A survey of the serpentine flora in the West Bulgarian Frontier Mts (Mt Vlahina and Mt Ograzhden)

Dolja K. Pavlova

Department of Botany, Faculty of Biology, St Kliment Ohridski Sofia University, 8 Dragan Tsankov Blvd., 1164 Sofia, Bulgaria, e-mail: pavlova@biofac.uni-sofia.bg

Received: January 21, 2010 ▷ Accepted: February 21, 2010

Abstract. The serpentine outcrops have distinctive flora, rich in endemics and rare plants and different morphotypes of well-known taxa. Distribution of the serpentine rocks in Bulgaria coincides with the spread of pre-Cambrian metamorphic volcanic layers. The object of this investigation was the serpentine terrains in the West Frontier Mts (Mt Vlahina and Mt Ograzhden). As a result of the field observations, 270 plant taxa are listed. The analysis of the Raunkiaer life-form spectrum has shown that 53.65 % of the flora consists of hemicryptophytes, followed by therophytes (27.37 %), phanerophytes (5.47 %), chamaephytes (4.01 %), and others (9.5 %). In all investigated areas the Mediterranean geoelements (28.89 %) prevail, followed by the European (22.22 %) and the Eurasian (18.15 %). The number of Balkan endemics distributed on the serpentines in the West Frontier Mts is considerably smaller, as compared to other serpentine regions in Bulgaria and on the Balkan Peninsula, most probably due to the lower altitude of their localities and the human impact.

Key words: diversity, flora, Mt Ograzhden, Mt Vlahina, phytogeographical elements, serpentine, Southwest Bulgaria

Introduction

For many years serpentine soils are known as representing a unique substrate for the flora. The cause of the "serpentine syndrome" has been traced to imbalance of calcium and magnesium, magnesium toxicity, heavy-metal toxicity, low levels of essential nutrients, or slow rock weathering (Kruckeberg 1984; Brooks 1987).

The Balkan Peninsula is one of the most interesting parts of Europe, with vast territories of ultramafic rocks, located predominantly in its western parts: Albania, Bosnia, Serbia, Montenegro, Greece, and Macedonia (Turrill 1929; Brooks 1987; Stevanović & al. 2003). These outcrops are characterized by a very distinctive flora, rich in endemics and rare plants and different morphotypes of well-known taxa (Brooks 1987; Stevanović & al. 2003). Edaphic islands, such as the serpentines, give rise to localized patterns of plant distribution, and provide a model setting for studying the role of the edaphic factor in plant evolution (Kruckeberg 1984; Kruckeberg & Rabinowitz 1985; Mayer & al. 1994; Rajakaruna 2004).

In Bulgaria, the total serpentine area is considerably smaller. The serpentine areas are scattered, but the largest serpentine bodies are located in the Eastern and Central Rhodopes, Vlahina, Ograzhden, Belasitsa and Rila Mts. Purposeful investigations into the serpentine flora in Bulgaria had started in 1997. In the course of several years a number of publications appeared, related to species composition and plant diversity of the serpentine areas in the Rhodopi Mts (Pavlova & al. 1998, 2002, 2003, 2004; Pavlova 2001, 2004; Pavlova & Dimitrov 2001; Pavlova & Nedelcheva 2007).

The main objectives of this study were: (a) to provide a checklist of the species from the West Frontier Mts' serpentine outcrops; (b) to describe the relationship between the flora of the investigated serpentine

areas and the taxonomical and phytogeographical groups and life form categories; (c) to present comparisons with other serpentine floras in Bulgaria, referring to the proportion of taxonomical spectra of biotypes and endemism.

Material and methods

Study area and data collection

The study area belongs to the South Bulgarian Climatic Region, where the Mediterranean influence is well pronounced. Four sites with serpentine terrains have been investigated in the Vlahina and Ograzhden Mts (Fig. 1). Following the floristic division of Bulgaria, these mountain areas form part of the West Frontier Mts. Distribution of the serpentinites coincides with the location of the most active metamorphic layers of pre-Cambrian origin. The serpentinites are included in these layers, which consist of amphibolites, schists and marbles.

The climate in this area changes in southward direction from a transitional continental to submediterranean. The mean annual temperature is 9 °C (Drenovski & al. 2002). The mean January temperature in the region of the town of Blagoevgrad (the nearest climatic station) is –1 °C and the mean July temperature is 18 °C. The precipitation maximum is recorded during the autumn-winter seasons. The mean annual precipitation at 300–600 m a.s.l. is about 600 mm.

Site 1: West Frontier Mts, Mt Vlahina, near Stara Zheleznitsa village; locality: peak Murdzhova Chuka, 720–760 m a.s.l., area *ca.* 0.09 km^2 (UTM Grid Map of Bulgaria, 1:1 500 000, Square FM-74). The serpentine terrains are located on the south and southeast facing slopes. They have characteristically higher content of Fe and Ni, as compared to similar sites in the Eastern Rhodopi Mts (Kozhoukharova 1984). The soil type is brown-forest. The natural vegetation is heavily destroyed. Occasionally it is of the shiblyak type composed of *Fraxinus ornus, Carpinus orientalis, Juniperus oxycedrus, Paliurus spina-christi,* and single trees of *Quercus pubescens*. The ridge is covered with a sparse mixed oak forest of *Quercus dalechampii, Q. pubescens, Fraxinus ornus, Acer campestre*, *Carpinus betulus, C. orientalis, Pyrus elaeagrifolia,* and *P. nivalis*. Herb vegetation is composed mainly of species of the following families: *Poaceae*, *Asteraceae*, *Fabaceae*, *Caryophyllaceae*, and *Lamiaceae*. Characteristic species are *Genista carinalis, Plantago holosteum*, *Sanguisorba minor* subsp. *minor*, and *Rumex acetosella* subsp. *multifidus*.

Site 2: West Frontier Mts, Mt Vlahina, in the region of Babaliyte village; locality: peak Yaitseto, 660 m a.s.l., area *ca.* 0.18 km^2 (FM-65). The serpentine terrains are located on the south and southeast facing slopes, westwards from Babaliyte village. The soil is brown-forest. The vegetation is of forest type, with a similar composition as at Site 1. The ridge is flat, covered by pastures.

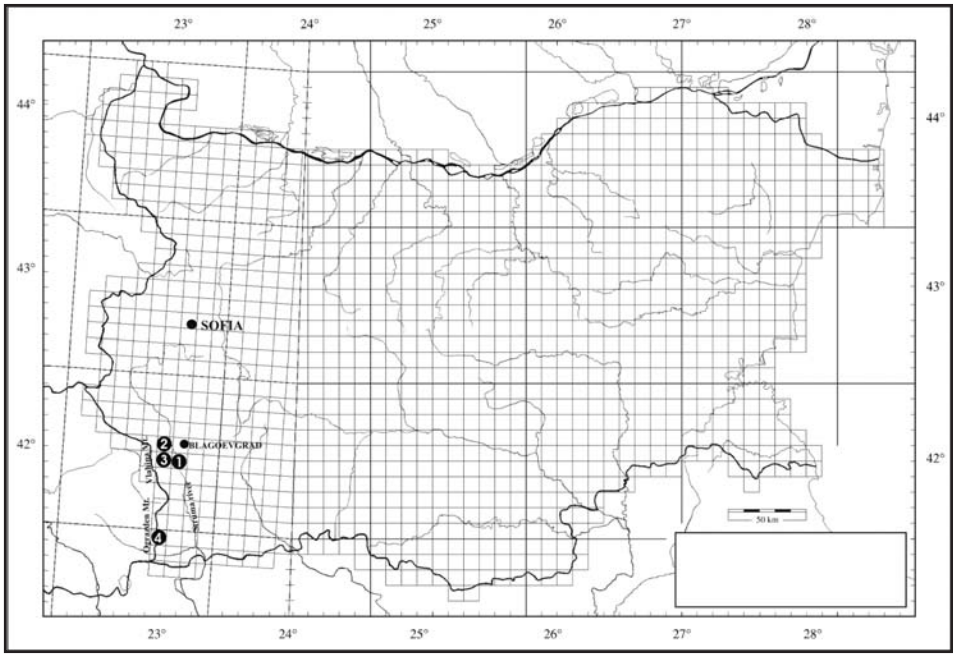

Fig. 1. UTM Grid Map of Bulgaria and the investigated areas of the West Frontier Mts.
Mt Vlahina: Site 1 – near Zheleznitsa village; Site 2 – Babaliyte village; Site 3 – near Selishte village;
Mt Ograzhden: Site 4 – near Gega village.

Site 3: West Frontier Mts, Mt Vlahina, in the vicinity of Selishte village; locality: Ovnarska Mahala, 600–610 m a.s.l., area *ca*. 0.4 km^2 (FM-64). The serpentine area occupies the south and east facing slopes. The basic rock is highly weathered. The soil layer is thick. The natural vegetation is destroyed. Single trees and shrubs, such as *Quercus pubescens*, *Fraxinus ornus*, *Carpinus betulus*, *Pyrus elaeagrifolia*, *Ligustrum vulgare*, and *Crataegus monogyna* are found. Vegetation is of the pasture type, mainly composed of *Poaceae*, *Asteraceae*, *Fabaceae*, and *Caryophyllaceae* species. The terrains close to the village are highly influenced by the anthropogenic activities, such as cattle-breeding, ploughing, re-forestation and tourism.

Site 4: West Frontier Mts, Mt Ograzhden, near Gega village; locality: Black Rocks, 600–620 m a.s.l., area *ca.* 0.05 km^2 (FL-69)**.** The serpentine area occupies the southeast facing slope, close to the village, with large black rocks. The natural vegetation is destroyed. Fragments of shiblyak vegetation composed of *Juniperus oxycedrus*, *Fraxinus ornus*, *Carpinus orientalis*, *Paliurus spina-christi*, *Crataegus monogyna*, and single trees of *Quercus pubescens* are found. The most characteristic species are *Cheilanthes maranthae*, *Silene frivaldszkyana* and *S. lydia*. These areas are subject to the ever increasing human impact, basically related to sheep and goat grazing.

Field work was carried out in April-July 2005 and June-July 2006. The transect method was selected for observations in the study area, where the outcrop of the basic rock was confirmed. Collected specimens were deposited in the Herbarium of Sofia University (SO) as part of the Bulgarian serpentine collection, which is now under construction. Nomenclature follows Kozhuharov (1992), Jordanov (1963–1979), Velchev (1982–1989), Kozhuharov (1995), and Tutin & al. (1968–1983, 1993).

The list of the taxa, including families, genera and species, is presented in the Appendix I. The taxon name is followed by the site number(s); the plants new for the floristic region of the West Frontier Mts are marked with an abbreviation "**N**". Endemic taxa are indicated by an asterisk (*) prior to the species name.

Calculation of percentages refers to the summarized data base by Kozhuharov (1992) and Petrova & al. (2005). The phytogeographical elements are given according to Assyov & al. (2006). The IUCN conservation category at national level, based on Velchev (1984), and on the more recent *Red List of Bulgarian vascular plants* (Petrova & Vladimirov 2009), and *Biological Diversity Act* (2002, 2007) is checked.

Appendix I

List of the vascular plant taxa found in the study area (for abbreviations see the text)

Polypodiophyta

Aspleniaceae

Asplenium adiantum-nigrum L.: 4; per; SO- 104 483
A. trichomanes L.: 1; 2, 4; SO- 104 384
A. ruta-muraria L.: 1
A. septentrionale (L.) Hoffm.: 2
Ceterach officinarum DC.: 1, 2

Hypolepidaceae

Pteridium aquilinum (L.) Kuhn: 1, 4

Sinopteridaceae

Cheilanthes maranthae (L.) Domin: 4; "N"; SO- 104373, 104374

Gymnospermae

Cupressaceae

Juniperus oxycedrus L.: 1, 2; 3; 4

Angiospermae

Aceraceae

Acer campestre L.: 1
A. tataricum L.: 1

Apiaceae

**Bupleurum apiculatum* Friv.: 1; "N"; SO-103 752
Eryngium campestre L.: 1, 2, 3, 4
Ferulago campestris (Besser) Grec.: 2
F. sylvatica (Besser) Rchb.: 1
Orlaya grandiflora (L.) Hoffm.: 1, 2, 4
Physospermum cornubiense (L.) DC: 2
Tordylium maximum L.: 2, 3, 4; SO- 104033

Aristolochiaceae

Aristolochia clematitis L.: 4; SO- 104 312

Asclepiadaceae

Vincetoxicum fuscatum (Hornem.) Rchb. fil.: 1;

Asteraceae

Achillea coarctata Poir.: 2, 3, 4; SO- 104 319
A. collina Becker ex Rchb.: 1, 4; SO- 104 318
**A. crithmifolia* Waldst. & Kit.: 4

A. millefolium L. gr.: 4
**A. depressa* Janka: 1
Anthemis arvensis L.: 1, 3, 4; SO- 104 320
**A. macrantha* Heuff.: 4; SO- 104 314
A. tinctoria L.: 1, 2
Carlina vulgaris L:1
Carthamus lanatus L.: 2
**Centaurea affinis* Friv.: 2, 3
C. biebersteinii DC.: 1; SO- 103 851
**C. chrysolepis* Vis.: 2; "N"; SO- 103751
C. cyanus L.: 1, 2
C. rhenana Boreau: 4; SO- 104317, 104316
C. rutifolia Sm. subsp. *jurineifolia* (Boiss.) Nyman: 1
Cichorium intybus L.: 2, 3, 4
Chamomilla recutita (L.) Rauscher: 1
Chondrilla juncea L.: 3
Crepis foetida L. subsp. *rhoeadifolia* (M. Bieb.) Čelak.: 1, 2, 4
C. sancta (L.) Babc.: 3, 4; SO- 104 321
C. setosa Haller f.: 3
Crupina vulgaris Cass.: 1, 2, 3
Filago lutescens Jordan: 4; SO- 104323
Hieracium hoppeanum L.: 2, 4
H. pilosella L.: 2, 4; SO- 104 324
H. piloselloides Vill. subsp. *piloselloides:* 1
Inula oculus-christi L.: 1
Lactuca serriola L.: 2
Leontodon crispus Vill. subsp. *crispus*: 1, 4; SO- 104 356
Logfia arvensis (L.) Holub: 1, 2
Scorzonera hispanica L.: 1
Senecio erucifolius L.: 1
S. rupestris Waldst. & Kit.: 1
S. vernalis Waldst. & Kit.: 4; SO- 104 355
Tragopogon crocifolius L. subsp. *samaritani* (Heldr. & Sart. ex Boiss.) I. Richardson: 2; SO- 103 842
T. pratensis L.: 3
Xeranthemum annuum L.: 1, 2; 3

Betulaceae
Carpinus betulus Mill.: 1, 2
C. orientalis Mill.: 1, 2, 3, 4
Corylus avellana L.: 4
Ostrya carpinifolia Scop.: 4

Boraginaceae
Anchusa officinalis L.:1, 4; SO- 104 313
Buglossoides purpurocoerulea (L.) I.M. Johnst.: 1
Echium italicum L.: 1, 3
Myosotis ramosissima Rochel: 1
Neatostema apulum (L.) I.M. Johnst.: 2
Onosma echioides L.: 1, 4; SO- 104 368
O. heterophylla Griseb.: 1, 2

Brassicaceae
Alyssum minus (L.) Rothm.: 1
A. murale Waldst. & Kit. subsp. *pichleri* (Velen.) Stoj. & Stef.: 4; SO- 104 031
A. tortuosum Willd.: 4; SO- 104 520; 104 521
Berteroa obliqua (Sm.) DC.: 2; "N"; SO- 104 575
Erysimum diffusum Ehrh.: 1, 2, 4; SO- 104369
**Rorippa prolifera* (Heuff.) Neilr.: 4; SO- 104370

Campanulaceae
Campanula lingulata Waldst. & Kit.: 1
Jasione heldreichii Boiss. & Orph.: 3, 4; SO- 104366; 104365
Legousia speculum-veneris (L.) Chaix: 2, 3, 4; SO- 104364

Caryophyllaceae
Arenaria leptoclados (Rchb.) Guss.: 3, 4; SO- 104 363
Cerastium pumilum Curtis: 1; SO-103 029
Dianthus armeria L. subsp. *armeria*: 1, 2
D. armeria L. subsp. *armeriastrum* (Wolfner) Velen.: 1
D. pallens Sm.: 3; "N"; SO- 103 746
D. pinifolius Sm. subsp. *pinifolius*: 2
Herniaria hirsuta L.: 1, 2, 3, 4; SO- 104 362
H. glabra L. subsp. *narbonensis* Janka ex Nyman: 2
Lychnis coronaria (L.) Desr.: 2
Minuartia attica (Boiss. & Spruner) Vierh.: 4; SO- 104 032
**Moenchia graeca* Boiss. & Heldr.: 1; SO-103 028
Petrorhagia illyrica (Ard.) P.W. Ball & Heywood subsp. *haynaldiana* (Janka) P. W. Ball & Heywood: 1; SO- 103538
P. illyrica (Ard.) P.W. Ball & Heywood subsp. *illyrica*: 2, 4; SO- 104359, 103756, 103753
P. prolifera (L.) P.W. Ball & Heywood: 1, 2; 3, 4; SO- 104330; 104843
Scleranthus perennis L.: 1, 4; SO- 104 361
Silene armeria L.: 4; SO- 104 360
S. bupleuroides L. subsp. *bupleuriodes*: 1;
S. chlorantha (Willd.) Ehrh.: 1; "N"; SO- 103 750
S. conica L.: 1, 4
**S. frivaldszkyana* Hampe: 4
S. italica (L.) Pers.: 2
S. lydia Boiss.: 4; "N"; SO-104035

Cistaceae
Cistus incanus L.: 4
Fumana procumbens (Dunal) Gren. & Godr.: 2
Helianthemum nummularium (L.) Mill.: 1, 2

Convolvulaceae
Convolvulus cantabrica L.: 1, 2, 3, 4; SO- 104 351

Crassulaceae
Sedum acre L.: 1, 2, 3
S. album L.: 4; SO- 104 328
S. cepaea L.; 4; SO- 104 329
S. hispanicum L.: 1, 3, 4; SO- 104 327
S. rubens L.: 4

Cuscutaceae
Cuscuta approximata Bab.
on Doricnium herbaceum: 1; "N"; SO- 103 747
C. europaea L.: 1

Cyperaceae
Carex caryophyllea Latourr.: 1
C. echinata Murr.: 2

Dipsaceae
Cephalaria laevigata (Waldst. & Kit.) Schrad.: 2
**Knautia macedonica* Griseb.: 4; SO- 104 326; 104 325
Scabiosa argentea L.: 1, 4; "N"; SO-103 761
**S. triniifolia* Friv.: 1, 2; SO- 103 853

Euphorbiaceae
Euphorbia cyparissias L.: 1, 2, 3, 4
E. niciciana Borbás ex Novak: 4; SO- 104348

Fabaceae
Astragalus onobrychis L. subsp. *chlorocarpus* (Griseb.) Kožuharov & D. Pavlova: 1, 2, 3, 4
Coronilla varia L.: 2, 4
Dorycnium herbaceum Vill.: 1, 2, 4; SO- 104 347
Genista carinalis Griseb.: 1, 4; SO- 103 032; 104 339
G. ovata Waldst. & Kit.: 2
Lotus corniculatus L.: 2, 3, 4
L. tenuis Waldst. & Kit. ex Willd.: 4; SO- 104 340
Medicago falcata L. subsp. *falcata*: 1, 2, 4
M. minima (L.) Bartel var. *minima*: 4; SO- 104 333
M. rigidula (L.) All. var. *glandulosa* (Podp.) Kožuharov: 4; SO-104 332
Melilotus officinalis (L.) Pall.: 2
Onobrychis alba (Waldst. & Kit.) Desv. subsp. *calcarea* (Vandas) P.W. Ball: 1; SO-103 033
O. gracilis Besser: 2
Ononis spinosa L. subsp. *antiquorum* (L.) Arcang.: 2; SO-103 745
Ornithopus compressus L.: 4; SO- 104 036
Trifolium alpestre L.: 1, 3, 4; SO- 104 337
T. angustifolium L.: 2, 3, 4; SO- 104 336
T. arvense L.: 1
T. campestre Schreb.: 1, 2, 3, 4; SO- 104 518
T. cherleri L.: 4; SO- 104 342
T. diffusum Ehrh.: 1
T. patens Schreb.: 1
T. scabrum L. subsp. *scabrum*: 1; SO-103 036
T. strictum L.: 4; SO- 104 341
Vicia tetrasperma (L.) Schreb.: 2, 4; SO- 104 519

Fagaceae
Quercus pubescens Willd.: 1, 2, 3, 4
Q. dalechampii Ten.: 1

Gentianaceae
Centaurium erythraea Rafin. subsp. *erythraea*: 1, 2

Geraniaceae
Erodium cicutarium (L.) L'Herit: 1
Geranium columbinum L.: 1
G. pusillum Curt.: 1
G. sanguineum L.: 2

Hypericaceae
**Hypericum rumeliacum* Boiss.: 1, 2, 3; SO- 103 030
H. perforatum L.: 2, 4; SO- 104 511

Iridacea*e*
Gladiolus illyricus Koch.: 1
**Iris reichenbachii* Heuff.: 1

Lamiaceae
Acinos arvensis (Lam.) Dandy: 1, 2, 3, 4
A. suaveolens (Sm.) G. Don fil.: 4; SO- 104 512
Ballota nigra L. subsp. *foetida* Hayek: 2
Clinopodium vulgare L.: 2, 4
Marrubium perregrinum L.: 4; SO- 104 504
M. vulgare L.: 2
Nepeta nuda L.: 4; SO- 104 506
Prunella laciniata (L.) L.: 1, 2, 4; SO- 104 503
P. vulgaris L.: 2
**Salvia amplexicaulis* Lam.: 2, 4; SO- 104 500
Stachys angustifolia M. Bieb.: 1, 2, 3, 4; SO- 104 502
S. annua (L.) L. var. *adenocalyx* (C. Koch) Hausskn.: 4; SO- 104 504
S. cassia (Boiss.) Boiss.: 4; SO- 104 028
Teucrium chamaedrys L.: 1, 2, 3, 4; SO- 104 513
T. polium L.: 1, 2, 3, 4; SO- 105 538
Thymus moesiacus Velen.: 1

Liliaceae
Alium flavum L.: 1, 2, 3, 4; SO- 104 514
A. paniculatum L.: 3
A. sphaerocephalum L.: 2
Fritillaria orientalis Adans.: 2
Hyacinthella leucophaea (C. Koch) Schur: 1
Muscari comosum (L.) Mill.: 1

Ornithogalum kochii Parl.: 1, 3

Linaceae
Linum tenuifolium L.: 1

Malvaceae
Alcea pallida (Willd.) Waldst. & Kit.: 2
Malva sylvestris L.: 2; 4; SO- 104 391

Moraceae
Ficus carica L.: 4

Oleaceae
Fraxinus ornus L.: 1, 2, 3
Ligustrum vulgare L.: 3, 4

Orchidaceae
Limodorum abortivum (L.) Schwartz: 1, 2; SO- 103 857

Orobanchaceae
Orobanche alba Stephan ex Willd. *on Thymus* sp.: 1

Plantaginaceae
Plantago lanceolata L.: 1, 2, 3, 4
P. scabra Moench.: 4; SO- 104 387
P. holosteum Scop.: 1, 2, 3

Poaceae
Aegilops triuncialis L.: 1, 2, 3; SO- 103 037
A. neglecta Req. ex Bertol.: 4; SO- 104 024
Aira elegantissima Schur: 1, 2, 3
Brachypodium sylvaticum (Huds.) P. Beauv.: 1, 4
Bromus arvensis L.: 1, 2, 3, 4
B. squarrosus L.: 3
B. sterilis L.: 4
B. tectorum L.: 1
Chrysopogon gryllus (L.) Trin.: 1, 2, 3, 4
Cynosurus echinatus L.: 1, 2, 3, 4; SO- 104 388
Dactylis glomerata L.: 2
Dasypyrum villosum (L.) P. Candargy: 2, 3
Dichantium ischaemum (L.) Roberty: 2, 3, 4
Elymus hispidus (Opiz) Melderis: 3; SO- 103 850
Festuca dalmatica (Hackel) K. Richter: 4; SO- 104 025
F. nigrescens Lam.: 1; SO- 104 324
Hordeum murinum L.: 1
**Koeleria simonkaii* Adamović: 1, 2, 3; SO-103 035
Lerchenfeldia flexuosa (L.) Schur: 2
Lolium perenne L.: 1
Melica ciliata L.: 1, 3, 4; SO- 104 386
Phleum graecum Boiss. & Heldr.: 4; "N"; SO- 104 034
Ph. phleoides (L.) H. Karst.: 2
Poa bulbosa L.: 1, 2, 3
P. compressa L.: 1, 4; SO- 104 027
Psilurus incurvus (Gouan) Schinz & Thell.: 1, 2, 3; SO-103 038
Stipa capillata L.: 1, 2, 3, 4; "N"; SO-104029; 103755
Taeniatherum caput-medusae (L.) Nevski: 1, 2
Trachynia distachya (L.) Link: 3, 4; "N"; SO- 103 749; 104 037
Vulpia ciliata Dumort.: 2, 3, 4; "N"; SO- 103 273; SO-103 754
V. myurus (L.) C.C. Gmel.: 4; SO- 104 390

Polygonaceae
Rumex acetosella L. subsp. *multifidus* (L.) Arcang.: 1, 2, 3, 4; SO- 104 821
R. conglomeratus Murray: 3

Primulaceae
Anagallis arvensis L. subsp. *arvensis*: 2

Ranunculaceae
Consolida regalis S.F. Gray: 2
**Delphinium balcanicum* Pawł.: 1; "N"; SO- 104 744
Nigella arvensis L.: 3, 4

Rhamnaceae
Paliurus spina-christi Mill.: 1, 2, 4

Rosaceae
Agrimonia eupatoria L.: 1, 2, 4
Crataegus monogyna Jacq.: 2, 3, 4; SO- 104 068
Filipendula vulgaris Moench: 2
Potentilla argentea L.: 1, 2, 3, 4; SO- 104 382
P. erecta (L.) Raeuschel: 4; SO- 104 381
P. inclinata Vill.: 1, 2;
P. neglecta Baumg. var. *dissecta* (Wallr.) Mark.: 2, 3
P. reptans L.: 4; SO- 104 393
Prunus spinosa L.: 1, 2, 3, 4
Pyrus elaeagrifolia Pall.: 2; 3
P. nivalis Jacq.: 1
Rosa arvensis Hudson: 1
R. canina L.: 2
Sanguisorba minor Scop. subsp. *minor:* 1, 2, 4; SO- 104 395

Rubiaceae
Asperula cynanchica L.: 1, 2, 3
A. purpurea (L.) Ehrend.: 4; SO- 104 380
A. tenella Heuffel ex Degen: 1; SO- 103 758
Crucianella angustifolia L.: 1, 2, 3, 4; SO- 104 375
**C. graeca* Boiss.: 4; SO- 104 376
Cruciata pedemontana (Bellardi) Ehrend.: 1
Galium album Mill.: 1
G. divaricatum Lam.: 1
G. heldreichii Halacsy: 1
G. lucidum All.: 1
**G. macedonicum* Krendl: 1; "N"; SO- 104 762

G. tenuissimum M. Bieb.: 1
G. verum L.: 1, 4; SO- 104 377

Santalaceae
Comandra elegans (Roch. ex Rchb.) Rchb. fil.: 2
Thesium arvense Horvatovszky: 2, 3

Scrophulariaceae
Digitalis lanata Ehrh.: 2, 4; SO- 103 411
Euphrasia pectinata Ten.: 1, 2, 3; SO- 103 034
Linaria genistifolia (L.) Mill. subsp. *genistifolia:* 2, 3, 4
L. pelisseriana (L.) Mill.: 3
Parentucellia latifolia (L.) Caruel: 1; SO- 103 031
**Verbascum banaticum* Schrader: 2, 4; SO- 104 394
V. longifolium Ten.: 1
V. xanthophoeniceum Griseb.: 1; "N"; SO- 103 748; 103740
Veronica austriaca L. subsp. *jaquinii* (Baumg.) Maly: 1
V. chamaedrys L.: 2
V. polita L.: 1
V. praecox All.: 1

Valerianaceae
Valerianella coronata (L.) DC: 1
V. dentata (L.) Poll.: 1

Violaceae
Viola arvensis Murray: 1

Data analysis

The taxonomic diversity, life-forms, phytogeographical elements, and a number of taxa with conservative status were analyzed for each site.

Non-parametric Spearman rank correlation coefficients were used to evaluate the relationship between the number of species and the surface of investigated serpentine sites.

Multivariate treatment of data was performed in order to obtain an objective grouping of the investigated ultramafic sites on the basis of all data on their floras. For this purpose, a matrix of phytogeographical elements vs. sites was subjected to cluster analysis using Euclidean distance and Unweighted Pair Group Average (UPGMA) as computational criteria. All statistics were performed with the Statsoft – Statistica 7 package.

β-diversity between the different sites was also calculated for all possible combinations on the basis of Sørensen's Similarity Index (*Qs*).

$Qs = 2c/(a + b)$,

where *a* and *b* are the numbers of taxa occurring on site *a* or *b* respectively, and *c* is the number of taxa shared by *a* and *b* (Kent & Coker 1994).

The percentages of taxa representing the phytogeographical elements are as follows (absolute number in brackets): Cosmopolitan, widespread across the world (8); Boreal, distributed mainly in the northern (boreal and subboreal) region of the northern hemisphere (16); European, central and south European (occasionally extending to the Caucasus) (60); Eurasian, belonging to the Eurasian flora (49); Pontian, with distribution area centred on the northern coast of the Black Sea (17); widespread Mediterranean (78); Oriental-Turanian (16); Balkan endemics (13); Balkan subendemics (including taxa extending to the Carpathians or Pannonia) (6); Balkan-Anatolian (8).

Results

Diversity, life-forms and phytogeographical elements

Currently, 270 taxa growing on serpentines in the Vlahina and Ograzhden Mts (Appendix I) have been reported and the floristic structure of the investigated sites is presented in Table 1. All seed plants, with the exception of *Juniperus oxycedrus*, were representatives of *Magnoliophytina*. In all four studied sites dicotyledons prevailed (over 82 %). The participation of *Polypodiophyta* with 2.5 % was insignificant.

The families with the largest number of species and infraspecific taxa (in brackets) were *Asteraceae* (38), *Poaceae* (31), *Fabaceae* (25), *Caryophyllaceae* (22), *Lamiaceae* (16), *Rosaceae* (14), *Rubiaceae* (13), and *Scrophulariaceae* (12). The monocotyledons were poorly represented in the serpentine flora. The *Poaceae* displayed the largest number of taxa (31) at all sites, followed by *Liliaceae* (7 taxa).

A comparison between the sites shows that 25.6 % of all taxa were distributed only in Site 1, 17.0 % in Site 4, 13.7 % in Site 2 and 3.3 % in Site 3. Only 8.9 % of the taxa were common to all sites, 17.8 % were found in two sites and 13.7 % occurred in three of the sites. This result shows the floristic differentiation between the sites which is probably related to the already discussed soil content (Pavlova 2009).

Analysis of the Raunkiaer life-form spectrum has shown that 53.65 % of the flora consisted of hemicryptophytes, followed by therophytes (27.37 %), phaner-

Table 1. Taxonomical structure of the investigated serpentine sites.

Locality	Taxonomical Rank	Pteridophytes		Gymnosperms		Angiosperms Monocotyledons		Dicotyledons		Total
		All	%	All	%	All	%	All	%	
Mt Vlahina Site 1	Family	2	4.88	1	2.44	5	12.20	33	80.49	**41**
	Genus	3	2.81	1	0.93	23	21.50	80	74.77	**107**
	Species &subsp.	4	2.72	1	0.68	25	17.01	117	79.59	**147**
Mt Vlahina Site 2	Family	1	2.86	1	2.86	4	11.83	29	82.86	**35**
	Genus	2	1.92	1	0.96	20	2.66	81	69.33	**104**
	Species &Subsp.	3	2.46	1	0.82	21	17.07	97	79.67	**122**
Mt Vlahina Site 3	Family			1	4.16	2	8.33	21	87.5	**24**
	Genus			1	1.59	17	26.98	45	71.43	**63**
	Species & subsp.			1	1.37	19	20.03	53	72.60	**73**
Mt Ograzhden Site 4	Family	3	9.09	1	3.03	2	6.06	27	81.81	**33**
	Genus	3	3.40	1	1.14	13	14.77	71	80.68	**88**
	Species &subsp.	4	3.31	1	0.83	16	13.22	100	82.64	**121**

ophytes (5.47 %), chamaephytes (4.01 %), and others (9.5 %). The same order of life-form spectrum have been found in each site.

Analysis of the floristic elements lays an emphasis on the phytogeographical specificity of the studied flora (Table 2). In all investigated serpentine areas the Mediterranean (28.89 %), European (22.22 %) and Eurasian (18.15 %) species prevailed. In the group of the Stenomediterranean elements 22 taxa occurred, including *Juniperus oxycedrus*, *Scorzonera hispanica*, *Tragopogon crocifolius* subsp. *samaritani*, *Neatostema apulum, Onosma echioides*, *Berteroa obliqua*, *Ornithopus compressus*, *Trifolium angustifolium*, *T. charleri, Ficus carica, Alium flavum*, *A. sphaerocephalum, Limodorum abortivum*, *Plantago holosteum*, *Aira elegantissima*, *Potentilla argentea*, *Prunus spinosa*, *Minuartia attica*, *Pyrus elaeagrifolia*, *Crucianella angustifolia*, *Galium divaricatum*, and *Linaria pelisseriana*.

Table 2. Percentage occurrence of the different phytogeographical elements in all studied sites, total percentage for all sites, and total number of the taxa.

Elements	Site 1	Site 2	Site 3	Site 4	Total (%)
Cosmopolitan	1.36	4.92	0	3.31	2.96
Boreal	4.08	4.92	2.74	6.61	5.92
European	25.85	25.41	23.29	25.62	22.22
Eurasian	18.37	18.85	17.81	16.52	18.15
Pontian	7.48	5.74	10.96	6.61	6.30
Mediterranean	28.58	28.69	35.62	29.75	28.89
Orientalo-Turanean	5.44	4.10	4.11	2.48	5.93
Balkan Endemic	6.12	3.27	2.74	2.48	4.81
Balkan subendemic	0	2.46	1.37	4.13	2.22
Balkan-Anatolian	2.72	1.64	1.37	1.65	2.96
Total number of taxa	**147**	**122**	**73**	**121**	**270**

The Mediterranean elements varied from site to site, from 28.58 % (Site 1) to 35.62 % (Site 3). The European component ranged from 23.29 % at Site 3 to 25.85 % at Site 1 and the Eurasian one from 16.52 % at Site 4 to 18.85 % at Site 2.

The participation of Oriental-Turanian and Pontic elements in the total investigated flora in the Vlahina and Ograzhden Mts was low (5.93 % and 6.30 % respectively).

The endemic element was divided into two subgroups: Balkan endemics and Balkan subendemics. The group of Balkan endemics was composed of 13 taxa, i.e. 4.81 % of the total flora of the studied area. This number constituted only 4.16 % of the Balkan endemics distributed on the territory of Bulgaria (ca. 312 taxa, Petrova & al. 2005). The highest number of Balkan endemics (9) was established in Site 1, while in Site 3 the endemic taxa were only two. The group of Balkan subendemics was composed of six taxa, five of them found in Site 4. The group of taxa occurring on the Balkan Peninsula and in Anatolia accounted for 2.96 % of the studied flora. Such taxa were *Dianthus pallens, D. pinifolius* subsp. *pinifolius, Scabiosa argentea, Euphorbia niciciana, Thymus moesiacus, Verbascum xanthofoeniceum, Centaurea affinis,* and *Salvia amplexicaulis*.

Not endemic but rare species, or species with a high conservation status have been also found on the serpentine soil in the Vlahina and Ograzhden Mts. The species *Limodorum abortivum* and *Fritillaria orientalis* are considered rare in the *Red Data Book of the PR Bulgaria* (Velchev 1984) and protected under the *Act of Biological Diversity* (2002, 2007). *Fritillaria orientalis,* along with *Silene lydia*, *Hypericum rumeliacum*, *Stachys cassia*, *Ficus carica*, and *Delphinium balcanicum* are also included in the *Red List of Bulgarian vascular plants* (Petrova & Vladimirov 2009).

Geographic variation in the study area

The floristic structure of the investigated serpentine sites is related to their surface and a weak negative correlation has been established (Spearman r = –0.4, p-level < 0.05; Fig. 2).

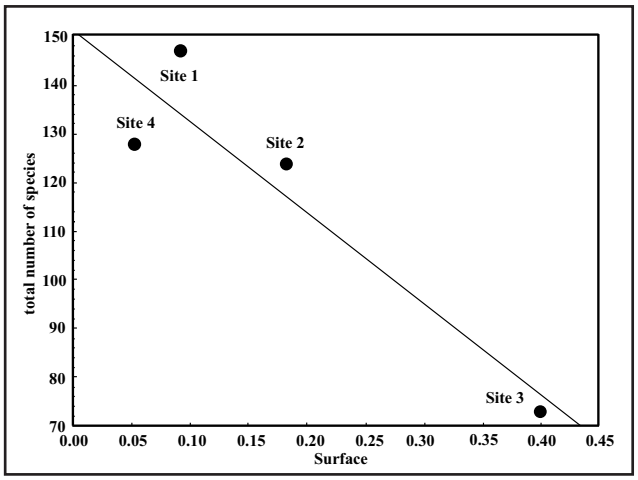

Fig. 2. Relationship between the surface (km^2) of the four studied serpentine areas and the total number of serpentine species recorded for each site. For site numbers see text.

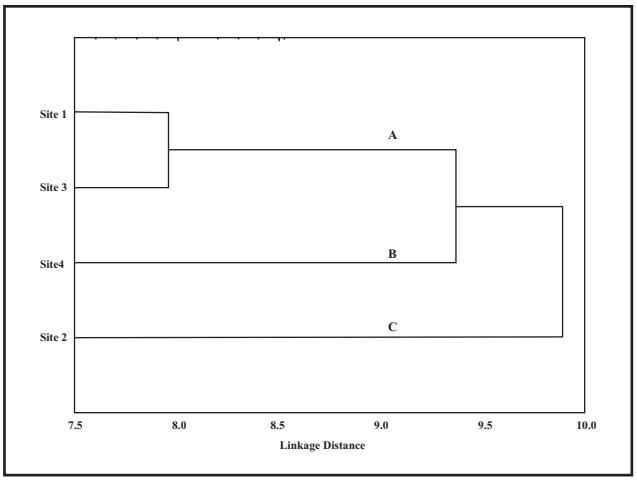

Fig. 3. UPGMA dendrogram of the four sites based on floristic affinity. Clusters described in the text are numbered (A-C).

The pairwise comparisons resulted in a data matrix with calculated similarity indices (β-diversity) varying from 0.360 to 0.520 (Table 3). Quotations of similarity within pairs of sites have showed that low levels of species overlap within each pair. Site 2 and Site 3, which were the closest in between (approximate distance of 25 km), have had the highest similarity index of any pair of serpentine sites in the study. Site 4 in Mt Ograzhden with its southern placement shows the lowest level of similarity (0.36) with Site 1.

Cluster analysis of the areas based on the main groups of phytogeographical elements and UPGMA dendrogram was performed in Fig. 3. The graph shows that the sites form three clusters. Mt Ograzhden, Site 4 (cluster B), and Site 2 in Mt Vlahina (cluster C) have isolated positions in the context of the examined floras. This might be due to the greater distance between them of more then 150 km and their placement: southernmost for Site 4 and northernmost for Site 3. Cluster (A) included the two sites, which are much closer to each other, located at approximately the same altitude in the low mountain belt.

Table 3. Sørensen's indices within serpentine sites (t = 19.317, p < 0.05).

Site	Sorensen' index
1 & 2	0.437
1 & 3	0.390
1 & 4	0.360
2 & 3	0.520
2 & 4	0.427
3 & 4	0.424
mean	**0.426 ± 0.054**

Discussion

The serpentine flora in open habitats in the study area is characterized by peculiar taxa, specific for the different sites. Moreover, this flora demonstrates the common peculiarities of the flora of the corresponding floristic region. Despite of the smaller serpentine areas in comparison with the Eastern Rhodopi Mts, the serpentine flora of Vlahina and Ograzhden Mts possesses characteristic species and should not be neglected from a floristic point of view, as indicated also by Constantinidis (2004) for the serpentines in Central Greece.

According to Brooks (1987), the large number of therophytes is typical for the serpentine floras, where the plants are adapted to ensure their reproduction within a short period of time under stress-conditions. The comparison of the phytogeographical units with the serpentine sites in the Rhodopi Mts (Pavlova 2004; Pavlova & al. 2003) confirms the characteristics of mid-latitude floras. While the best represented phytogeographical units in the serpentine flora of the Eastern Rhodopi Mts are the Mediterranean, Oriental-Turanian and Central-European elements (Pavlova & al. 2003), in the West Frontier Mts the Mediterranean, European and Eurasian species prevail. The proportion of the Oriental-Turanian elements in the study area is quite low, following the common trend for the country of decrease from east to west direction. A comparison with the Central Rhodopi Mts, where Central-European, Mediterranean and Eurasian species prevail (Pavlova 2004), shows a lower participation of Central-Eu-

ropean elements in the studied serpentine area. The higher proportion of Mediterranean phytogeographical units in the study area is in accordance with the common tendency of the flora of Southwest Bulgaria, where along river Struma many Mediterranean elements reach the territory of the country.

The Balkan endemics and sub-endemics are heliophilous xerophytes, unevenly distributed in the studied serpentine area. They are of significant local importance, because they demonstrate the specificity of this flora and the necessity of extensive research and effective conservation measures (Stevanović & al. 2003). According to Kruckeberg (1992), serpentine endemics were not found on the territory of the investigated sites. The local serpentine indicator plants are: *Cheilanthes maranthae, Alyssum murale* subsp. *pichleri, Onosma echioides*, *Silene bupleuroides, Plantago holosteum*, *Euphorbia niciciana*, *Stachys angustifolia,* and *Koeleria simonkaii*. These plants, along with *Trinia glauca* subsp. *glauca, Stipa tirsa, Asyneuma limonifolium*, *Convolvulus boissieri* subsp. *parnassicus*, and *Thymus bracteosus* are cited as local indicators, bound but not restricted to the serpentines for the Rhodopi Mts (Pavlova 2007), and demonstrate the specificity of this local flora. A great number of local indicator species are common for the serpentine areas in Mt Vourinos, Greece (Babalonas 1989) and Tuscany, Italy (Chiarucci & De Dominicis 2001; Selvi 2007). These taxa show the similarities of the Mediterranean serpentine floras, matched also by Brooks (1987).

In comparison with other serpentine regions in Bulgaria (Pavlova 2004, 2007; Pavlova & al. 1998, 2003), the Balkan Peninsula (Rechinger 1961; Krause & al. 1963; Babalonas 1984, 1989; Ritter-Studnicka 1970; Tatić & Veljović 1992; Constantinidis 2004), and the Apennines (Ferrari & al. 1991; Chiarucci & De Dominicis 2001; Selvi 2007), the smaller number of endemics distributed on the serpentines in the West Frontier Mts and the lack of serpentine endemics is most probably due to the lower altitude of the studied localities and the human impact.

As a result of this study, new chorological data have been provided for the following taxa: *Verbascum xanthophoeniceum*, *Cuscuta approximata*, *Berteroa obliqua*, *Bupleurum apiculatum*, *Dianthus pallens*, *Silene chlorantha*, *Galium macedonicum*, *Scabiosa argentea*, *Centaurea chrysolepis*, *Delphinium balcanicum, Cheilanthes maranthe, Silene lydia, Trachynia distachya*, *Vulpia ciliata*, *Phleum graecum,* and *Stipa capillata.* All these plants were found for the first time on the territory of the floristic region of West Frontier Mts.

Despite anthropogenic interference, the serpentine flora of the West Frontier Mts in Bulgaria possesses specific features and efficient measures are needed for the conservation and protection of these floristically rich sites in Bulgaria.

References

Assyov, B., Petrova, A., Dimitrov, D. & Vassilev, R. 2006. Conspectus of the Bulgarian Vascular Flora. Distribution Maps and Floristic Elements. Bulgarian Biodiversity Foundation, Sofia.

Babalonas, D. 1984. Zur Kenntnis der Flora und Vegetation auf Serpentin-Standorten Nordgrichenlands I. – Serpentinvegetation im Voras-Gebiirge. – Feddes Repert., **95**: 687-697.

Babalonas, D. 1989. Beitrag zur Flora des serpentinischen Vourinos-Gebirges (Nordgriechenland). – Willdenowia, **18**: 387-399.

Biological Diversity Act. 2002. Decree no. 283 accepted by the 39th National Assembly on 02 August 2002. – Darzhaven Vestnik, no. 77/09.08.2002. Pp. 9-42 (in Bulgarian).

Biological Diversity Act (Act on Amending and Supplementing). 2007. Decree no. 354 accepted by the 40th National Assembly on 01 November 2007. – Durzhaven Vestnik, no. 94/16.11.2007, pp. 2-44 (in Bulgarian).

Brooks, B. 1987. Serpentine and its Vegetation. A Multidisciplinary Approach. Dioscorides press, Portland, Oregon.

Chiarucci, A. & De Dominicis, V. 2001. The diversity and richness of the serpentine flora of Tuscany. – Bocconea, **13**: 557-560.

Constantinidis, Th. 2004. The floristic diversity of serpentine in Greece 1. An inventory of the Aliki Area (Sterea Ellas, Central Greece). – Phyton (Horn), **44**(1): 45-67.

Drenovski, I., Yordanova, M. & Velev, S. 2002. Physical and geographical regionalization. – In: **Kopralev, I.** (ed.), Geography of Bulgaria. Physical Geography. Socio-Economic Geography. Pp. 404-405. ForCom, Sofia (in Bulgarian).

Ferrari, C., Lombini, A. & Carpené, B. 1991. Serpentine flora of the Northern Apennines, Italy. – In: **Baker, A., Proctor, J. & Reeves, R.** (eds), The Vegetation of Ultramafic (Serpentine) Soils. Pp. 159-173. Intercept, Andover.

Jordanov, D. (ed.). 1963–1979. Flora Reipublicae Popularis Bulgaricae. Vols **1**-**7**. In Aedibus Acad. Sci. Bulgaricae, Serdicae (in Bulgarian).

Kent, M. & Coker, P. 1994. Vegetation Description and Analysis: a Principal Approach. John Wiley & Sons, Chichester.

Kozhoukharova, E. 1984. Origin and structural position of the serpentinized ultrabasic rocks of the Precambrian ophiolite association in the Rhodope Massif. I. Geologic position and composition of the ophiolite association. – Geol. Balcan., **14**(4): 9-36.

Kozhuharov, S. (ed.). 1992. Field Guide to the Vascular Plants in Bulgaria. Nauka & Izkustvo, Sofia (in Bulgarian).

Kozhuharov, S. (ed.). 1995. Flora Reipublicae Bulgaricae. Vol. **10**. Editio Acad. "Prof. Marin Drinov", Serdicae (in Bulgarian).

Krause, W., Ludwig, W. & Siedel, F. 1963. Zur Kenntnis der Flora und Vegetation auf Serpentinstandorten des Balkans. – Bot. Jahrb. Syst., **82**(4): 337-403.

Kruckeberg, A. 1984. California Serpentines: Flora, Vegetation, Geology, Soils and Management Problems. California Univ. press, California.

Kruckeberg, A. 1992. Plant life of western North American Ultramafics. – In: **Robertis, B. & Proctor, J.** (eds), The Ecology of Areas with Serpentinized Rocks. A World View. Pp. 31-73. Kluwer Acad. Publishers, Dordrecht.

Kruckeberg, A. & Rabinowitz, D. 1985. Biological aspects of endemism in higher plants. – Annual Rev. Ecol. Syst., **16**: 447-479.

Mayer, M., Soltis, P. & Soltis, D. 1994. The evolution of *Streptanthus glandulosus* complex (*Cruciferae*): Genetic divergence and gene flow in serpentine endemics. – Amer. J. Bot., **81**: 1288-1299.

Pavlova, D. 2001. Mountain vegetation on serpentine areas in the Bulgarian Eastern and Central Rhodope Mts. – ecology and conservation. – In: **Radoglou, K.** (ed.), Proc. Int. Conf.: Forest Research: a Challenge for an Integrated European Approach, Thessaloniki 2001. Vol. **1**, pp. 227-232. Thessaloniki.

Pavlova, D. 2004. The serpentine flora in the Central Rhodope Mts, Southern Bulgaria, – In: Proc. Second Congr. Ecologists of R Macedonia, Ohrid 2004. Special issues Macedonian Ecol. Soc. Vol. **6**, pp. 450-457. Skopie.

Pavlova, D. 2007. Endemics and rare plants growing on serpentines in the Rhodopes mountains (Bulgaria). – In: **Filipovski G., Lozanovski R. & Matevski V.** (eds), Collection of papers devoted to academician Kiril Micevski: on the occasion of the 80 years of his birth. Pp. 157-170. Macedonian Acad. Sci. & Arts, Skopje.

Pavlova, D. 2009. Morphological variation in *Teucrium chamaedrys* from serpentine and non-serpentine populations. – In: Proc. 6th Int. Conf. Serpentine Ecol. Soil and Biota of Serpentine: A World View. – N.E. Naturalist, **16**(Special Issue 5): 39-55.

Pavlova, D. & **Dimitrov, D.** 2001. A contribution to the flora of the serpentine areas in the Rhodopes Mts. (Southern Bulgaria). – Ot, **8**(2): 13-19.

Pavlova, D. & **Dimitrov, D.** & **Kozuharova, E.** 2004. Flora of the serpentine complexes in Eastern Rhodopes (Bulgaria). – In: **Beron, P. & Popov, A.** (eds), Biodiversity of Bulgaria. **2**. Biodiversity of Eastern Rhodopes (Bulgaria and Greece). Pp. 199-129. Pensoft & Natl. Mus. Nat. Hist., Sofia.

Pavlova, D., Kozuharova, E. & Dimitrov, D. 1998. The serpentine flora of the Eastern Rhodopes Mountains (Bulgaria). – In: **Tsekos I. & Moustakas M.** (eds), Progress of Botanical Research. Proc. First Bot. Congr., Tessaloniki. Pp. 133-136. Kluwer Acad. Publishers, Dordrecht.

Pavlova, D., Kozuharova, E. & Dimitrov, D. 2002 . New chorological data for the flora of the East Rhodope Mts. – God. Sofiisk. Univ. "St. Kliment Ohridski" Biol. Fak., 2. Bot., **90**: 79 – 87.

Pavlova, D., Kozuharova, E. & Dimitrov, D. 2003. A floristic catalogue of the serpentine areas in the Eastern Rhodope Mountains (Bulgaria). – Polish J. Bot., **48**(1): 21-41.

Pavlova, D., & Nedelcheva, A. 2007. The serpentine flora in the Vlahina Mountain (Southwest Bulgaria). – In: **Pesić, V. & Hadziablanović, S.** (eds), Proc. Second Int. Symp. Ecologist of Montenegro, Kotor 2007. Pp. 251-257. Kotor.

Petrova, A. & Vladimirov, V. 2009. Red List of Bulgarian vascular plants. – Phytol. Balcan., **15**(1): 63-94.

Petrova, A., Vladimirov V., Dimitrova D. & Ivanova D. 2005. Current state of the Bulgarian fern and seed plant biodiversity. – In: **Petrova, A.** (ed.), Current Stage of Bulgarian Biodiversity – Problems and Perspectives. Pp. 75-104. Bulgarian Bioplatform, Sofia.

Rajakaruna, N. 2004. The edaphic factor in the origin of plant species. – Int. Geol. Rev., **46**: 471-478.

Rechinger, K. 1961. Die Flora von Euboea. – Bot. Jahrb. Syst., **80**: 294-465.

Ritter-Studnicka, H. 1970. Die Vegetation der Serpentinvorkommen in Bosnien. – Vegetatio, **21**:75-156.

Selvi, F. 2007. Diversity, geographic variation and conservation of the serpentine flora of Tuskany (Italy). – Biodivers. & Conservation, **16**: 1423-1439.

Stevanović, V., Tan, K. & Iatrou, G. 2003. Distribution of the endemic Balkan flora on serpentine I. Obligate serpentine endemics. – Pl. Syst. Evol., **242**: 149-170.

Tatić, B. & Veljović, V. 1992. Distribution of serpentinized massives on the Balkan Peninsula and their ecology. – In: **Roberts, B.A & Proctor, J.** (eds), The Ecology of Areas with Serpentinized Rocks. A World View. Pp. 199-215. Kluwer Acad. Publishers, Dordrecht.

Turrill, W. 1929. The Plant-life of the Balkan Peninsula. A Phytogeographical Study. Clarendon Press, Oxford.

Tutin, T.G., Burges, N.A., Chater, A.O., Edmondson, J.R., Heywood, V.H., Moor, D.M., Valentine, D.H., Walters, S.M. & Webb, D.A. (eds). 1993. Flora Europaea. Ed. 2. Vol. **1**. Cambridge Univ. Press, Cambridge.

Tutin, T.G., Heywood, V.H., Burges, N.A., Moor, D.M., Valentine, D.H., Walters, S.M. & Webb, D.A. (eds). 1968–1983. Flora Europaea. Vols **2**-**5**. Cambridge Univ. Press, Cambridge.

Velchev, V. (ed.). 1982–1989. Flora Reipublicae Popularis Bulgaricae. Vols **8-9**. In Aedibus Acad. Sci. Bulgaricae, Serdicae (in Bulgarian).

Velchev, V. (ed.). 1984. Red Data Book of the PR Bulgaria. Vol. **1**. Plants. Publishing House Bulg. Acad. Sci., Sofia (in Bulgarian).