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INTERPOPULATION GENETIC-ECOLOGICAL VARIATION OF SCOTS PINE *(Pinus sylvestris L.)* IN SERBIA

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The genetic-ecological variation of Scots pine (*Pinus sylvestris* L.) in Serbia was studied in the populations at five localities in western and south-western Serbia. Three groups of Scots pine (*Pinus sylvestris* L.) populations were differentiated based on genetic research (seed protein analysis) and plant community research. The first group consists of Scots pine populations on Šargan (FMU "Šargan") and on Tara (FMU "Kaluđerske Bare"), where the forests belong to the community of Scots pine and Austrian pine (*Pinetum sylvestris-nigrae* Pavlović 1951). The second group covers the localities Stolovi (FMU "Radočelo-Crepuljnik")

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and Zlatar (FMU "Zlatar I"), where the forests belong to the community of Scots pine and spruce (*Piceo abietis-Pinetum sylvestris* Stefanović 1960). The third group comprises the Scots pine population on Pešter (FMU "Dubočica-Bare") which belongs to the community of Scots pine with erica (*Erico-Pinetum sylvestris* Stefanović 1963). Cluster analysis was performed on the basis of seed protein data and showed that there are three groups of Scots pine populations. The three populations coincide with plant communities. The community of Scots pine with erica (*Erico-Pinetum sylvestris* Stefanović 1963) recorded on Pešter at the locality "Dubočica-Bare" in the area of FE "Golija" Ivanjica, is a special Scots pine population displayed at the greatest distance from all other populations in the cluster analysis dendrogram.

Key words: Pinus sylvestris, proteins, plant communities

INTRODUCTION

In the growing stock of Serbia, pines (genus: *Pinus* L.) have a significant position among coniferous species both by representation and by economic significance. They are: Austrian pine (*Pinus nigra* Arnold), Scots pine (*Pinus silvestris* L.), white-bark pine (*Pinus heldreichii* Crist), Balkan pine (*Pinus peuce* Grsb.) and mountain pine (*Pinus mugo* Turr.). Of the above pine species, Austrian pine (*Pinus nigra* Arnold), and Scots pine (*Pinus silvestris* L.) are the most represented. Scots pine populations are most represented in western and south-western Serbia, on the mountain massifs: Povlen, Maljen, Tara, Mokra Gora, Šargan, Ozren (near Sjenica), Zlatibor, Zlatar, Radečelo, Gola Brda-Ponor (between Priboj and Pljevlja). They are much less represented in central Serbia (on Kopaonik) and in southern Serbia (on Šar Planina).

The Scots pine and Austrian pine characteristics of with the highest general biological and applicative significance in forestry, are: high genetic potential and genetic variation, taxonomic complexity, and the species adaptability. In general, conifers are characterised by a very high level of genetic variability, HAMRICK (1979), the potential factors of which are: a) long life, free pollination with high fertility, and b) divergent selection for macro-micro geographical adaptation. According to SCALTSOYIANNES *et al*. (1994), pine is characterised by high total variation due to intra-population genetic variability, which points to a significant genetic differentiation in local populations and to the possibility that the same alleles are distributed throughout the entire range of the species.

Thanks to the successful tree growth and development and the survival of Scots pine and Austrian pine populations on the lands characterised by unfavourable soil conditions (shallow, skeletal soils of low fertility) and climate conditions (deficit and unfavourable precipitation regime over the growing season), these species are used in reclamation and erosion-control afforestation. The fact that pines thrive over large areas affected by erosion processes, or on completely degraded and denuded areas on which they produce excellent results, makes them economically the most important species used in forestry. All the above qualities, in addition to a vast natural range of distribution and a disjunctive range, led to their intensive

introduction also to the sites outside their natural range. This resulted in a high number of subspecies, varieties and transitive forms. The result of this natural variation is a high genetic potential which produces the basis and the potential for successful breeding.

A synthetic survey of the complex (belt) of thermophilous pine forest types on basic parent rocks in Serbia was reported by JOVIĆ and TOMIĆ in 1985. The authors classified the belt into the lower coeno-ecological groups and described 40 ecological units. This research is the base for the interventions in both natural and artificial stands and in the afforestation of bare lands.

The organisation of production and the control of seed trade requires the knowledge on the potential and spontaneous variation of traits which more or less affect the Scots pine generative reproduction and yield. The orientation to the desirable qualities of seeds and planting material for afforestation programmes requires the abandoning of the technology of seed and planting material production at the level of a species, because its quality is difficult to guarantee. The success of these activities includes the designation and limitation of the areas in which the new selections or provenances will be used. The advancement of the concepts of nursery production, i.e. the trend of abandoning the planting stock production at the species level (TUCOVIĆ *et al.,* 1990*,* ISAJEV *et al., 1998,* MATARUGA *et al., 1998*) requires a better understanding of the genetic potential of Scots pine populations, in order to improve the seed and seedling production, and in this way also the success of afforestation and the establishment of specific-purpose plantations.

A significant contribution to the study of the genetic potential of the genus Pinus in Serbia, using molecular and biochemical markers, was given by LUČIĆ, *et al.,* (2008), ISAJEV *et al*. (2008), ISAJEV, V., *et al.,* (2009) and.LUČIĆ *et al* (2010). The above studies provided the base for the conservation and utilization of the genetic resources of the analysed tree species.

MATERIALS AND METHODS

The analysis of genetic-ecological characteristics of Scots pine (*Pinus sylvestris* L.) populations in a part of its range in Serbia enhanced the knowledge on its bio-ecological characteristics and the genetic potential. The study of Scots pine qualities at the level of the selected populations, is significant for their directed utilisation in the production of seeds and seedlings of desired qualities.

The research included five Scots pine populations, at different locations in western and south-western Serbia, where Scots pine forms its most wide-spreading forests. The spatial distribution of the study seed stands is presented in Figure 1.

Figure 1: Spatial distribution of the study Scots pine (Pinus sylvestris L.) populations

Legend:
P1 - FMU "Dubočica-Bare" FE "Golija" Ivanjica
P2 - FMU "Šargan" FE "Užice" Užice
P3 - FMU "Radočelo-Crepuljnik" FE "Stolovi" Kraljevo
P4 - FMU "Kaluđerske Bare" N.P. "Tara" Bajina Bašta
P5 - FMU "Zlatar I" FE "Prijepolje" Prijepolje

The coenological characteristics of the designated seed stands were researched using the plant community methods. Plant community research in the field resulted in 24 relevés, classified in three Plant Community Tables (Tables 1, 2 and 3).

The research was performed using the floristic system by Braun-Blanquet method. Plant species were determined based on the Flora of Serbia (JOSIFOVIĆ, M.,

1970-1986) and "Ikonographie der flora des südöstlichen Mitteleuropa" (JÁVORKA, S., CSAPODY, V., 1979). Syntaxon names were given after TOMIĆ, 2006.

In each population at the selected localities, the seeds were collected by felling 8 to 15 test trees. Averagely 100 cones were collected from each marked tree, and the seeds were processed and grouped by trees. The bulk sample for biochemical analysis was made by taking 15 seeds from each analysed pine tree. Protein isolation was performed according to WANG *et al.* (1994) and SDS-polyacrylamide gel electrophoresis following the method of LEAMMLI (1970). Qualitative and quantitative differences (number and distribution) in protein fractions were determined based on the electrophoregrams. Coefficients of similarity were calculated using SOKAL and MICHENER (SM) (1958) method.

Sokal and Michener $\mathbf{GS_{ij} = a+d/a+b+c+d}$

where:
a - band presence in both genotype *i* and *j* (1.1)
b - band presence in genotype *i* and absence in genotype *j* (1.0)
c - band presence in genotype *j* and absence in genotype *and* (0.1)
d - band absence in both genotype *i* and genotype *j* (0.0)

The computing of the coefficient of genetic similarity after Sokal and Michener takes into account also the band absence in both genotypes (component d) and for this reason it was applied in this study. The coefficients of similarity and cluster analysis were computed using NTSYS-pc software (ROFHL, *2000*)**.**

RESULTS

The plant community research shows that Scots pine in the study area forms three forest communities, i.e.: association of Austrian pine and Scots pine (*Pinetum sylvestris-nigrae* PAVLOVIĆ 1951), association of Scots pine and erica (*Erico-Pinetum sylvestris* STEFANOVIĆ 1963) and association of Scots pine and spruce (*Piceo abietis-Pinetum sylvestris* STEFANOVIĆ 1960).

The community of Scots pine and Austrian pine (*Pinetum sylvestris-nigrae* PAVLOVIĆ 1951) was studied on Tara (FMU "Kaluđerske Bare") and on Šargan (FMU "Šargan"). It was recorded at the altitude range from 1000 to 1110 m, almost on all aspects, on steep to very steep slopes (15-35º).

Table 1: Phytocoenological Table of the community of Scots pine and Austrian pine

Association	***Pinetum sylvestris-nigrae*** Pavlović 1951										
Locality	Tara					Šargan					
Management unit	Kaluđerske Bare					Šargan					
Relevé number	1a	1b	1c	1d	1e	2a	2b	2c	2d	2e	
Compartment	1	1	1	1	1	25	25	25	25	25	
Elevation (m)	1030	1020	1010	1005	1000	1110	1105	1100	1090	1086	
Aspect	NW	S	S	SW	SW	NNE	N	N	N	N	
Slope (○)	15	35	25	25	30	20	25	20	25	15	
LAYER I											
Canopy	0.6	0.6	0.7		0.6	0.7	0.7	0.8	0.7	0.7	
Mean height (m)	35	25	22		22	25	23	22	19	19	**Degree of presence**
Mean diameter (cm)	45	40	35			30	27	28	29	30	
Mean distance (m)	6	6	5			4	5	4	5	5	
Pinus sylvestris	2.3	1.2	1.2	1.1	4.4	5.5	4.4	4.4	4.4	4.4	V
Pinus nigra	2.3	3.3	3.3	4.4	1.1	1.1	1.2	1.1	1.2	1.2	V
Picea abies								+			I
LAYER II											
Canopy	0.3	0.1	0.3	0.3	0.1	0.2	0.1	0.1	0.2	0.1	
Mean height (m)	5	3	5	3	3	4	2	2	2	3	
Pinus nigra	3.2	+.2	2.3	2.2	+				1.1	1.1	IV
Sorbus aucuparia		1.2				2.3	+	1.2	1.2		III
Pinus sylvestris	3.2				+	+					II
Crataegus monogyna	+										I
Abies alba		+									I
Juniperus communis					+						I
Rosa pendulina					+.2						I
Picea abies								+			I
LAYER III											
Degree of coverage	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	
Erica carnea	4.4	2.3	5.5	5.5	2.2	+.2	+.2	+.2	+.2	+.2	V
Calamagrostis varia	3.3	1.2	1.2	1.2	2.3	3.3	2.2	5.5		5.5	V
Sesleria serbica		5.5		+.2	3.3	+.2	5.5	+	5.5	1.2	IV
Sorbus aucuparia	R		+	+		+	+.2		+	+	IV
Deschampsia flexuosa	1.2				1.2	+.2	1.2	+.2	+.2	+	IV
Symphytum tuberosum	+				+	+	+	+	+	+	IV
Pteridium aquilinum	1.3	+				4.4		+.2		+.2	III
Daphne blagayana	1.2	1.2	1.2	1.2	1.2						III
Campanula persicifolia	+	+	+		+		+			+	III
Anemone nemorosa		+			+	+	+		+		III
Vaccinium myrtillus					1.2	1.2	1.2	+.2	1.2	+.2	III
Brachypodium pinnatum					2.2	1.2	+.2	1.2		+.2	III
Potentilla alba	1.2	+.2	+.2		+.2					+	III
Vicia cracca	+		+	+	+				+		III
Galium schultesii		+					+.2	+		+	II
Galium vernum	+	+			+						II
Euphorbia cyparissias	+.2		+.2	+							II

Stachys scardica	+.2	+.2		+							II
Aremonia agrimonioides	+		+	+						+	II
Chrysanthemum corymbosum	r							+		+	II
Quercus dalechampii	+.2		+						+		II
Trifolium alpestre	+			+	+						II
Dorycnium germanicum	+.2		1.2	+							II
Galium verum	+				+		+			+	II
Genista tinctoria	+			+			+.2			+	II
Gentiana asclepiadea						+	+	+			II
Euphorbia amygdaloides						+			+	+	II
Knautia dipsacifolia						+	+	+			II
Rosa pendulina		+.2			+	+					II
Laserpitium marginatum						+		+		+	II
Hypericum barbatum		+		+							I
Chamaecytisus hirsutus			+.2	+.2							I
Potentilla heptaphylla				+					+		I
Tanacetum corymbosum					r	+					I
Luzula sylvatica						+.2	+.2				I
Epimedium alpinum								+		+	I
Filipendula hexapetala	+.2	+									I
Rosa spinosissima	+.2	+.2									I
Leucanthemum vulgare										+	I
Hieracium transsilvanicum		+				+					I
Muscari botryoides				1.2	+						I
Peucedanum carvifolia								+	+		I

Companions occurring in one relevé in ground flora layer: *Genista pilosa* 2.2, *Lotus corniculatus* +.2, *Thymus pulegioides* +.2, *Poa nemoralis* +.2, *Festuca ovina* +.2, *Aquilegia vulgaris* +, *Scabiosa columbaria* +, *Prunus avium* +, *Euphorbia glabriflora* +, *Peucedanum officinale* +, *Prenanthes purpurea* +, *Luzula luzuloides* +, *Abies alba* +, *Melittis melysophyllum* +, *Galium tenuissimum* +, *Rubus hirtus* +, *Galium lucidum* +, *Galium purpureum* +, *Silene vulgaris* +, *Centaurea phrygia* + and *Phyteuma orbiculare* +.

The floristic composition (Table 1) of the community of Scots pine and Austrian pine (*Pinetum sylvestris-nigrae* PAVLOVIĆ 1951) is characterised by the following: spruce (*Picea abies* Karst.) is recorded only in one stand in addition to the edificators (Austrian pine and Scots pine) in the tree layer. In the shrub layer, Austrian pine is more dominant than Scots pine in most stands. In addition to the two pine species, the percentage of mountain ash (*Sorbus aucuparia*) is rather high, and in individual stands there are: fir (*Abies alba*), spruce (*Picea abies*), juniper (*Juniperus communis*), one-seed hawthorn (*Crataegus monogyna*), and alpine rose (*Rosa pendulina*). The ground flora layer is well developed, and the dominant species are *Erica carnea* and *Calamagrostis varia*. The following species have the degree of presence IV: *Sesleria serbica*, *Sorbus aucuparia*, *Deschampsia flexuosa* and *Symphytum tuberosum*.

The community of Scots pine with erica (*Erico-Pinetum sylvestris* Stefanović 1963) was studied on Pešter, at the site "Dubočica-Bare" in the area of FE "Golija" Ivanjica. Plant communities were researched in five 5 relevés and classified in the Phytocoenological Table (Table 2). The community ranges at the altitudes between 1260 and 1280 m, on northern and north-western aspects, medium steep to steep slopes (10-25º).

Table 2 shows that Scots pine (*Pinus sylvestris*) is dominant in the tree layer, and there are also sporadical spruces (*Picea abies* Karst.) of low abundance and coverage. Fir (*Abies alba*) occurs only in one stand, Austrian pine (*Pinus nigra*) also in one stand. In the shrub layer, in addition to Scots pine, juniper (*Juniperus communis*) occurs in all stands. The shrub layer also comprises: spruce (*Picea abies*), wild pear (*Pyrus pyraster*), alpine rose (*Rosa pendulina*), fir (*Abies alba*), Scotch rose (*Rosa spinosissima*), and one-seed hawthorn (*Crataegus monogyna*). The ground flora layer is well developed, and the following species have the highest degree of presence: *Erica carnea*, *Pteridium aquilinum*, *Vaccinium myrtillus*, *Sorbus aria* and *Rosa pendulina*.

The community of Scots pine and spruce (*Piceo abietis-Pinetum sylvestris* Stefanović 1960) was studied at two localities: Radočelo (FMU Radočelo-Crepuljane) and Zlatar (FMU Zlatar I). It ranges at the altitudes from 1205 to 1250 m, primarily on cooler aspects, on gentle to medium steep slopes (3-20º).

Table 3 shows that the tree layer in all stands consists of both Scots pine (*Pinus sylvestris*) and spruce (*Picea abies*). Fir (*Abies alba*) occurs sporadically, and birch (*Betula pendula*) grows in one stand. The shrub layer is medium developed (canopy ranges from 0.2 to 0.4), and spruce (*Picea abies* Karst.) is dominant compared to Scots pine (*Pinus sylvestris*). The ground flora layer is well developed, and the dominant species (with the degree of presence V) is blueberry (*Vaccinium myrtillus*), followed by (with the degree of presence IV) spruce (*Picea abies* Karst.) and alpine rose (*Rosa pendulina*).

Table 2: Phytocoenological Table of the community of Scots pine and erica

Association	***Erico-Pinetum sylvestris*** Stefanović 1963					
Locality	Pešter					
Management unit	Dubočica-Bare					
Relevé number	1a	1d	1b	1c	1e	
Compartment	60	60	60	60	60	
Elevation (m)	1260	1260	1280	1270	1265	
Aspect	N	N	NW	N	-	
Slope (◦)	25	10	15	18	-	
LAYER I						
Canopy	0.6	0,5	0.6	0.6	0.5	**Degree of**
Mean height (m)	19	22	15	22	17	**presence**
Mean diameter (cm)	30	40	25	35	40	
Mean distance (m)	5	7	6	5	6	
Pinus sylvestris	4.5	2.2	4.5	5.5	5.5	V
Picea abies		1.2		+	1.1	III
Pinus nigra	1.1					I
Abies alba		1.1				I
LAYER II						
Canopy	0.2	0.4	0.2	0.4	0.3	
Mean height (m)	3	4	2	3	4	
Juniperus communis	2.3	2.2	3.1	2.1	1.2	V
Pinus sylvestris	1.1	1.1	1.1	+	+	V
Picea abies	1.1	1.2	+	2.2		IV
Pyrus pyraster		1.1		+		II
Rosa pendulina		1.2			+.2	II
Abies alba		+.2				I
Rosa spinosissima					+.2	I
Crataegus monogyna					+	I
LAYER III						
Degree of coverage	1.0	1.0	1.0	1.0	1.0	
Erica carnea	3.3	1.2	3.3	3.3	2.2	V
Pteridium aquilinum	1.2	1.2	+.2	2.3	2.2	V
Vaccinium myrtillus	1.2	2.3	1.3	2.3	2.3	V
Sorbus aria	+	+	+	+	+	V
Rosa pendulina	+.2	1.2	+	+.2	2.2	V
Lotus corniculatus	+	+	+	+	+	V
Brachypodium pinnatum	2.3	2.2	2.3		2.3	IV
Trifolium alpestre	+.2	+	+.2		+.2	IV
Dactylis glomerata	+	+	+		+	IV
Sesleria serbica	1.2		+.2	2.2		III
Daphne blagayana	2.3		2.3	3.2	3.2	IV
Stachys scardica	+.2		+.2	+.2	+.2	IV
Symphytum tuberosum	+	+			+	III
Anemone nemorosa	+	+			+.2	III
Aremonia agrimonioides	+	+		+		III
Euphorbia amygdaloides	+		+	+		III

Campanula persicifolia	+			+	+	III
Knautia arvensis			+.2	+	+	III
Vicia cracca	+	+				II
Chamaecytisus hirsutus	+		+.2			II
Campanula patula	+		+			II
Festuca heterophylla	2.3			1.2		II
Filipendula hexapetala	+			+		II
Briza media	1.2				+.2	II
Bupleurum sibthorpianum		+		+		II
Pyrus pyraster		+			+	II
Laserpitium marginatum		+			+	II
Veronica officinalis			+	+.2		II
Poa nemoralis			1.3		1.2	II
Dorycnium germanicum			+.2		+.2	II
Potentilla erecta			+		+	II
Fragaria vesca			r		+	II
Calamagrostis varia				2.2	+	II

Companions occurring in one relevé in ground flora layer: *Rosa spinossisima* 1.2, *Genista sagitallis* 1.2, *Deschampsia flexuosa* 1.2, *Rubus hirtus* +.2, *Juniperus communis* +.2, *Picea abies* +.2, *Thymus pulegioides* +.2, *Genista ovata* +.2, *Knautia arvensis* +.2, *Knautia dipsacifolia* +, *Euphorbia amygdaloides* +, *Platanthera bifolia* +, *Galium purpureum* +, *Peucedanum carvifolia* +, *Lilium martagon* +, *Prunus avium* +, *Corylus avellana* +, *Lathyrus pratensis* +, *Sorbus aucuparia* +, *Abies alba* +, *Salix caprea* +, *Betula pendula* +, *Achillea milefolium* +, *Veronica teucrium* +, *Solidago virgaurea* +, *Solidago virgaurea* +, *Trifolium medium* +, *Galium schultesii* +, *Chrysanthemum corymbosum* +, *Crataegus monogyna* + and *Cotoneaster intergerimus* +.

Table 3: Phytocoenological Table of the community of Scots pine and spruce

Association	***Piceo abietis-Pinetum sylvestris*** Stefanović 1960									
Locality	Radočelo-Divan				Zlatar					
Management unit	Radočelo-Crepuljane				Zlatar I					
Relevé number	3a	3b	3v	3g	7a	7b	7v	7g	7d	
Compartment	4	4	4	4	22	22	22	22	22	
Elevation (m)	1205	1205	1200	1210	1235	1235	1240	1245	1250	
Aspect	NE	N	-	N	ESE	E	NW	W	NW	
Slope (◦)	20	15	-	15	5	10	3	5	7	
LAYER I										
Canopy	0.6		0.6	0.8	0.6	0.7	0.7	0.6	0.8	**Degree of presence**
Mean height (m)	25		20	25	25	25	22	25	28	
Mean diameter (cm)	22		17	32	45	40	37	37	40	
Mean distance (m)	4		5	3	3	6	5	5	4	
Pinus sylvestris	4.4	2.2	5.5	1.1	1.1	1.1	1.2	1.2	1.2	V
Picea abies	+	3.3	1.1	3.3	3.4	4.4	4.4	4.4	5.5	V
Abies alba	1.2	1.1		1.2						II
Betula pendula	+									I
LAYER II										
Canopy	0.3	0.4	0.2	0.3	0.3	0.4	0.3	0.4	0.4	
Mean height (m)	4	3		4	4	5	4	5	3	
Picea abies	1.2	1.2		1.2	2.3	3.3	3.3	3.3	4.4	V
Abies alba	1.1	1.2	1.1	1.2						III
Rosa pendulina	1.2	+.2		+						II
Juniperus communis	+		1.2						+	II

Pinus sylvestris	1.2				1.1					II
Corylus avellana					+.2	+		1.2		II
Fagus moesiaca		+	+	1.1						II
Lonicera xylosteum					1.1		1.1			II
Sorbus aucuparia		+								I
Prunus avium					+					I
Daphne mezereum					+					I
Viburnum lantana					+					I
Lonicera nigra							+			I
Sorbus aria								+		I
LAYER III										
Degree of coverage	1.0	1.0	1.0	0.9	0.9	0.8	0.9	0.9	0.9	
Vaccinium myrtillus	3.2	4.4	1.2	3.3	3.4	2.2	3.3	2.3	3.3	V
Rosa pendulina	1.2	1.2		+	+.2	1.2	+	+.2		IV
Picea abies	+.2	+		1.2	1.2		+.2	1.3	1.2	IV
Pyrola secunda	+	+.2	+.2	+.2		+				III
Brachypodium silvaticum	3.4	3.3	5.5		2.2	1.2				III
Knautia dipsacifolia	+	+	+		+	+				
Trifolium alpestre	+	+	+		+.2				+	III
Galium schultesii	+.2	+	+.2					+.2		III
Pteridium aquilinum	1.2	2.3	1.2						+.2	III
Galium cruciata	+	+.2			+.2			+.2		III
Melampyrum silvaticum	+		+				+	1.2	+.2	III
Anemone nemorosa	+			+	+	+		+.2	+.2	III
Euphorbia amygdaloides	+				+	+	+	+	+	III
Corylus avellana	+				+	+	+		+	III
Daphne blagayana	+				+.2	+		+.2		II
Sorbus aucuparia	+				+		+	+		III
Campanula persicifolia		+	+	+	+			+	+	III
Fragaria vesca			+	+	+	+	+	+		III
Carex digitata				+.2	+.2	+	+.2	+.2		III
Sanicula europaea				1.2	+.2		+.2	+		III
Aremonia agrimonioides					+	+	+.2	+	+.2	III
Galium rotundifolium					1.2	1.2	1.2	+.2	1.2	III
Daphne mezereum					+	+	+	+	+	III
Hieracium murorum					+	+	+	+	+	III
Lonicera xylosteum					+.2	+.2		+.2	+.2	III
Brachypodium pinnatum	2.3	+.2					1.2			II
Luzula sylvatica	+.2	+.2								II
Betula pendula	+	+		+						II
Symphytum tuberosum	+	+							+	II

Pinus sylvestris	+				+					II
Deschampsia flexuosa		1.2	+		1.2					II
Festuca drymeia		+		+.2						II
Gentiana asclepiadea		+.2			+					II
Salix caprea		+			+			+		II
Abies alba		+			+				+	II
Musci ssp.		1.3				2.3	3.3			II
Vicia cracca			+		+					II
Veronica officinalis				+	+				+	II
Laserpitium marginatum				+			+		+	II
Helleborus odorus					+	+	+			II
Asarum europaeum					1.2	1.2		+.2		II
Lonicera nigra					+	+.2				II
Lilium martagon					+	+				II
Mycelis muralis					+	+		+	+	II
Viola sylvestris					+	+			+.2	II
Calamintha vulgaris					+	+		+		II
Dactylis glomerata					+.2		+.2	+.2		II
Poa nemoralis					+		2.3	2.3		II
Campanula patula					+		+		+	II
Carex pendula					+.2			+.2		II
Leucanthemum vulgare					+		+			II
Hypericum maculatum					+			+		II
Polygonatum verticillatum					+				+.2	II
Prunus avium						+	+	+		II
Oxalis acetosella						1.2	2.3		2.3	II
Phyteuma spicatum						+			+	II
Potentilla erecta								+	+	II
Digitalis ambigua								+	+	II

Companions occurring in one relevé in ground flora layer: *Melampyrum pratense* +.2, *Lamiastrum galeobdolon* +.2, *Stachys scardica* +.2, *Chamaecytisus hirsutus* +.2, *Festuca heterophylla* +.2, *Fagus moesiaca* +.2, *Polypodium vulgare* +.2, *Carex silvatica* +.2, *Moehringia muscosa* +.2, *Luzula luzulina* +.2, *Rubus hirtus* +.2, *Genista saggitalis* +.2, *Luzula luzuloides* +.2, *Laserpitum siler* +, *Geum rivale* +, *Genista ovata* +, *Filipendula hexapetala* +, *Lotus corniculatus* +, *Lathyrus pratensis* +, *Galium pseudoaristatum* +, *Peucedanum carvifolia* +, *Sorbus aria* +, *Epilobium angustifolium* +, *Epilobium montanum* +, *Geranium robertianum* +, *Helianthemum nummularium* +, *Stachys officinalis* +, *Hypericum umbellatum* +, *Ribes grossularia* +, *Danaa cornubiensis* +, *Galium purpureum* +, *Leontodon crispus* +, *Hieracium transsilvanicum* +, *Heracleum sphondilium* +, *Viburnum lantana* +, *Stachys silvatica* +, *Potentilla micrantha* +, *Clematis vitalba* +, *Alchemilla hybrida* +, *Aegopodium podagraria* +, *Chaerophyllum aureum* +, *Trifolium medium* +, *Pinus sylvestris* +, *Hieracium villosum* + and *Ajuga reptans* +.

The polymorphism of protein markers between Scots pine populations was determined based on the selected genotypes within each population. The genetic similarity, i.e. dissimilarity between the chosen genotypes were determined by cluster analysis.

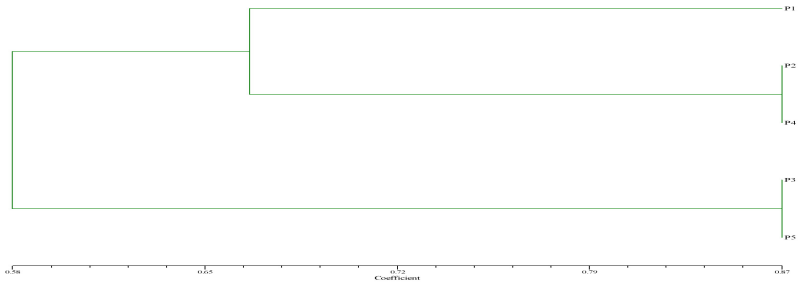

Diagram 1. Cluster analysis dendrogram of Scots pine populations after Sokal and Michener

The dendrogram obtained from cluster analysis consist of two subclasters and the separate population **P1**, with a loose linkage. One subcluster consists of the populations **P2** and **P4** and the other one consists of the populations **P3** and **P5**.

The Scots pine dendrogram shows clearly that the populations **P3** (FMU "Radočelo-Crepuljnik" FE "Stolovi" Kraljevo) and **P5** (FMU "Zlatar I", FE "Prijepolje", Prijepolje) occur at the smallest genetic distances, and also **P2** (FMU "Šargan", FE "Užice" Užice) and **P4** (FMU "Kaluđerske Bare", NP "Tara", Bajina Bašta). Population **P1** (FMU "Dubočica Bare" FE "Golija" Ivanjica) is more closely linked to populations **P2** and **P4** than to **P3** and **P5.**

DISCUSSION

The plant community research points out the similarities and differences between the communities with Scots pine (*Pinus sylvestris*) as the main species.

In all three communities with Scots pine, there are 30 common plant species, which amounts to only 1/5 of the recorded plant species. These plant species are not uniformly represented in all three communities, e.g. blueberry (*Vaccinium myrtillus*), as an acidophilous species, is far more represented (with the degree of presence V) in the communities of Scots pine and spruce (*Piceo abietis-Pinetum sylvestris* STEFANOVIĆ 1960) and Scots pine with erica (*Erico-Pinetum sylvestris* STEFANOVIĆ 1963).

TOMIĆ (2006) reports that Austrian pine and Scots pine forest (*Pinetum sylvestris-nigrae* PAVLOVIĆ 1951) occurs most often as a transitory community at the boundaries of the altitudinal ranges of Austrian pine and Scots pine with their alternating predominance, which is the case also in the study stands on Tara and Šargan. The altitudinal range after TOMIĆ ranges from 1000 to 1400 m which agrees with this research. The community of Austrian pine and Scots pine (*Pinetum sylvestris-nigrae* PAVLOVIĆ 1951) and the community of Scots pine with erica (*Erico-Pinetum sylvestris* STEFANOVIĆ 1963), in addition to common species for all three communities, also have 8 common species which are not recorded in the community of Scots pine and spruce (*Piceo abietis-Pinetum sylvestris* STEFANOVIĆ

1960). These plant species are characteristic for pine forests. They are: *Erica carnea*, *Calamagrostis varia*, *Sesleria serbica*, *Deschampsia flexulosa*, *Dorycnium germanicum*, *Chrysanthemum corymbosum*, *Rosa spinossisima* and *Thymus pulegioides*.

The community of Austrian pine and Scots pine (*Pinetum sylvestris-nigrae* PAVLOVIĆ 1951) and the community of Scots pine and spruce (*Piceo abietis-Pinetum sylvestris* Stefanović 1960) in addition to common species for all three communities also have 9 common species which are not recorded in the community of Scots pine with erica (*Erico-Pinetum sylvestris* Stefanović 1963). They are: *Gentiana asclepiadea*, *Hypericum barbatum*, *Luzula sylvatica*, *Leucenthemum vulgare*, *Phyteuma orbiculare*, *Hieracium transsilvanicum* and *Luzula luzuloides*.

In the community of Austrian pine and Scots pine (*Pinetum sylvestris-nigrae* PAVLOVIĆ 1951) there are 23 plant species which do not occur the other two communities in which Scots pine is the edificator. Among them, there are some typical basophilous species, such as: *Potentilla alba*, *Potentilla heptaphylla*, *Galium vernum*, *Galium verum*, *Galium temuissium*, *Galium lucidum*, *Euphorbia cyparisias*, *Quercus dalechampii*, *Genista tinctoria*, *Aquilegia vulgaris*, *Scabiosa columbaria*, *Euphorbia glabriflora*, *Tanacetum corymbosum*, *Peucedanum officinale*, *Prenanthes purpurea*, *Epimedium alpinum*, *Melitis melysophyllum*, *Mercurilalis perennis*, *Festuca ovina*, *Genista pilosa*, *Muscari botryoides*, *Silene vulgaris* and *Centaurea phrygia*.

The community of Scots pine with erica (*Erico-Pinetum sylvestris* STEFANOVIĆ 1963) and the community of Scots pine and spruce (*Piceo abietis-Pinetum sylvestris* Stefanović 1960), in addition to common species for all three communities, also have 16 common species which are not recorded in the community of Austrian pine and Scots pine (*Pinetum sylvestris-nigrae* PAVLOVIĆ 1951). They are: *Sorbus aria*, *Dactylis glomerata*, *Campanula patula*, *Veronica officinalis*, *Potentilla erecta*, *Festuca heterophylla*, *Coryllus avellana*, *Lilium martagon*, *Salix caprea*, *Betula pendula*, *Trifolium medium*, *Genista sagitalle*, *Genista ovata* and *Lathyrus pratensis*.

In the community of Scots pine with erica there are 8 plant species which do not occur in the other two communities in which Scots pine is the edificator. They are: *Knautia arvensis*, *Briza media*, *Bupleurum sibtorpianum*, *Platantera bifolia*, *Achilea millefollium*, *Veronica teucrium*, *Solidago virgaurea* and *Cotoneaster integerimus.*

TATIĆ and TOMIĆ (2006) report that the community of Scots pine and spruce is formed as a transitory stage of secondary character in the region of beech-fir-spruce forests at the altitudes from 1000 to 1400 m. In the community of Scots pine and spruce (*Piceo abietis-Pinetum sylvestris* STEFANOVIĆ 1960), there are 50 plant species (as much as 1/3 of all registered species) among which also the species which characterise the spruce forests, such as: *Pyrola secunda*, *Melampyrum silvaticum*, *Galium rotundifolium*, *Galium cruciatum*, *Lonicera nigra*, *Oxalis acetosella,* etc.

The clustering of Scots pine populations in the cluster analysis of seed proteins agrees with the plant community differentiation of the same populations.

The results of seed protein analysis point to a great significance of the effect of geographic distance on the population grouping.

It can be said that the grouping of populations **P3** and **P5** in the zone of greater similarity is marked by their own geographic similarity. The same refers also to populations **P2** and **P4**. On the other hand, a specific case is the somewhat greater genetic distance of the population **P1** compared to other populations. This is explained not by a great geographic distance, but by an exceptional isolation of the population **P1** by the Pešter Plateau and also by its gravitation to Montenegro forests.

A few studies was focused on the analysis of Pinus genus protein markers (COSTA *et al.,* 1998, 1999, 2000, GERBER *et al*., 1998, PLOMION *et al.,* 1995, 1997, KONSTANTINOV *et al*., 2005, MATARUGA *et al.,* 2007). According to WANG (1991), who studied Scots pine isoenzymes in three northern Sweden populations and four Chinese populations, the mean value of genetic distance between these two groups was extremely small. A year later, SZMIDT and WANG (1992) included four Scots pine populations from Turkey and also obtained small genetic distances on the relation of Scots pine in Sweden, China and Turkey. PRUS-GLOWACKI and BERNARD (1994) analysed 13 Scots pine populations covering almost all significant localities in Europe and eastern Asia, and concluded that population grouping had not a geographical indication.

BAHRMAN (1994) draws attention to interesting results indicating the variation between the populations which are spatially isolated. Similar results were obtained by LUČIĆ (2008) in the study of Austrian pine population at almost the same localities. He points to the possible site effect on the protein complex, but he does not claim it to be the decisive factor of grouping.

However, all the above studies did not include the plant community aspect, so the impact of the environment on the differentiation of populations cannot be decided with certainty. The multi-disciplinary approach to this problem demonstrated in this paper is the first attempt to correlate directly the dependence of the protein complex and the environmental conditions expressed by plant community taxonomy.

CONCLUSION

Five Scots pine populations were studied on 5 localities in western and south-western Serbia. The variation of Scots pine populations (*Pinus sylvestris* L.) was determined based on the genetic (seed protein analysis) research and plant community research.

Based on seed protein cluster analysis, there are three groups which represent three Scots pine populations. The populations correspond to plant communities, so the community of Scots pine with erica (*Erico-Pinetum sylvestris* Stefanović 1963) at the locality "Dubočica-Bare" on Pešter in the area of FE "Golija" Ivanjica is a special Scots pine population which is separated at the greatest distance from all the study populations in the cluster analysis. The community of

Scots pine and Austrian pine (*Pinetum sylvestris-nigrae* Pavlović 1951) was studied on Kaluđerske Bare and Šargan. Based on the cluster analysis, these two sites are grouped at the smallest distance. The forest of Scots pine and spruce (*Piceo abietis-Pinetum sylvestris* Stefanović 1960) was studied on Zlatar and in FMU "Radočelo-Crepuljnik". Based on the cluster analysis, these two sites are grouped at the smallest distance.

The study of Scots pine (*Pinus sylvestris* L.) inter-population genetic-ecological variation in Serbia is multidisciplinary, it applies molecular markers and plant community analyses. The applied study methods contributed to a better understanding of genetic-ecological characteristics of Scots pine populations in a part of its range in Serbia, which is the base for further directed utilisation of the total biological potential of this species.

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MEĐUPOPULACIONA GENETIČKO-EKOLOŠKA VARIJABILNOST BELOG BORA (*Pinus sylvestriS* L.) U SRBIJI

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I z v o d

U radu su predstavljeni rezultati proučavanja genetičko-ekološke varijabilnosti belog bora (*Pinus sylvestris* L.) u Srbiji. Za istraživanja su izabrane populacije na 5 lokaliteta u zapadnoj i jugozapadnoj Srbiji. Na osnovu genetičkih (analizom proteina u semenu) i fitocenoloških istraživanja izdiferencirane su tri grupe populacija belog bora (*Pinus sylvestris* L.). Prvu grupu populacija čini beli bor na Šarganu (G.J. „Šargan“) i na Tari (G.J. Kaluđerske bare) čije šume fitocenološki pripadaju zajednici belog i crnog bora (*Pinetum sylvestris-nigrae* Pavlović 1951). Drugu grupu čine lokaliteti Stolovi (G.J. „Radočelo-Crepuljnik“) i Zlatar (G.J. „Zlatar I“) koji fitocenološki pripadaju zajednici belog bora i smrče (*Piceo abietis-Pinetum sylvestris* Stefanović 1960).Treću grupu čine populacije belog bora na Pešteru (G.J.„Dubočica-Bare“) koja fitocenološki pripada zajednici belog bora sa crnjušom (*Erico-Pinetum sylvestris* Stefanović 1963). Na osnovu dendrograma klaster analize koji je urađen prema sadržaju proteina u semenu, ustanovljene su tri grupe populacija belog bora. Te populacije se poklapaju sa fitocenozama tako da zajednica belog bora sa crnjušom (*Erico-Pinetum sylvestris* Stefanović 1963) ustanovljena je na Pešteru, na lokalitetu „Dubočica-Bare“ i na području Š.G. „Golija“ Ivanjica predstavlja posebnu populaciju belog bora koja se na dendrogramu klaster analize odvaja na najvećoj distanci od svih ostalih populacija.

Proučavanja međupopulacione genetičko-ekološke varijabilnost belog bora (*Pinus sylvestris* L.) u Srbiji, obavljena su multidisciplinarno, primenom molekularnih markera i fitocenološkim analizama. Primenjene metoda ispitivanja, omogućile su bolje upoznavanje genetičko-ekoloških karakteristika populacija belog bora u delu areala na prostoru Srbije, što je osnova za dalje usmereno korišćenje ukupnog biološkog potencijala vrste.

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