The high-altitude serpentine flora of Mt Belasitsa (Bulgaria)

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Abstract. The preliminary data on the high-mountain serpentine flora of the Mt Belasitsa was presented. The specificity of the serpentine flora is determined by the characteristics of the climate, relief and biogeohistory of the area. As a result of the investigation, 115 taxa of higher plants from 37 families and 80 genera are established. The flora is mainly composed of Submediterranean, Euroasian, and European geoelements. The presence of Oriental-Turanian geoelements is rather low but the number of alpine species is higher, as compared to other serpentine areas in Bulgaria. The endemic elements are predominantly Balkan species. Serpentine endemics were not found.

Key words: Bulgaria, flora, geoelements, Mt Belasitsa, serpentine

Introduction

Due to their physical and chemical composition, ultramafic soils (traditionally referred to as serpentine) are famous for their distinctive flora and vegetation, as compared to adjacent non-serpentine areas. Ultramafic soils are frequently shallow, deficient in nutrients, with high Mg/Ca ratio, and relatively high concentrations of potentially toxic metals, such as Ni, Cr, and Co (Proctor & Woodell 1975; Backer & al. 1992; Roberts & Proctor 1992). These characteristics support a unique serpentine flora, a flora which presents taxonomical, phytogeographical and ecological phenomena of great interest.

The influence of ultramafic soils on the speciation process and species richness has been the subject of much investigation (Kruckeberg 1984, 1992; Brooks 1987; Roberts & Proctor 1992). The high number of endemics indicates the importance of serpentine habitats as centres for floristic differentiation and speciation, and this endemism ranges from strictly local (a single outcrop) to regional and widespread occurrences (Kruckeberg 1984). Serpentine areas also appear to be important refugia for many nonendemic native species, since they are relatively little invaded by other plant communities. These unique characteristics gave us grounds to concentrate on the serpentine flora of Bulgaria. This flora distributed between 300–700 m a.s.l. in different regions of the country (Rhodopi Mts, Mt Vlahina and Mt Ograzhden) has been subject of recent studies (Pavlova & al. 2003; Pavlova 2004, 2007; Pavlova & Nedelcheva 2006), but it is still insufficiently investigated, especially at high altitudes. One such serpentine area occurs on Mt Belasitsa, which lies in Bulgaria, Greece, and Macedonia. Although the flora of Mt Belasitsa has been subject of earlier studies, the authors then have not focused on the serpentine flora. A detailed analysis of the flora and vegetation of that mountain was published by Stojanov (1921). Although the author has mentioned the presence of serpentine rocks around peak Demir Kapiya in the western and southern parts of the mountain, the serpentine flora was not studied. New data about the vascular flora of forest and shrubland communities of Mt Krousia and Mt Beles (Belasitsa) were provided by Fotiadis & Athanasiadis (2008), but their study did not mention the presence of a serpentine terrain in the southern part of Mt Belasitsa and did not focus on the high-altitude flora and vegetation. Other earlier works include a survey of the vegetation and flora of Southwest Bulgaria, including Mt Belasitsa (Velchev & Tonkov 1986) and data on the flora of the Bulgarian part of the mountain in terms of new floristic records (Kostadinova & Dimitrov 2002).

A primary floristic analysis is therefore essential in order to better understand the origin and specificity of the serpentine flora of Mt Belasitsa and its relation to similar floras in other parts of the Balkan Peninsula. Geographic isolation by altitude in high mountains and edaphic differentiation by soil types may underlie plant endemism in such regions (Médail & Quézel 1997). Serpentine outcrops can be regarded as inland formations in mainland environments and biogeographic theory may help understand their species richness and species distribution (Kruckeberg 1991; Chiarucci & De Dominicis 2001; Selvi 2007).

The aim of the paper is to present data on the composition and diversity of the high-altitude serpentine flora of Mt Belasitsa, including on taxonomical structure, endemism, and conservation status, and to compare the results with other serpentine regions in Bulgaria and the neighbouring Balkan countries.

Study area

Mount Belasitsa is part of the South Bulgarian mountain climatic region, with Mediterranean influence (Tishkov 1982), or the Continental-Mediterranean region (Velev 2002). This mountain region displays higher winter and summer temperatures, as compared to the other climatic regions in Bulgaria, and precipitation is characterized by an autumn-winter maximum and a summer minimum (Velev 2002).

According to the geobotanical division of Bulgaria (Bondev 2002), the study area lies in both the Balkan Province (Belasitsa) and the Macedonian-Thracian Province (Blagoevgrad region). The study area comprises two rocky, north-facing serpentine slopes located in the area of peak Demir Kapiya, at 1610 m and 1700 m respectively (Fig. 1). The serpentine areas lie within the upper part of the *Fagus* vegetation belt (Velchev & Tonkov 1986). These open habitats are dominated by subalpine floristic elements, such as *Ju-*

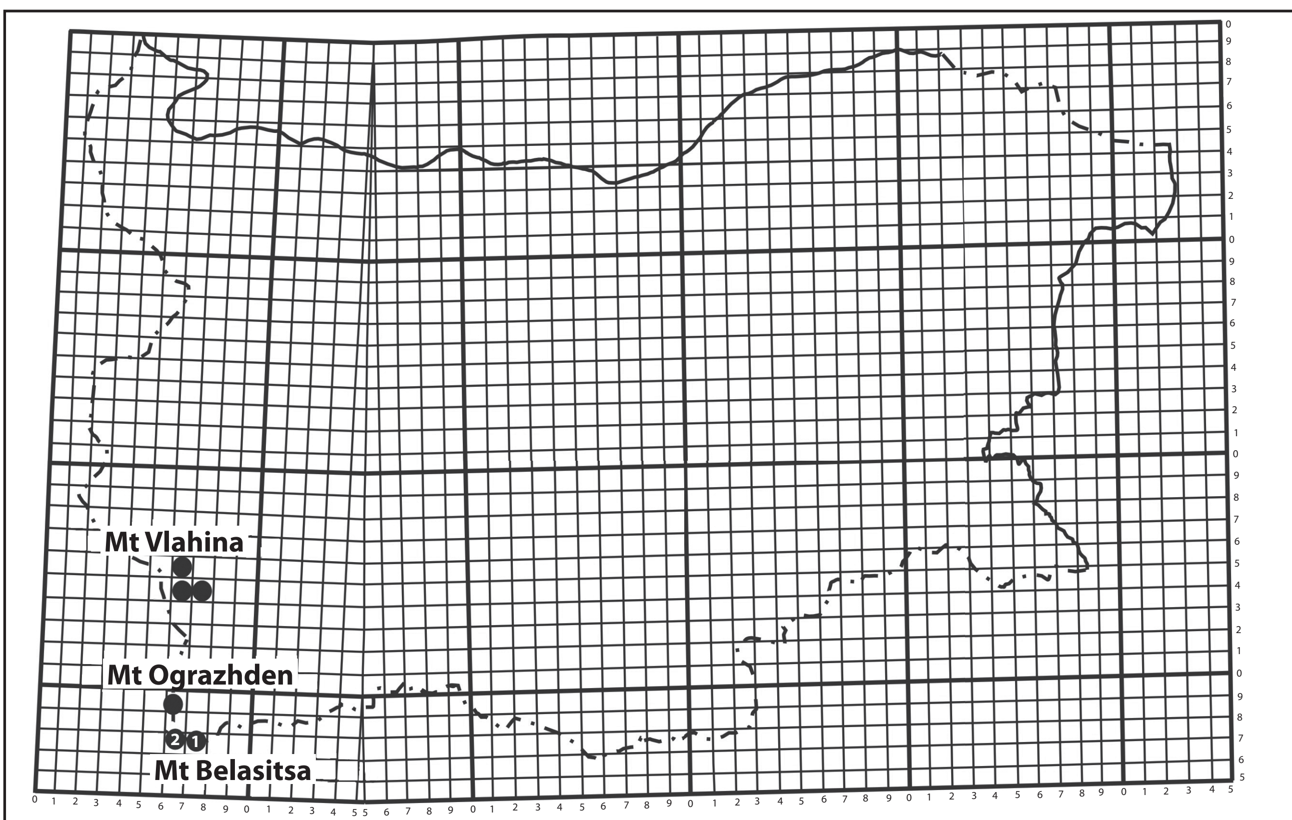

Fig. 1. UTM Grid Map of the study area.

niperus pygmaea, *Vaccinium myrtillus*, *V. uliginosum*, *Bruckenthalia spiculifolia*, *Chamaecytisus absinthioides*, *Nardus stricta, Festuca valida*, *Deschampsia cespitosa*, *Agrostis capillaris*, etc. The overall vegetation in this belt corresponds to the climatic conditions, especially to humidity (Stojanov 1921; Fotiadis & Athanasiadis 2008).

Material and methods

Fieldwork was carried out in July 2006. Plant material was collected from all serpentine bodies, which were approximately 600 m^2 each. These areas lie in quadrants FL-67 and FL–77 of the UTM grid map of Bulgaria (1: 1500000) and are designated by numbers 1 and 2 respectively (Fig. 1). The serpentine areas studied earlier in Mt Ograzhden and Mt Vlahina are also indicated. Specimens were determined according to the *Flora of Bulgaria* and *Flora Europaea*, and nomenclature follows entirely Jordanov (1963-1979), Velchev (1982-1985) and Kozhuharov (1992, 1995). Voucher specimens have been stored in the Herbarium of Sofia University (SO), and the final checklist has been added to the database of the Bulgarian Serpentine Collection, which is part of the general Herbarium collection at SO.

The list of taxa is presented in Appendix I. Site number follows each taxon name and endemic taxa are indicated by an asterisk (*). The numbers of voucher sheets deposited in the Herbarium of the Sofia University (SO) are also indicated. All taxa unknown earlier from the West Frontier Mts floristic region are marked with "N".

The geoelement characteristic of the taxa follows Assyov & Petrova (2006). The calculation of percentage values is based on the data presented by Kozhuharov (1992).

Similarity indices were calculated for all possible pairwise combinations of investigated serpentines in the West Frontier Mts (Fig. 1). The index used was: I = 2C: (A + B), where A is the total number of taxa in one mountain, B is the total number of taxa in the other, and C is the number of shared taxa.

Appendix I. List of plants

Bryophyta

Dicranaceae

Dicranum scoparium Hedw. – 2

Grimmiaceae

Racomitrum canescens Hedw. – 2

Pottiaceae

Syntrichia ruralis (Hedw.) F. Weber & D. Mohr – 1

Polytrichaceae

Polytrichum piliferum Hedw. – 2

Pogonatum urnigenum (Hedw.) P. Beauv. – 2

Polypodiophyta

Aspleniaceae

Asplenium septentrionale (L.) Hoffm. – 2; SO 104 572

A. trichomanes L. – 1, 2; SO 104 567

Ceterach officinarum DC. – 1

Aspidiaceae

Dryopteris filix-mas (L.) Schott – 2

D. carthusaiana (Vill.) H.P. Fuchs – 2

Gymnocarpium dryopteris (L.) Newman – 2; SO 104 577, 104 897

Athyriaceae

Cystopteris fragilis (L.) Bernh. – 1; SO 105 526, 105 518

Polypodiaceae

Polypodium vulgare L. – 1

Spermatophyta

Pinophytina

Cupressaceae

Juniperus pygmaea C. Koch – 1; SO 104 616

Magnoliophytina

Apiaceae

Ligusticum mutellina (L.) Crantz – 2; N; SO 104 887

Peucedanum austriacum (Jacq.) W.D.J. Koch – 2; N; SO 104 881

Seseli rigidum Waldst. & Kit. – 1

Asteraceae

Achillea coarctata Poir. – 1

A. millefolium L. – 2

Antennaria dioica (L.) Gaertn. – 1, 2; SO 104 624,104 566

Anthemis carpatica Willd. – 1, 2; SO 105 527, 105 508

A. tenuiloba (DC.) R. Fern. – 1; N; SO 105 021

Centaurea rhenana Boreau – 1; SO 105 528

C. triumfetti All. – 1; SO 104 982
Crepis conyzifolia (Gouan) A. Kern. – 1
Doronicum austriacum Jacq. – 2; SO 105 522
Hieracium cymosum L. – 2; SO 105 036
H. hoppeanum Schult. – 2; SO 104 989
H. pilosella L. – 2; 104 995
Hypochaeris radicata L. – 1, 2; SO 104 988
Jurinea mollis (L.) Rchb. – 1; SO 104 994, 105 039
Leontodon hispidus L. – 1, 2; SO 104 985, 105 504
Senecio papposus (Rchb.) Less. – 1; SO 105 001

Brassicaceae
Alyssum murale Waldst. & Kit. – 1, 2; SO 105 502
Cardamine resedifolia L. – 1, 2; SO 104 990
Thlaspi praecox Wulfen. subsp. *praecox* – 1, 2; SO 104 599

Campanulaceae
Campanula glomerata L. – 1; SO 105 517
C. *rotundifolia* L. – 1
*C. *velebitica* Borbás – 1

Caryophyllaceae
Arenaria serpyllifolia L. – 2
Cerastium alpinum L. – 1
**C. decalvans* Schloss. subsp. *macedonicum* (T. Georgiev) Stoj. & Stef. – 1, 2; N; SO 104 879, 104 882
Dianthus petraeus Waldst. & Kit. – 1, 2; SO 104 626, 104 570
D. superbus L. – 2
Minuartia recurva (All.) Schinz & Thell. – 2; SO 105 044
Scleranthus annuus L. – 2; 104 564
S. neglectus Rochel ex Baumg. – 2; SO 104 554
Silene armeria L. – 2; SO 105 029
Stellaria graminea L. – 1

Crassulaceae
Sedum annuum L. – 1, 2; N; SO 104 563

Cuscutaceae
Cuscuta epithymum (L.) L. – 2

Dipsacaceae
Scabiosa ochroleuca L. – 2; SO 105 014

Ericaceae
Bruckenthalia spiculifolia (Salisb.) Rchb. – 1, 2; SO 105 040
Vaccinium myrtillus L. – 2; SO 104 557
V. vitis-idaea L. – 1; SO 105 525

Euphorbiaceae
Euphorbia barrelieri Savi – 1, 2

Fabaceae
**Chamaecytisus absinthioides* (Janka) Kuzmanov – 2; SO 104 618
Ch. hirsutus (L.) Link – 1
Genista carinalis Griseb. – 2; SO 104 639
G. depressa M. Bieb. – 2
G. sagitalis L. – 1, 2
Lotus angustissimus L. – 1, 2; N; SO 104 885
Trifolium aureum Pollich – 2; SO 105 013
T. hybridum L. – 2; SO 104 613
T. medium L. – 2; SO 105 015

Hypericaceae
Hypericum barbatum Jacq. – 1, 2; N; SO 104 895
H. olympicum L. – 1

Juncaceae
Luzula campestris (L.) Lam. & DC. – 1; SO 105 516
L. italica Parl. – 1, 2

Lamiaceae
Acinos alpinus (L.) Moench – 2
A. suaveolens (Sm.) G. Don fil. – 1
Mentha spicata L. – 2; SO 105 000
Thymus callieri Borbás ex Velen. subsp. *urumovii* Velen. – 2; N; SO 104 894
T. thracicus Velen. – 2; N; SO 104 893

Liliaceae
Allium paniculatum L. subsp. *paniculatum* – 2
**Lilium albanicum* Griseb. – 2

Poaceae
Anthoxanthum odoratum L. – 1
Festuca dalmatica (Hack.) K. Richt. – 2
F. nigrescens Lam. – 2
**F. picturata* Pils – 2; N; SO 105 049
Koeleria schurii Ujhelyi – 1, 2; SO 105 005
Lerchenfeldia flexuosa (L.) Schur subsp. *montana* (L.) Tzvelev – 1, 2; SO 105 050
Phleum alpinum L. – 2
P. phleoides (L.) Karst. – 2
Poa alpina L. – 1, 2; SO 105 524
P. compressa L. – 1
P. media Schur – 2; N; SO 104 888

Polygonaceae
Pleuropteropyrum undulatum (A. Murray) A. Löve & D. Löve – 1
Rumex acetosella L. – 1; SO 105 006

Polygalaceae
Polygala major Jacq. – 2; SO 104 556

Plantaginaceae
Plantago subulata L. – 1, 2; SO 103 357

Plumbaginaceae
**Armeria alpina* Willd. – 1, 2; N; SO 104 605

Ranunculaceae

Ranunculus montanus Willd. – 2; SO 104 597

R. polyanthemos L. subsp. *polyanthemos* – 2; SO 105 048

Rosaceae

Alchemilla glaucescens Wallr. – 2

Cotoneaster integerrimus Medicus – 1

Fragaria viridis Duchesne – 2; SO 104 550

Potentilla argentea L. – 1; SO 105 045

P. erecta (L.) Raeusch. – 1

P. haynaldiana Janka – 2; SO 104 505

P. pedata Willd. – 2; SO 104 993

Rosa canina L. – 1

R. caryophyllacea Besser – 1, 2

R. pimpinellifolia L. – 1

Rubiaceae

Asperula cynanchica L. – 1, 2; SO 105 009

Galium album Mill. – 2

G. pseudoaristatum Schur – 2

Santalaceae

Thesium alpinum L. – 1, 2; N; SO 104 352

Saxifragaceae

Saxifraga paniculata Mill. – 1, 2; SO 104 559, 105 505

Scrophulariaceae

**Pedicularis leucodon* Griseb. – 1

**Digitalis viridiflora* Lindl. – 1

**Veronica orbelica* (Peev) Peev – 2; N; SO 104 892

V. officinalis L. – 2

Thymelaeaceae

Daphne oleoides Schreb. – 2; SO 104 551

Violaceae

**Viola stojanowii* W. Becker – 1, 2; SO 104 569

Results and discussion

Taxonomic structure

The preliminary list of high-altitude serpentine flora of Mt Belasitsa consists of 115 species and infraspecific taxa, belonging to 80 genera and 37 families (Appendix I). Five (4.34 % of all taxa) members of *Bryophyta* and eight (6.95 %) *Pteridophytes* were documented. The *Pteridophyte* species represent four families, six genera and eight species, and their percentage composition is the highest yet reported of serpentines in Bulgaria. Monocotyledons account for 13.04 % of angiosperms in the studied area, comprising 8.1 % of the families, 11.25 % of the genera, and 13.04 % of the species and infraspecific taxa (Table 1). The *Poaceae* family is the largest among the monocots, with 73.33 % of the species and 9.56 % of the total flora. The second largest monocot family is *Liliaceae*.

Dicotyledons are dominant at family (67.56 %), genera (73.75 %) and species and infraspecific taxon (74.78 %) levels. The leading families are *Asteraceae*, *Caryophyllaceae*, *Poaceae*, *Fabaceae*, and *Rosaceae* (Table 2). These families are also among the largest at other investigated serpentine sites (Pavlova & al. 2003; Pavlova 2004; Pavlova & Nedelcheva 2006).

The species/genus ratio was calculated to indicate the distribution of taxa in the family (Table 2). *Asteraceae* is the family with the highest number of species (16) and a species/genus ratio of 1.45. In the case of *Campanulaceae* family this ratio is 3, indicating that more species are distributed within the same genus. The two investigated sites differ by the number of species found. The families represented by more than five taxa in both sites are shown in Fig. 2. The families *Poaceae*, *Caryophyllaceae* and *Fabaceae* are better represented in site 2, while *Asteraceae* and *Rosaceae* are better represented in site 1.

Table 1. Number of families, genera, species and infraspecific taxa for the basic taxa.

Taxonomical level	Bryophytes		Pteridophytes		Gymnosperms		Angiosperms				All total
							Monocots		Dicots		
	total	%	total	%	total	%	total	%	total	%	
Family	4	10.81	4	10.81	1	2.70	3	8.10	25	67.56	37
Genus	5	6.25	6	7.50	1	1.25	9	11.25	59	73.75	80
Species and infraspecific taxa	5	4.34	8	6.95	1	0.86	15	13.04	86	74.78	115

Table 2. Number of genera, species and infraspecific taxa in families represented by two or more species and the species/genus ratio.

Family	Genera		Species		Species: Genus
	total	%	total	%	
Asteraceae	11	14.47	16	14.4	1.45
Caryophyllaceae	7	7.89	10	8.1	1.42
Poaceae	5	6.50	10	9.0	2
Rosaceae	4	6.57	9	9.0	2.25
Fabaceae	4	5.26	9	8.1	2.25
Lamiaceae	3	3.94	5	4.5	1.66
Scrophulariaceae	3	3.94	4	2.7	1.33
Apiaceae	3	3.94	3	2.7	1
Brassicaceae	3	3.94	3	2.7	1
Aspidiaceae	2	2.63	3	2.7	1.5
Ericaceae	2	2.63	3	2.7	1.5
Rubiaceae	2	2.63	3	2.7	1.5
Liliaceae	2	2.63	2	1.8	1
Polygonaceae	2	2.63	2	1.8	1
Campanulaceae	1	1.31	3	2.7	3

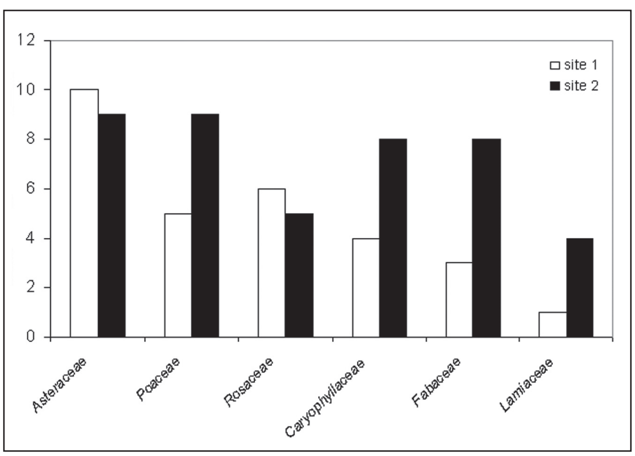

Fig. 2. Comparison of the families presented with more than five taxa in site 1 and site 2.

Perennial plants claimed a greater percentage of the studied flora (78.3 %), followed by shrubs (9.43 %), biennial-perennials (3.77 %), semi-shrubs (2.83 %), annuals and annuals-biennials (1.8 %). The higher percentage of shrubs and the lower participation of the annuals found is probably due to the high elevation of the study area. This result differs from all earlier serpentine areas studied in Bulgaria. Of the 115 recorded taxa, three (*Viola stojanowii, Lilium albanicum* and *Armeria alpina*) are listed in the *Red Data Book of Bulgaria* (Velchev 1984). *Veronica orbelica* is the only species included in the *Atlas of Bulgarian Endemic Plants* (Petrova 2006).

Geoelement composition

The flora is mainly composed of Submediterranean (28.3 %), Euroasian (18.86 %) and European (16.03 %) geoelements (Fig. 3). The percentage of circumboreal (12.26 %) and alpine geoelements (11.32 %) is quite high, as compared to other serpentine areas in Bulgaria. In spite of the relatively southern location of Mt Belasitsa in Bulgaria, the percentage of typical Mediterranean species in the study area is quite low (3.77 %). This fact corresponds to the data provided by Stojanov (1921) about the mountain.

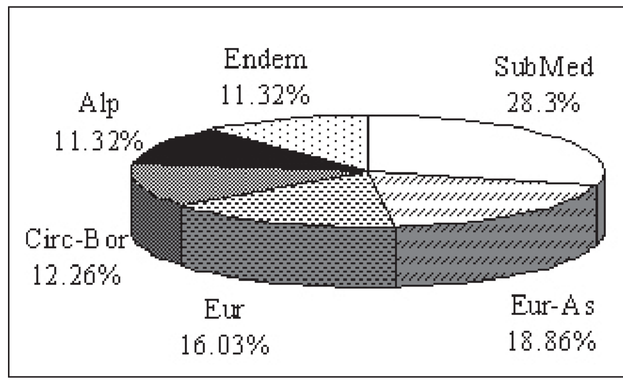

Fig. 3. Spectra of the main geoelements on ultramafic rocks studied.

The endemic elements constitute 11.32 % of all geoelements. They are predominantly Balkan species. *Veronica orbelica* is the only Bulgarian endemic found in the study area. Such percentages of endemics and subendemics distributed on serpentines have not been established so far for Bulgaria. This fact can be explained with the location of the investigated sites in the subalpine vegetation belt where, as a rule, the higher number of species forming the floristic complex of the mountain is found. Serpentine endemics were not found. The local endemics for this mountain, *Viola stojanowii* and *Lilium albanicum,* are found in serpentine areas too. *Lilium albanicum* is cited also on serpentines in Mt Ozren in Serbia (Pavlović 1953).

Similarity index

The similarity indices between the serpentine floras of Mt Belasitsa, Mt Ograzhden, and Mt Vlahina were calculated (Table 3). The results show low similarity indices between Mt Belasitsa and the other Southwest Bulgarian mountains. The serpentine floras of Vlahina and Ograzhden mountains shared most of the taxa (76).

Table 3. The similarity index calculated for the serpentine floras in the southwest Bulgarian mountains.

Index of similarity / Number of shared taxa	Mt Belasitsa	Mt Ograzhden	Mt Vlahina
Mt Belasitsa	**115**	0.12	0.11
Mt Ograzhden	14	**125**	0.34
Mt Vlahina	25	76	**342**

Conclusions

These preliminary data indicate that the serpentine flora of Mt Belasitsa is unique in relation to the other investigated regions in Bulgaria. The similarity indices between the Belasitsa/Vlahina serpentine floras and the Belasitsa/Ograzhden serpentine floras are rather low (0.11–0.12). This reflects the differences in altitude, climatic and ecological conditions, and the differential status of floristic exploration.

The flora is mainly composed of Submediterranean, Euroasian and European geoelements. Distribution of some phytogeographical elements has shown marked differences: the number of circumboreal and alpine elements in the serpentine flora of Mt Belasitsa is rather high, as compared to all serpentine outcrops studied (Pavlova & al. 2003; Pavlova 2004; Pavlova & Nedelcheva 2006). In spite of the relatively southern location of the mountain (at the boundary of the Mediterranean influence), the number of steno-Mediterranean geoelements is lower than that on the serpentine terrains in the Eastern Rhodopi Mts, Mt Ograzhden, and Mt Vlahina. This is probably due to the climatic conditions, and especially to the altitude of the study area. The percentage of Oriental-Turanian geoelements (0.94 %) is rather low, as compared to the other serpentine areas in Bulgaria.

Species like *Plantago subulata, Rumex acetosella*, *Arenaria serpyllifolia*, *Alyssum murale*, *Thlaspi praecox, Minuartia recurva, Centaurea rhenana*, etc. are characteristic of all serpentine areas in Bulgaria. The plants included in Kruckeberg's group of bodenvag species is the largest one.

The endemic elements are predominantly Balkan species. The taxa restricted to the Balkan Peninsula plus the Carpathians constitute 5.77 %, and 0.94 % are restricted to the Balkan Peninsula plus Anatolia, or another smaller area. The local endemics constitute 1.8 % of the flora.

As a result of this study, enhanced was the chorological information about the taxa *Ligusticum mutellina*, *Peucedanum austriacum*, *Cerastium decalvans* subsp. *macedonicum*, *Sedum annuum*, *Hypericum barbatum*, *Thymus callieri* subsp. *urumovii*, *Thymus thracicus*, *Festuca picturata*, *Poa media*, *Armeria alpina*, *Thesium alpinum*, *Veronica orbelica*, *Anthemis tenuiloba*, and *Lotus angustissimus*, and they were documented as new for the floristic region of Mt Belasitsa.

Further floristic investigations are needed to fully document the flora of these interesting areas.

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