), with statistically approved differences between parks BB and PP for needle length (Ta-

Table 2. Influence of parks and crown exposure (E, N, S, W) on needle morphological traits of nine conifers
Tablica 2. Utjecaj parkova i izloženosti krune (E, N, S, W) na morfološka svojstva iglica devet četinjača

a) *Abies alba*						
Park	Trait	E	N	S	W	Mean
BB (n=1)	Length	21.05 a	30.87 b	21.89 a	18.69 a	23.13
	Width	1.99 ab	2.14 ab	1.91 a	2.30 b	2.08
	Area	36.87 a	52.15 b	38.52 a	38.50 a	41.51
	Perimeter	46.08 a	66.02 b	47.61 a	41.99 a	50.42
PP (n=2)	Length	18.68 ab	20.32 b	16.11 a	15.99 a	17.78
	Width	2.13 a	2.12 a	1.92 a	1.90 a	2.02
	Area	33.41 ab	38.71 b	28.45 a	29.42 a	32.50
	Perimeter	41.62 ab	44.88 b	36.06 a	25.78 a	39.58
b) *Abies concolor*						
Park	Trait	E	N	S	W	Mean
BB (n=3)	Length	43.03 ab	43.60 ab	49.81 b	37.23 a	42.82
	Width	2.59 c	2.53 bc	2.14 a	2.26 ab	2.38
	Area	90.88 a	92.14 a	92.30 a	77.08 a	87.40
	Perimeter	91.24 ab	92.26 ab	103.89 b	78.99 a	90.40
PP (n=2)	Length	49.34 b	46.88 b	34.70 a	41.07 ab	43.02
	Width	2.40 b	20.90 ab	2.30 b	1.87 a	2.17
	Area	97.40 b	79.61 ab	70.59 a	70.99 a	79.64
	Perimeter	103.67 b	97.95 b	73.98 a	85.88 ab	90.37
c) *Cedrus atlantica*						
Park	Trait	E	N	S	W	Mean
AC (n=3)	Length	13.31 ab	14.15 b	13.41 b	11.32 a	13.05
	Width	1.48 b	1.35 ab	1.25 a	1.39 ab	1.37
	Area	17.30 a	16.78 a	15.40 a	14.58 a	16.02
	Perimeter	34.52 ab	36.24 b	34.45 ab	29.18 a	33.60
BB (n=3)	Length	13.93 a	14.55 a	13.22 a	12.51 a	13.42
	Width	1.26 bc	1.40 c	1.21 ab	1.08 a	1.22
	Area	16.15 ab	18.97 b	13.96 a	12.90 a	15.08
	Perimeter	35.88 a	37.57 a	32.78 a	30.84 a	33.78
PP (n=4)	Length	8.31 a	10.37 ab	17.02 c	15.62 bc	14.42
	Width	1.30 bc	1.01 a	1.15 ab	1.33 c	1.20
	Area	8.90 a	9.82 a	18.23 b	19.40 b	16.03
	Perimeter	20.72 a	25.65 a	41.17 b	39.33 b	35.50
PS (n=4)	Length	13.37 a	12.29 a	14.17 a	11.53 a	12.89
	Width	1.34 a	1.40 a	1.32 a	1.163 b	1.42
	Area	16.42 a	15.34 a	16.45 a	16.36 a	15.72
	Perimeter	33.43 a	32.43 a	35.37 a	29.70a	32.90
d) *Picea abies*						
Park	Trait	E	N	S	W	Mean
BB (n=1)	Length	20.10 c	17.88 b	15.96 a	17.56 b	17.87
	Width	1.65 b	1.59 ab	1.43 a	1.72 b	1.60
	Area	31.70 c	28.24 b	23.12 a	28.93 b	28.00
	Perimeter	50.03 c	45.51 b	40.16 a	45.50 b	45.30

PP (n=2)	Length	12.90 a	20.90 b	14.10 a	14.65 a	15.52
	Width	1.22 a	1.39 bc	1.29 ab	1.48 c	1.35
	Area	14.80 a	28.58 c	17.36 ab	19.20 b	19.99
	Perimeter	28.26 a	44.58 c	30.79 a	31.28 a	33.73
e) *Picea omorika*						
Park	Trait	E	N	S	W	Mean
BB (n=2)	Length	20.66 a	20.15 a	19.21 a	19.17 a	19.80
	Width	1.50 a	1.82 b	1.64 b	1.55 a	1.63
	Area	29.52 ab	34.35 b	29.29 ab	28.61 a	30.44
	Perimeter	44.31 a	43.94 a	41.70 a	41.44 a	42.85
MM (n=2)	Length	13.53 a	15.91 a	13.97 a	14.31 a	14.43
	Width	1.31 a	1.68 c	1.44 ab	1.53 bc	1.49
	Area	16.46 a	25.96 b	19.70 a	21.51 ab	20.91
	Perimeter	29.69 a	35.18 b	30.81 ab	31.69 ab	31.84
PS (n=2)	Length	23.55 b	21.14 ab	21.84 ab	19.90 a	21.61
	Width	1.90 b	1.73 ab	1.79 ab	1.62 a	1.76
	Area	39.52 b	30.06 a	37.39 b	31.02 a	34.50
	Perimeter	50.88 b	45.76 ab	47.25 ab	43.03 a	46.73
TP (n=1)	Length	22.69 b	15.24 a	20.71 b	17.89 a	19.13
	Width	1.60 ab	1.49 a	1.65 b	1.50 ab	1.56
	Area	32.96 b	20.33 a	30.88 b	23.12 a	26.82
	Perimeter	48.57 b	33.44 a	44.73b	38.78 a	41.38
f) *Picea pungens*						
Park	Trait	E	N	S	W	Mean
MM (n=2)	Length	28.93 c	12.45 a	17.03 b	17.65 b	19.01
	Width	1.77 b	1.21 a	1.35 a	1.29 a	1.40
	Area	23.49 b	14.97 a	42.44 c	22.90 b	25.95
	Perimeter	61.40 c	27.30 a	36.78 b	37.87 b	40.84
PP (n=2)	Length	29.22 c	22.80 b	21.59 b	17.83 a	22.86
	Width	1.90 b	1.68 ab	1.46 a	1.55 a	1.65
	Area	44.83 c	33.34 b	30.58 ab	25.01 a	33.44
	Perimeter	62.23 c	48.95 b	46.11 b	38.77 a	49.01
PS (n=2)	Length	26.69 b	23.62 a	27.58 b	30.67 b	27.89
	Width	1.67 a	1.56 a	1.71 a	1.78 a	1.68
	Area	44.20 b	34.32 a	43.37 b	49.55 b	42.86
	Perimeter	62.70 b	50.36 a	58.57 b	64.90 b	59.13
g) *Pinus nigra*						
Park	Trait	E	N	S	W	Mean
BB (n=3)	Length	118.15 a	123.08 a	118.20 a	129.58 a	122.52
	Width	1.18 b	1.01 a	1.07 ab	1.05 ab	1.08
	Area	135.66 a	150.53 a	159.44 a	155.69 a	150.33
	Perimeter	238.02 a	247.45 a	237.92 a	260.55 a	245.98

MM (n=1)	Length	132.80 a	-	176.92 b	137.76 a	149.16
	Width	1.58 a	-	1.99 b	1.46 a	1.67
	Area	206.97 a	-	312.02 b	192.00 a	237.00
	Perimeter	268.75 a	-	357.80 b	278.45 a	301.67
PP (n=2)	Length	122.65 a	138.42 b	136.30 b	119.77 a	129.29
	Width	1.41 a	1.84 b	2.03 b	1.24 a	1.63
	Area	167.19 a	237.45 b	240.13 b	146.94 a	197.93
	Perimeter	248.13 a	280.54 b	276.67 b	242.02 a	261.84
PS (n=4)	Length	148.00 c	114.96 a	128.10 ab	145.25 bc	136.86
	Width	1.51 a	1.80 b	1.82 b	1.75 ab	1.68
	Area	208.64 a	190.58 a	203.13 a	208.87 a	203.97
	Perimeter	299.02 c	233.51 a	259.86 ab	294.01 bc	277.08
h) *Pseudotsuga menziesii*						
Park	Trait	E	N	S	W	Mean
BB (n=3)	Length	26.08 a	32.57 b	22.69 a	24.39 a	26.19
	Width	1.66 bc	1.50 a	1.53 ab	1.73 c	1.62
	Area	39.66 a	48.51 b	34.40 a	39.12 a	40.12
	Perimeter	55.48 a	68.15 b	48.43 a	52.23 a	55.63
MM (n=1)	Length	34.37 b	-	18.84 a	22.43 a	25.21
	Width	1.64 ab	-	1.47 a	1.83 b	1.65
	Area	52.75 c	-	26.79 a	37.82 b	39.12
	Perimeter	72.02 b	-	40.62 a	48.52 a	53.72
PP (n=2)	Length	37.42 b	27.12 a	29.53 a	28.77 a	31.22
	Width	1.54 a	1.64 a	1.51 a	1.67 a	1.58
	Area	52.38 a	41.67 a	41.95 a	44.88 a	45.73
	Perimeter	77.92 b	57.53 a	62.08 a	60.89 a	65.61
i) *Taxus baccata*						
Park	Trait	E	N	S	W	Mean
BB (n=3)	Length	20.56 b	22.05 b	16.46 a	21.87 b	20.24
	Width	2.24 bc	2.40 c	1.76 a	2.13 b	2.13
	Area	41.54 b	48.97 c	27.49 a	42.84 bc	40.21
	Perimeter	45.61 b	48.90 b	36.44 a	48.01 b	44.74
MM (n=3)	Length	17.34 a	16.16 a	17.72 a	18.59 a	17.45
	Width	2.27 a	2.27 a	2.26 a	2.27 a	2.27
	Area	38.06 a	34.35 a	38.00 a	39.73 a	37.54
	Perimeter	39.22 a	36.86 a	39.96 a	41.73 a	39.44
PP (n=2)	Length	21.98 b	20.45 b	18.07 a	19.92 ab	20.10
	Width	2.66 ab	2.70 b	2.37 a	2.63 ab	2.59
	Area	49.45 b	48.56 ab	40.11 a	47.75 ab	46.47
	Perimeter	49.28 b	46.30 b	40.88 a	45.10 ab	45.39
PS (n=3)	Length	18.89 b	19.81 b	13.58 a	18.52 b	17.70
	Width	2.40 ab	2.36 ab	2.23 a	2.57 b	2.39
	Area	41.06 b	42.59 b	27.67 a	43.83 b	38.78
	Perimeter	42.57 b	44.34 b	31.63 a	42.20 b	40.18

TP (n=1)	Length	16.60 a	19.31 b	18.69 ab	18.90 ab	18.38
	Width	2.17 a	2.24 a	2.22 a	2.27 a	2.25
	Area	33.90 a	40.69 a	39.80 a	39.56 a	38.49
	Perimeter	37.55 a	43.10 b	41.82 ab	42.35 ab	41.20

Parks: AC – Academic; BB – Banovo Brdo; MM – Milutin Milanković; PP – Pioneer; PS – Palace 'Serbia', and TP – Topčider park. Traits: Length, Width and Perimeter in mm, Area in mm^2.
Crown exposure: E- eastern, N – northern, S – southern, and W – western. a,b,c...: homogeneous groups.

Parkovi: AC – Akademski; BB – Banovo Brdo; MM – Milutin Milanković; PP – Pionirski; PS – Palata „Srbija" i TP – Topčiderski park. Svojstva: duljina, širina i opseg u mm, površina u mm^2.
Ekspozicija krune: E-istok, N-sjever, S-jug i W-zapad. a,b,c...: homogene grupe.

Table 3. Summary statistics and ANOVA tables of needle length and width of nine conifers with respect to following factors: park and crown exposure
Table 3.Sumarna statistika i ANOVA tabele dužine i širine iglica devet četinjača u pogledu sledećih faktora: park i izloženost krošnje

a) *Abies alba*, NEEDLE LENGTH

Descriptive Statistics

PARK	n	Average	SD	CV	Min.	Max.	Range
BB	20	23,1285	5,52571	23,89%	16,58	39,8	23,22
PP	40	17,7765	4,26236	23,98%	10,64	25,92	15,28
Total	60	19,5605	5,3212	27,20%	10,64	39,8	29,16
EXPOSURE							
E	15	19,474	3,13181	16,08%	12,45	23,15	10,70
N	15	23,8387	6,88201	28,87%	14,35	39,8	25,45
S	15	18,0373	4,05932	22,51%	10,64	23,9	13,26
W	15	16,892	3,99332	23,64%	12,00	24,17	12,17
Total	60	19,5605	5,3212	27,20%	10,64	39,8	29,16

ANOVA Table

Source	SS	D.f.	MS	F-Ratio	P-Value
Between groups	381,919	1	381,919	17,19	0,0001
Within groups	1288,68	58	22,2186		
Between groups	416,267	3	138,756	6,19	0,001
Within groups	1254,33	56	22,3988		
Total (Corr.)	1670,6	59			

a) *Abies alba*, NEEDLE WIDTH

Descriptive Statistics

PARK	n	Average	SD	CV	Min.	Max.	Range
BB	20	2,083	0,28195	13,54%	1,45	2,68	1,23
PP	40	2,0165	0,328965	16,31%	1,36	2,72	1,36
Total	60	2,03867	0,313263	15,37%	1,36	2,72	1,36
EXPOSURE							
E	15	2,07933	0,245807	11,82%	1,67	2,72	1,05
N	15	2,12467	0,27404	12,90%	1,55	2,68	1,13
S	15	1,938	0,243111	12,68%	1,45	2,38	0,93
W	15	2,05267	0,460008	21,65%	1,36	2,56	1,2
Total	60	2,03867	0,313263	15,37%	1,36	2,72	1,36

ANOVA Table

Source	SS	D.f.	MS	F-Ratio	P-Value
Between groups	0,058963	1	0,058963	0,6	0,443
Within groups	5,73093	58	0,0988039		
Total (Corr.)	5,78989	59			
Between groups	0,354693	3	0,118231	1,22	0,3116
Within groups	5,4352	56	0,097057		
Total (Corr.)	5,78989	59			

b) *Abies concolor*, NEEDLE LENGTH

Descriptive Statistics

PARK	n	Average	SD	CV	Min.	Max.	Range
BB	50	42,8184	9,78399	22,85%	21,04	73,02	51,98
PP	40	43,019	12,3762	28,77%	23,06	72,51	49,45
Total	90	42,9076	10,9468	25,51%	21,04	73,02	51,98
EXPOSURE							
E	20	46,2305	8,5577	18,51%	29,09	64,05	34,96
N	25	44,9144	9,4834	21,11%	30,56	72,51	41,95
S	20	42,251	12,209	28,90%	25,12	73,02	47,9
W	25	38,7676	12,1183	31,26%	21,04	64,9	43,86
Total	90	42,9076	10,9468	25,51%	21,04	73,02	51,98

ANOVA Table

Source	SS	D.f.	MS	F-Ratio	P-Value
Between groups	1337,31	1	1337,31	1,95	0,1662
Within groups	60387,6	88	686,223		
Total (Corr.)	61724,9	89			
Between groups	758,627	3	252,876	2,2	0,0944
Within groups	9906,49	86	115,192		
Total (Corr.)	10665,1	89			

b) *Abies concolor*, NEEDLE WIDTH

Descriptive Statistics

PARK	n	Average	Standard deviation	Coeff. of variation	Min.	Max.	Range
BB	50	2,383	0,423177	17,76%	1,7	3,29	1,59
PP	40	2,166	0,480858	22,20%	0,86	3,09	2,23
Total	90	2,28656	0,460081	20,12%	0,86	3,29	2,43
EXPOSURE							
E	20	2,496	0,599011	24,00%	0,86	3,29	2,43
N	25	2,3536	0,44439	18,88%	1,45	3,13	1,68
S	20	2,219	0,250723	11,30%	1,74	2,68	0,94
W	25	2,106	0,417911	19,84%	1,27	2,88	1,61
Total	90	2,28656	0,460081	20,12%	0,86	3,29	2,43

ANOVA Table

Source	Sum of Squares	D.f.	Mean Square	F-Ratio	P-Value
Between groups	1,04642	1	1,04642	5,18	0,0253
Within groups	17,7926	88	0,202189		
Total (Corr.)	18,839	89			
Between groups	1,896	3	0,631999	3,21	0,0271
Within groups	16,943	86	0,197012		
Total (Corr.)	18,839	89			

c) *Cedrus atlantica*, NEEDLE LENGTH

Descriptive Statistics

PARK	n	Average	SD	CV	Min.	Max.	Range
AK	60	13,0477	2,91941	22,38%	7,67	17,89	10,82
BB	50	13,4178	3,56549	26,57%	8,51	23,22	14,71
PP	35	14,4243	5,96231	41,34%	6,37	23,74	17,37
PS	70	12,8954	4,55584	35,33%	5,77	24,89	19,12
Total	215	13,3083	4,22873	31,78%	5,77	24,89	19,12
EXPOSURE							
E	45	12,9128	4,97501	38,51%	5,77	24,89	19,12
N	50	13,109	3,23041	24,64%	7,42	19,23	11,81
S	65	14,4334	4,0487	28,05%	6,21	22,17	15,96
W	55	12,4836	4,4085	35,31%	6,23	23,74	17,51
Total	215	13,3083	4,22873	31,78%	5,77	24,89	19,12

ANOVA Table

Source	SS	D.f.	MS	F-Ratio	P-Value
Between groups	60,1975	3	20,0658	1,12	0,3403
Within groups	3766,59	211	17,8511		
Total (Corr.)	3826,79	214			
Between groups	128,719	3	42,9065	2,45	0,0647
Within groups	3698,07	211	17,5264		
Total (Corr.)	3826,79	214			

c) *Cedrus atlantica*, NEEDLE WIDTH

Descriptive Statistics

PARK	n	Average	SD	CV	Min.	Max.	Range
AK	60	1,3675	0,284269	20,79%	0,78	2,05	1,27
BB	50	1,218	0,238755	19,60%	0,76	1,91	1,15
PP	35	1,20371	0,21769	18,08%	0,77	1,8	1,03
PS	70	1,416	0,31205	22,04%	0,93	2,04	1,11
Total	215	1,32186	0,287303	21,73%	0,76	2,05	1,29
EXPOSURE							
E	45	1,36667	0,215797	15,79%	0,93	1,87	0,94
N	50	1,3476	0,27587	20,47%	0,77	1,91	1,14
S	65	1,23954	0,285041	23,00%	0,76	2,04	1,28
W	55	1,35909	0,33461	24,62%	0,78	2,05	1,27
Total	215	1,32186	0,287303	21,73%	0,76	2,05	1,29

ANOVA Table

Source	SS	D.f.	MS	F-Ratio	P-Value
Between groups	1,77323	3	0,591078	7,85	0,0001
Within groups	15,8910	211	0,075313		
Total (Corr.)	17,6643	214			
Between groups	0,640203	3	0,213401	2,64	0,0502
Within groups	17,0241	211	0,080683		
Total (Corr.)	17,6643	214			

d) *Picea abies*, NEEDLE LENGTH

Descriptive Statistics

PARK	n	Average	SD	CV	Min.	Max.	Range
BB	20	17,8755	1,66522	9,32%	14,74	20,88	6,14
PP	40	15,5167	4,19521	27,04%	8,63	25,07	16,44
Total	60	16,303	3,71269	22,77%	8,63	25,07	16,44
EXPOSURE							
E	15	15,3013	4,13428	27,02%	9,4	20,88	11,48
N	15	19,8907	2,79999	14,08%	16,46	25,07	8,61
S	15	14,722	3,23634	21,98%	8,63	20,14	11,51
W	15	15,298	2,01444	13,17%	11,52	18,69	7,17
Total	60	16,303	3,71269	22,77%	8,63	25,07	16,44

ANOVA Table

Source	SS	D.f.	MS	F-Ratio	P-Value
Between groups	74,1827	1	74,1827	5,82	0,019
Within groups	739,079	58	12,7427		
Total (Corr.)	813,262	59			
Between groups	260,764	3	86,9214	8,81	0,0001
Within groups	552,498	56	9,86603		
Total (Corr.)	813,262	59			

d) *Picea abies*, NEEDLE WIDTH

Descriptive Statistics

PARK	n	Average	SD	CV	Min.	Max.	Range
BB	20	1,6005	0,182885	11,43%	1,19	1,89	0,7
PP	40	1,3475	0,163138	12,11%	0,97	1,61	0,64
Total	60	1,43183	0,206951	14,45%	0,97	1,89	0,92
EXPOSURE							
E	15	1,36733	0,25084	18,35%	0,97	1,78	0,81
N	15	1,46	0,182483	12,50%	1,1	1,89	0,79
S	15	1,34133	0,174514	13,01%	1,1	1,7	0,6
W	15	1,55867	0,149994	9,62%	1,27	1,8	0,53
Total	60	1,43183	0,206951	14,45%	0,97	1,89	0,92

ANOVA Table

Source	SS	D.f.	MS	F-Ratio	P-Value
Between groups	0,853453	1	0,853453	29,58	0,0000
Within groups	1,67345	58	0,028853		
Total (Corr.)	2,5269	59			
Between groups	0,438458	3	0,146153	3,92	0,0131
Within groups	2,08844	56	0,037294		
Total (Corr.)	2,5269	59			

Table 3. Continued
Table 3. Nastavak

e) *Picea omorika*, NEEDLE LENGTH

Descriptive Statistics

PARK	n	Average	SD	CV	Min.	Max.	Range
BB	40	19,7990	3,46399	17,50%	13,04	25,93	12,89
MM	40	14,4300	2,92821	20,24%	9,81	19,13	9,32
PS	40	21,6075	3,43966	15,83%	14,87	30,25	15,38
TP	20	19,1295	3,46942	18,14%	14,27	28,33	14,06
Total	140	18,6861	4,32888	23,17%	9,81	30,25	20,44
EXPOSURE							
E	35	19,7366	4,90104	24,83%	9,81	28,33	18,52
N	35	18,5214	4,04122	21,82%	12,98	30,25	17,27
S	35	18,878	4,66269	24,98%	11,76	27,18	15,42
W	35	17,8083	3,54414	19,90%	9,94	22,73	12,79
Total	140	18,6861	4,32888	23,17%	9,81	30,25	20,44

ANOVA Table

Source	SS	D.f	MS	F-Ratio	P-Value
Between groups	1119,43	3	373,144	34,17	0,0000
Within groups	1485,32	136	10,9215		
Total (Corr.)	2604,75	139			
Between groups	66,5431	3	22,181	1,19	0,3166
Within groups	2538,21	136	18,6633		
Total (Corr.)	2604,75	139			

e) *Picea omorika*, NEEDLE WIDTH

Descriptive Statistics

PARK	n	Average	SD	CV	Min.	Max.	Range
BB	40	1,62625	0,28848	17,62%	1,02	2,2	1,18
MM	40	1,491	0,22886	15,35%	1,1	1,98	0,88
PS	40	1,75925	0,28657	16,29%	0,91	2,36	1,45
TP	20	1,56000	0,13310	8,53%	1,28	1,79	0,51
Total	140	1,61614	0,27235	16,84%	0,91	2,36	1,45
EXPOSURE							
E	35	1,57343	0,31742	20,17%	1,02	2,13	1,11
N	35	1,70657	0,19435	11,39%	1,36	2,2	0,84
S	35	1,62743	0,32248	19,82%	0,91	2,36	1,45
W	35	1,55714	0,21511	13,81%	1,19	1,93	0,74
Total	140	1,61614	0,27236	16,84%	0,91	2,36	1,45

ANOVA Table

Source	SS	D.f	MS	F-Ratio	P-Value
Between groups	1,51274	3	0,50425	7,81	0,0001
Within groups	8,78278	136	0,06458		
Total (Corr.)	10,2955	139			
Between groups	0,47635 7	3	0,15879	2,2	0,091
Within groups	9,81916	136	0,0722		
Total (Corr.)	10,2955	139			

f) *Picea pungens*, NEEDLE LENGTH

Descriptive Statistics

PARK	n	Average	SD	CV	Min.	Max.	Range
MM	40	19,014	6,53589	34,37%	9,05	33,08	24,03
PP	40	22,859	5,31442	23,25%	16,01	37,43	21,42
PS	40	27,889	4,4012	15,78%	17,7	35,65	17,95
Total	120	23,254	6,55141	28,17%	9,05	37,43	28,38
EXPOSURE							
E	30	29,2773	3,8111	13,02%	22,59	37,43	14,84
N	30	19,6207	6,47529	33,00%	9,05	31,7	22,65
S	30	22,0683	4,57123	20,71%	15,19	29,29	14,10
W	30	22,0497	6,68068	30,30%	15,33	35,65	20,32
Total	120	23,254	6,55141	28,17%	9,05	37,43	28,38

ANOVA Table

Source	SS	D.f	MS	F-Ratio	P-Value
Between groups	1584,67	2	792,337	26,31	0,0000
Within groups	3522,93	117	30,1105		
Total (Corr.)	5107,6	119			
Between groups	1570,14	3	523,379	17,16	0,0000
Within groups	3537,46	116	30,4958		
Total (Corr.)	5107,6	119			

f) *Picea pungens*, NEEDLE WIDTH

Descriptive Statistics

PARK	n	Average	SD	CV	Min.	Max.	Range
MM	40	1,40575	0,289357	20,58%	0,86	2,14	1,28
PP	40	1,6475	0,307527	18,67%	1,1	2,3	1,2
PS	40	1,67825	0,254658	15,17%	1,1	2,17	1,07
Total	120	1,57717	0,307673	19,51%	0,86	2,3	1,44
EXPOSURE							
E	30	1,77933	0,283609	15,94%	1,1	2,3	1,2
N	30	1,48133	0,336511	22,72%	0,86	2,17	1,31
S	30	1,50733	0,244511	16,22%	1,02	1,93	0,91
W	30	1,54067	0,27709	17,99%	1,03	2,12	1,09
Total	120	1,57717	0,307673	19,51%	0,86	2,3	1,44

ANOVA Table

Source	SS	D.f	MS	F-Ratio	P-Value
Between groups	1,78193	2	0,890966	10,99	0,0000
Within groups	9,4829	117	0,081051		
Total (Corr.)	11,2648	119			
Between groups	1,68795	3	0,562643	6,82	0,0003
Within groups	9,57691	116	0,08256		
Total (Corr.)	11,2648	119			

g) *Pinus nigra*, NEEDLE LENGTH

Descriptive Statistics

PARK	n	Average	SD	CV	Min.	Max.	Range
BB	60	122,253	17,0964	13,98%	91,28	155,25	63,97
MM	15	149,159	21,3491	14,31%	124,79	194,69	69,9
PP	40	129,288	13,9529	10,79%	99,66	162,59	62,93
PS	25	136,864	18,9578	13,84%	93,5	191,28	97,78
Total	140	129,754	18,9894	14,63%	91,28	194,69	103,4
EXPOSURE							
E	40	128,572	18,571	14,44%	98,81	191,28	92,47
N	30	126,841	14,3072	11,28%	93,5	162,59	69,09
S	35	133,173	26,0471	19,56%	91,28	194,69	103,4
W	35	130,185	14,2897	10,98%	107,99	155,25	47,26
Total	140	129,754	18,9894	14,63%	91,28	194,69	103,4

ANOVA Table

Source	SS	D.f	MS	F-Ratio	P-Value
Between groups	10296,8	3	3432,27	13,72	0,0000
Within groups	39826	136	292,838		
Total (Corr.)	50122,8	139			
Between groups	726,236	3	242,079	0,67	0,574
Within groups	49396,6	136	363,21		
Total (Corr.)	50122,8	139			

g) *Pinus nigra*, NEEDLE WIDTH

Descriptive Statistics

PARK	n	Average	SD	CV	Min.	Max.	Range
BB	60	1,07883	0,213256	19,77%	0,46	1,62	1,16
MM	15	1,67533	0,326122	19,47%	1,03	2,23	1,2
PP	40	1,6315	0,40152	24,61%	0,91	2,4	1,49
PS	25	1,678	0,255848	15,25%	1,19	2,04	0,85
Total	140	1,40764	0,410512	29,16%	0,46	2,4	1,94
EXPOSURE							
E	40	1,36825	0,259041	18,93%	0,97	1,97	1
N	30	1,422	0,462187	32,50%	0,68	2,17	1,49
S	35	1,58343	0,513672	32,44%	0,59	2,4	1,81
W	35	1,26457	0,333214	26,35%	0,46	1,98	1,52
Total	140	1,40764	0,410512	29,16%	0,46	2,4	1,94

ANOVA Table

Source	SS	D.f	MS	F-Ratio	P-Value
Between groups	11,3936	3	3,79787	42,93	0,0000
Within groups	12,0307	136	0,088461		
Total (Corr.)	23,4243	139			
Between groups	1,86621	3	0,622069	3,92	0,0101
Within groups	21,5581	136	0,158516		
Total (Corr.)	23,4243	139			

h) *Pseudotsuga menziesii*, NEEDLE LENGTH

Descriptive Statistics

PARK	n	Average	SD	CV	Min.	Max.	Range
BB	50	26,191	6,2374	23,82%	13,35	39,04	25,69
MM	15	25,2113	8,00369	31,75%	16,46	42,75	26,29
PP	35	31,2249	7,19603	23,05%	16,65	43,49	26,84
Total	100	27,8059	7,25042	26,08%	13,35	43,49	30,14
EXPOSURE							
E	30	31,2417	7,28229	23,31%	17,13	43,49	26,36
N	15	30,754	5,87802	19,11%	22,45	39,04	16,59
S	25	24,6536	6,61014	26,81%	13,35	34,21	20,86
W	30	25,523	6,55145	25,67%	16,65	41,94	25,29
Total	100	27,8059	7,25042	26,08%	13,35	43,49	30,14

ANOVA Table

Source	SS	D.f	MS	F-Ratio	P-Value
Between groups	640,496	2	320,248	6,81	0,0017
Within groups	4563,8	97	47,0494		
Total	5204,29	99			
Between groups	889,278	3	296,426	6,59	0,0004
Within groups	4315,01	96	44,9481		
Total (Corr.)	5204,29	99			

h) *Pseudotsuga menziesii*, NEEDLE WIDTH

Descriptive Statistics

PARK	n	Average	SD	CV	Min.	Max.	Range
BB	60	26,191	6,2374	23,82%	13,35	39,04	25,69
MM	60	25,2113	8,00369	31,75%	16,46	42,75	26,29
PP	40	31,2249	7,19603	23,05%	16,65	43,49	26,84
Total	260	27,8059	7,25042	26,08%	13,35	43,49	30,14
EXPOSURE							
E	65	31,2417	7,28229	23,31%	17,13	43,49	26,36
N	65	30,754	5,87802	19,11%	22,45	39,04	16,59
S	65	24,6536	6,61014	26,81%	13,35	34,21	20,86
W	65	25,523	6,55145	25,67%	16,65	41,94	25,29
Total	260	27,8059	7,25042	26,08%	13,35	43,49	30,14

ANOVA Table

Source	SS	D.f	MS	F-Ratio	P-Value
Between groups	5,79693	4	1,44923	13,48	0,0000
Within groups	27,4208	255	0,107532		
Total	33,2177	259			
Between groups	1,99806	3	0,666021	5,46	0,0012
Within groups	31,2196	256	0,121952		
Total (Corr.)	33,2177	259			

ble 3a). Northern crown exposure was the best for needle length, too (Table 3a). In *A. concolor,* needle mean values for BB and PP were nearly identical. Northern exposure had almost the best needle length and width (Figure 3b, Figure 4b), but it was not statistically approved in both properties (only in needle width,Table 3b). In *Cedrus atlantica* needles, great differences in the analyzed traits between parks were found only in needle width (Figure 3c, Figure 4c, Table 3c), where parks AK and BB had statistically the best values. At the same time, we can not conclude that some exposures gave the best results (Table 3c). In *Picea abies* needles (Figure 3d, Figure 4d), needle length and width were significantly higher in BB than in PP (Table 3d). The best results were found on northern and western exposure (needle length and width, resp.). In *P. omorika* needles the highest values were statistically approved in park PS (Figure 3e, Figure 4e, Table 3e). The longest needles were found on eastern exposure, but it was not statistically significant. For *P. pungens* needles (Figure 3f, Figure 4f, Table 3f), the highest and statistically approved length and width were found in park PS, while eastern exposure was the best (Table 3f). In *Pinus nigra* needles (Figure 3g, h;

Table 3. Continued
Table 3. Nastavak

i) *Taxus baccata*, NEEDLE LENGTH

Descriptive Statistics							
PARK	n	Average	SD	CV	Min.	Max.	Range
BB	60	20,24	4,1521	20,51%	11,43	27,6	16,17
MM	60	17,4545	3,52819	20,21%	10,22	26,52	16,3
PP	60	20,105	2,78989	13,88%	13,95	26,00	12,05
PS	60	17,7012	2,64244	16,62%	8,97	21,43	12,46
TP	60	18,3777	3,24885	17,68%	12,35	24,8	12,45
Total	288	18,7561	3,6099	19,25%	8,97	27,6	18,63
EXPOSURE							
E	65	18,8857	4,01856	21,26%	10,22	27,6	17,38
N	65	19,4698	3,24349	16,66%	11,32	26,78	15,46
S	65	17,0722	3,70726	21,72%	8,97	24,44	15,47
W	65	19,6186	2,86815	14,62%	14,1	27,42	13,32
Total	288	18,7561	3,6099	19,25%	8,97	27,6	18,63

ANOVA Table					
Source	SS	D.f.	MS	F-Ratio	P-Value
Between groups	393,85	4	89,9124	7,00	0,0000
Within groups	3015,48	255	11,8254		
Total	3375,11	259			
Between groups	266,344	3	88,7815	7,31	0,0001
Within groups	3108,79	256	12,1437		
Total (Corr.)	3375,13	259			

ii) *Taxus baccata*, NEEDLE WIDTH

Descriptive Statistics							
PARK	n	Average	SD	CV	Min.	Max.	Range
BB	60	2,13083	0,350234	16,72%	1,31	3,15	2,84
MM	60	2,26833	0,336512	14,83%	1,81	3,03	1,42
PP	60	2,58975	0,364428	14,07%	1,73	3,25	1,52
PS	60	2,39075	0,274033	11,46%	1,81	2,9	1,09
TP	60	2,22483	0,295506	13,28%	1,69	2,9	1,21
Total	288	2,29489	0,358125	15,61%	1,31	3,25	2,34
EXPOSURE							
E	65	2,32692	0,31827	13,71%	1,61	3,07	1,46
N	65	2,37185	0,342531	14,44%	1,67	3,15	1,48
S	65	2,14631	0,369186	17,20%	1,31	3,25	2,34
W	65	2,34031	0,364533	15,58%	1,7	3,25	1,55
Total	288	2,29483	0,358125	15,61%	1,31	3,25	2,34

ANOVA Table					
Source	SS	D.f.	MS	F-Ratio	P-Value
Between groups	5,79693	4	1,44923	13,48	0,0000
Within groups	27,4208	255	0,107532		
Total	33,2177	259			
Between groups	1,99806	3	0,666021	5,46	0,0012
Within groups	31,2196	256	0,121952		
Total (Corr.)	33,2177	259			

Figure 4g, h), the highest needle length was found in MM and PS (Table 3g). Southern exposure was found to be also statistically the best. In needles of *Pseudotsuga menziesii,* the highest values of length and width were exibited in PP (Table 2, Figure 3h, Figure 4h, Table 3h). The largest needles (statistically approved) according to needle length and width were found on eastern and northern exposures, resp. In needle length of *T. baccata*, park BB was the best (Table 2, Figure 3i, Figure 4i, Table 3i), while in needle width PP was the best. Western and northern exposures were significantly the best, resp.

DISCUSSION
RASPRAVA

Abies alba, according to Jovanović (1967) and Janković (1973), is a sciophilic species (thrives in the shade), which agrees with presented results where the maximum values of needle length on northern exposure was shown, even though, according to Robakowski et al. (2004), young seedlings require somewhat more light. *A. concolor* is also a shade-loving species, however, it copes well with sunny locations as well and is a desirable park species (Jovanović 1967; Vukićević 1982). Presented results, since no statistical differences in crown exposure were found, confirmed statements of both authors. Furthermore, Mori and Takeda (2004) reported that branches of alpine species, *A. mariesi* and *A. veitchii*, developed more slowly in the shade. Needle masses per area of these species (results of current-year needles!) were lower in the shade. *Cedrus atlantica* is favorite park species which in the examinations presented therein exhibited variability concerning exposure. Its both heliophilic (Vukićević 1982) and xerotherm characters (Jovanović 1967), were not statistically approved in presented results, although on southern exposure needle length was the highest. *Picea abies* is a species that copes better in the shade (Jovanović 1967) or in partial shade (Janković 1973). The both opinions were approved in presented examination where higher needle length was found on northern, and higher needle width on western exposure. *P. omorika*, though a sciophilic species, it can thrive in the light as well (Jovanović 1967). In presented results its needle length had the highest mean value on the eastern side, but its needle width was the best on the northern side. It is important to notice that both findings didn't have statistical support. *P. pungens* is also considered a heliophilic species (Jovanović 1967), which coincides with the maximum values found mostly on eastern exposure (presented results, statistically approved). Furthermore, needle masses per area (of current-year needles) of *P. jezoensis* (Mori and Takeda, 2004) was lower in the shade. *Pinus nigra* is a distinct heliophilous (Jovanović 1967; Janković 1973), as confirmed in presented results where maximum values were found on southern exposure, but it was not statistically confirmed. *Pseudotsuga menziesii* is considered a partial shade species and is successfully grown in forest cultures (Vukićević 1982). It was in accordance with presented evidence where the longest needles were found on southern exposure, but the thickest needles were found on northern exposure. *Taxus baccata* is a species that tolerates deep shade (Jovanović 1967; Janković 1973; Robakowski et al. 2004), and in presented results it achieved the best results on eastern or northern exposures (needle length and needle width, resp.).

The significant impact between light and shade on leaf mass per area had also been established in some tropical species (Martin et al. 2020) and other leaf physiological traits. It was founded that differences in needle morphology between parks could be consequence of tree maturation, too (quoted in the case of Douglas-fir needles, where length, width, thickness, and roundness of needles grew through the needle age, Apple et al. 2002).

Increased dryness and the poverty of soil led to decreased length and area of needles (Tyukavina et al. 2019a). Needle area of Scots pine forests in taiga was reduced in conditions far from optimal water regime, so consequences in changing the width and thickness of needles occured (Tyukavina et al. 2019b).

In previous study (Nikolić et al. 2019), for all investigated species significant differences in needle morphology (and anatomy) between species as well as between individuals were found, too. Our results is in accordance to general data which was well known (Vukićević et al. 1982).

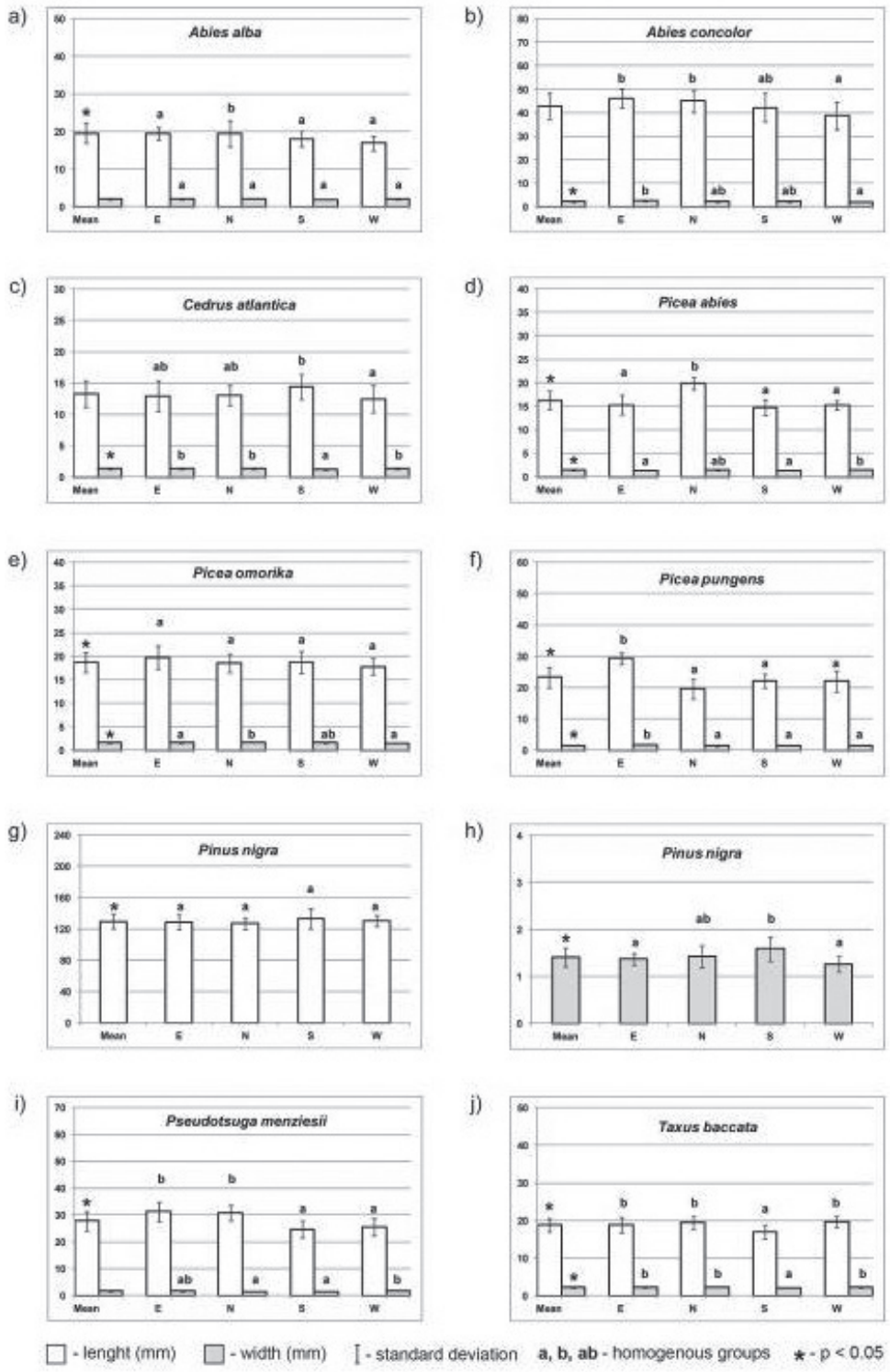

Figure 3. Differences in the length and width of the needles of nine conifers with respect to crown exposure
Slika 3. Razlike u duljini i širini iglica devet četinjača s obzirom na izloženost krošnji

BB is the only park on serpentinite ground that has most likely favoured the development of the needles of species *A. alba, P. abies and T. baccata* (primarily needle length). The remaining six studied species demonstrated better results on limestone surfaces. According to Vukićević (1982), *P. pungens* is not too demanding in terms of soil characteristics but we couldn't approve this since all investigated trees of this species were on same substrat, loam. Speaking of soil properties, this paper's findings and conclusions should be taken with reservation because some of the parks implemented cultivation measures, primarily fertilization (but, unfortunatelly, it was known for sure only for parks AC and BB).

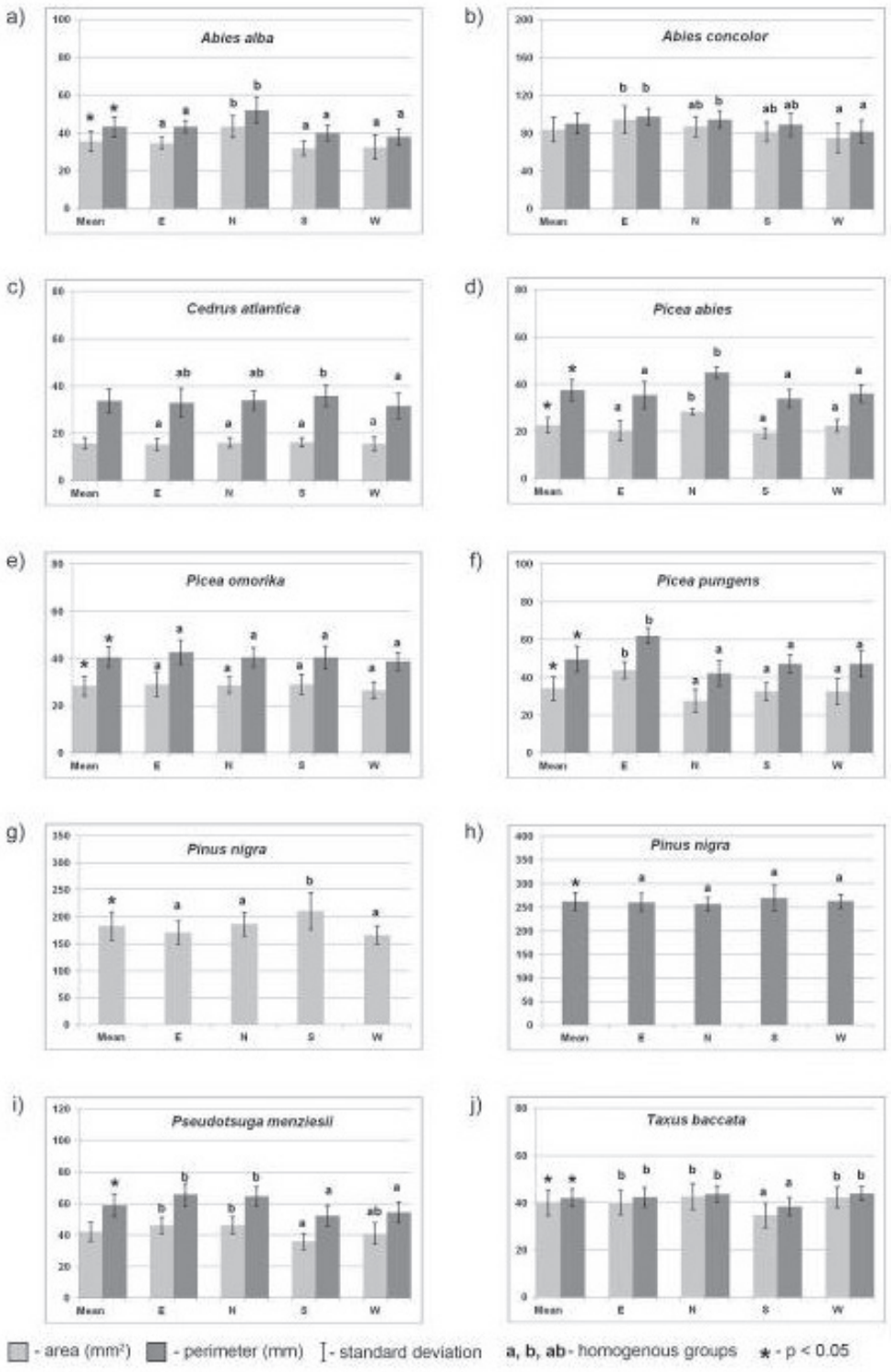

Figure 4. Differences in the needle area and perimeter of the needles of nine conifers with respect to crown exposure
Slika 4. Razlike u površini i opsegu iglica devet četinjača s obzirom na izloženost krošnji

CONCLUSIONS
ZAKLJUČCI

According to obtained results the crown exposure influenced to needle properties in many of analyzed conifers. Species, parks in which they were found, as well as crown exposures, differed mostly in needle length and needle width.

The differences among the species in terms of light requirement found in the present research determined species for individual cooperation in parks (i.e. as solitary trees) as

light-loving or partial shade species (*C. atlantica*, *P. abies*, *P. omorika*, *P. pungens*, *P. nigra* and *P. menziesii*), or group cooperation as shade-loving species (*A. alba*, *A. concolor* and *T. baccata*), which is something to be taken into consideration when setting up parks in the future.

ACKNOWLEDGEMENTS
ZAHVALE

This study was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, grant numbers: 451-03-47/2023-01/200027 and 451-03-47/2023-01/200169.

REFERENCES
LITERATURA

- Apple M., K. Tiekotter, M. Snow, J. Young, A. Soeldnerb, D. Phillips, D. Tingey, B. J Bond, 2002: Needle anatomy changes with increasing tree age in Douglas-fir. Tree Physiol, 22(2-3):129-136.
- Aranda, I., L. Castro, M. Pardos, L. Gil, J.A. Pardos, 2005: Effects of the interaction between drought and shade on water relations, gas exchange and morphological traits in cork oak (*Quercus suber* L.) seedlings. For Ecol Manage, 210(1-3):117-129.
- Donovan, R.G., H.E. Stewart, S.M. Owen, A.R. MacKenzie, C.N. Hewitt, 2005: Development and application of an urban tree air quality score for photochemical pollution episodes using the Birmingham, United Kingdom, area as a case study. Environ Sci Technol, 39(17):6730-6738.
- Dutilleul, P., L. Han, F. Valladares, C. Messier, 2015: Crown traits of coniferous trees and their relation to shade tolerance can differ with leaf type: a biophysical demonstration using computed tomography scanning data. Front Plant Sci, 6:172.
- Freer-Smith, P. H., K. P. Beckett, G. Taylor 2005: Deposition velocities to *Sorbus aria*, *Acer campestre*, 'Beaupre', *Pinus nigra* and *x Cupressocyparis leylandii* for coarse, fine and ultra-fine particles in the urban environment. Environ Pollut, 133(1):157-167.
- Gebauer, R., D. Volařík, J. Urban, I. Børja, N.E. Nagy, T.D. Eldhuset, P. Krokene, 2019: Effects of mild drought on the morphology of sun and shade needles in 20- year-old Norway spruce trees. IForest, 12(1):27-34.
- Hällgren, J.E., S.Å. Fredriksson, 1982: Emission of hydrogen sulfide from sulfur dioxide-fumigated Pine trees. Plant Physiol, 70(2):456-459.
- Holmgren, M., 2000: Combined effects of shade and drought on tulip poplar seedlings: trade-off in tolerance or facilitation? Oikos, 90(1):67-78.
- Janković, M., 1973: Enciklopedijski leksikon mozaik znanja – Biologija, Interpres, Tom 19, Beograd.
- Jovanović, B., 1967: Dendrologija sa osnovama fitocenologije. Naučna knjiga, 576 str., Beograd.
- Martin, R.E., G.P. Asner, L.P. Bentley, A. Shenkin, N. Salinas, K.Q. Huaypar, M.M. Pilco, F.D. Ccori Alvarez, B.J. Enquist, S. Diaz, Y. Malhi, 2020: Covariance of sun and shade leaf traits along a tropical forest elevation gradient. Front Plant Sci,10:1810.
- Mori A., H. Takeda, 2004: Functional relationships between crown morphology and within-crown characteristics of understory saplings of three codominant conifers in a subalpine forest in central Japan. Tree Physiol, 24(6):661-670.
- Nikolić, M.B., A.M. Stefanović, M.M. Veselinović, D.S. Milanović, D.K. Mladenović, Ž.S. Mitrović, M.S. Eremija, B.Lj Rakonjac, 2019: Needle morpho-anatomy and pollen morpho-physiology of selected conifers in urban conditions. Appl Ecol Env Res, 17(2):2831-2848.
- Osada, N., 2012: Crown exposure to light and tree allometry of 11 tree species in a snowy cool-temperate forest in Japan. Plant Ecol, 213(5):783-794.
- Robakowski, P., T. Wyka, S. Samardakiewicz, D. Kierzkowski, 2004: Growth, photosynthesis and needle structure of silver fir (*Abies alba* Mill.) seedlings under different canopies. For Ecol Manage, 201(2-3):211-227.
- Shenkin, A., B. Bolker, M. Peña-Claros, J.C. Licona, N. Ascarrunz, F. E. Putz, 2018: Interactive effects of tree size, crown exposure and logging on drought-induced mortality. Philos Trans R Soc B, 373:20180189.
- Tyukavina, O. N., N. A. Neverov, D. N. Klevtsov, 2019a: Influence of growing conditions on morphological and anatomical characteristics of pine needles in the northern taiga. J For Sci, 65(1):33-39.
- Tyukavina, O. N., N. A. Neverov, A. L. Mineev, 2019b: Variations in the length of Scots pine (*Pinus sylvestris* L.) needles under the influence of climatic factors and solar activity in different conditions of northern taiga. J For Sci, 65(8):313-320.
- Vukićević, E. 1982: Dekorativna dendrologija. Univerzitet u Beogradu, 781 str., Beograd.
- Wyckoff, P.H., J.S. Clarck, 2005: Tree growth prediction using size and exposed crown area. Can J For Res, 35(1):13-20.

SAŽETAK

Analizirano je 66 stabala devet vrsta četinjača: atlaskog cedra, crnog bora, bodljikave smreke, duglazije, obične smreke, šumske tise, Pančićeve omorike, koloradske jele i obične jele, iz šest beogradskih parkova. Analizirano je pet iglica sa svake od četiri glavne ekspozicije krošnje. Ispitivana je duljina, širina, površina i opseg iglica. Vrste, parkovi u kojima su pronađene, kao i ekspozicije njihovih kruna, razlikovali su se po duljini i širini iglica. Korelacije između izmjerenih svojstava iglica određene su linearnom regresijskom analizom. Utvrđene su jake pozitivne korelacije između duljine, opsega i površine iglica. Razlike među vrstama u zahtjevima za svjetlom određuju vrste za pojedinačnu sadnju kao vrste koje vole svjetlo ili polusjenu (atlaski cedar, obična smreka, Pančićeva omorika, bodljikava smreka, crni bor i duglazija) ili za grupnu sadnju kao sjenoljubne vrste (obična jela, dugoigličava jela i šumska tisa).

KLJUČNE RIJEČI: četinjače, korelacije, izloženost, morfologija iglica, parkovi.