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COMPARATIVE ANALYSES OF THE VASCULAR FLORA OF THE PČINJA RIVER GORGES IN SERBIA AND MACEDONIA

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Abstract - The study's aim is the comparative chorologic and ecological analysis of the vascular flora of the two gorges of the Pčinja River in Serbia and Macedonia which are 27 km apart. In the two gorges 1564 taxa have been recorded, 1057 being in the upper gorge in Serbia and 1174 in the lower gorge in Macedonia. Common to both gorges are 666 taxa. Chorological spectra show that in both gorges the most abundant are Mediterranean-submediterranean plants, 32.85% being in the upper and 43.97% in the lower gorge. Differences in the studied vegetation result from a diverse participation of other floristic elements such as Central European ones that are more abundant in the upper gorge (17.05%) than in the lower gorge (10.86 %). The life-form spectrum reveals that the flora in both gorges is hemicryptophyte-therophyte in character. Both gorges belong to an enclave of a Mediterranean-submediterranean region, i.e. to its submediterranean Macedonian-Thracian province.

Key words: Vascular flora, floristic elements, life-forms, gorges, Pčinja River, Serbia, Macedonia.

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INTRODUCTION

Canyons and gorges represent major centers of flora and vegetation diversity in the Balkan Peninsula. They differ from the surrounding area by the steady micro- and mesoclimate typical for a deep and narrow river valley bordered by mountains. Favorable climatic conditions, along with geomorphologic characteristics such as terrain slope, direction of the river valley, varied geological bedrock, made the gorges and canyons very significant refuges of ancient flora. The chorological composition of canyon flora includes floristic elements of different origin, age and distribution, among which endemic and relict species assume particular place. This is best confirmed by hitherto performed surveys of the flora of the canyons and gorges of the western and central Balkans (Grebenščikov, 1950; Bulić et al., 2008; Diklić and Nikolić, 1972; Jovanović and Jovanović-Dunjić, 1986; Lakušić, 1972; Lakušić & Redžić, 1989; Lakušić et al. 1996; Micev, 1952; Mišić, 1981; Ostojić and Zlatković 2010; Soška, 1939; Stefanović, 1979).

Depending on the geographical position and orientation, each canyon and/or gorge is characterized by a specific composition of plants. In addition to being refuges of ancient flora, canyons and gorges are often the most suitable corridors of species spreading from different regions. Thus, the western and central parts of the Balkan Peninsula are the most important pathways for the spreading of Mediterranean elements towards continental regions. This is how Mediterranean floristic impacts expand along the valley of the Vardar river from the Aegean Sea northwards

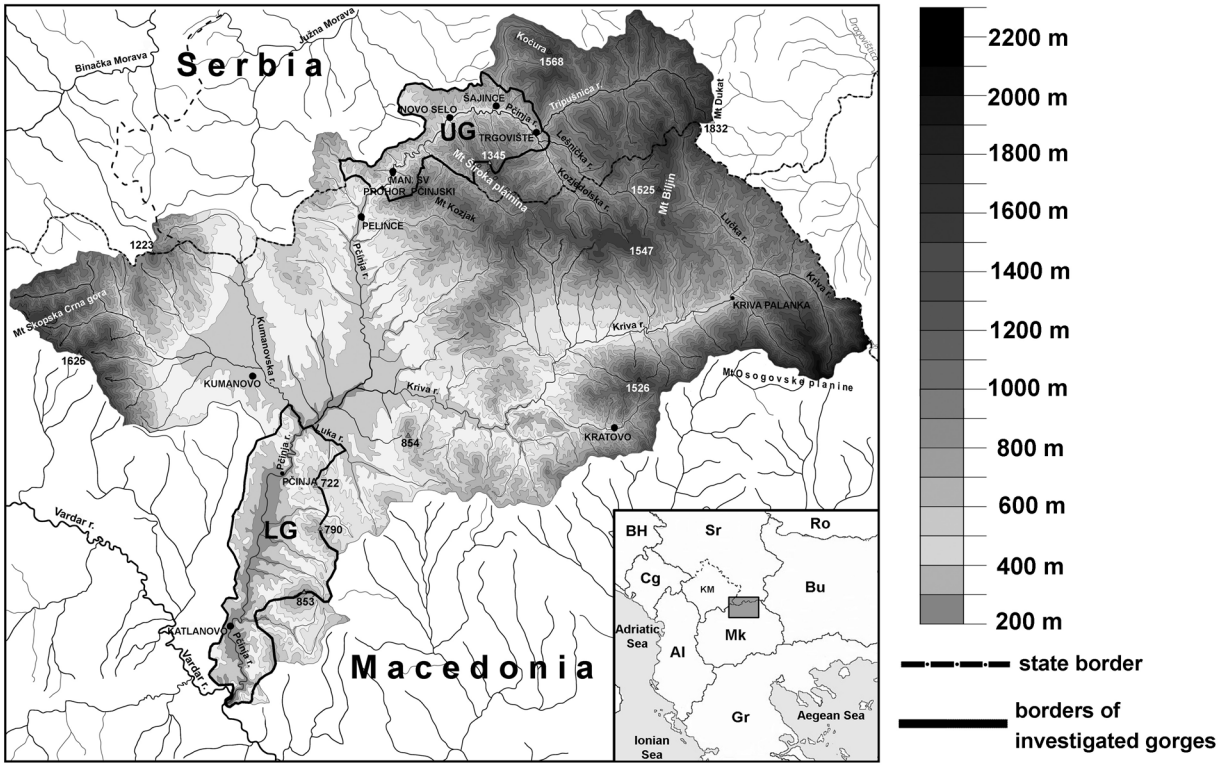

Fig.1. Map of the Pčinja river watershed showing the position of the upper gorge (UG) in Serbia and the lower gorge (LG) in Macedonia.

along the valleys of the Pčinja and Lepenac rivers, reaching Kosovo and southern and southeastern Serbia.

The studies of the flora of the Pčinja river gorges were carried out from the upper river course in southeastern Serbia up to its confluence into the Vardar river in Macedonia. On its 122 km-long watercourse, the Pčinja river carves two gorges that are 27 km apart. The upper gorge is located between the village Trgovište in Serbia, up to the border between Serbia and Macedonia and below the monastery of St. Prohor Pčinjski. The lower gorge is in Macedonia in the reach of the Pčinja river, situated on the point where the Pčinja flows into the Vardar, up to the area where its left tributary, the Luka, flows into the Pčinja. Between these two gorges sprawls a wide lowland valley (Fig.1).

The aim of the study was to establish, on the basis of floristic composition, i.e. the spectra of basic groups of floristic elements and life forms, to what extent Mediterranean and Pontic impacts on the one hand, and Central European and Eurasian floristic impacts on the other hand, face, spread and overlap in the gorges of the Pčinja river.

MATERIAL AND METHODS

Data on the floristic composition of the upper gorge (UG) of the Pčinja river in Serbia were accumulated by long-standing field surveys as well as by reviewing relevant literature (Zlatković and Ranđelović, 2004; Zlatković and Stevanović, 2007; Zlatković et al., 2009; Zlatković et al., 2009a). Data on the flora of the lower gorge (LG) in Macedonia were also gathered both by reviewing literature published in the last two centuries (Jurisić, 1923; Matevski, 2010; Micev, 1952; Micevski, 1985-2005; Nikolić, 2009; Soška; 1939; Šmarda, 1968) and by field surveys in the last few years. The similarity between the flora of the upper and lower gorges was analyzed at the

level of main groups of floristic elements and life forms by calculating similarity coefficient after Jaccard (1928).

Classification of floristic elements is given according to Meusel et al. (1965, 1978), Meusel and Jäger (1992) and Stevanović (1992a). They are sorted into the following chorological groups: Arcto-alpine (A-A), Boreal (BOR), Central European (CE), Mediterranean-submediterranean (MED), Pontic (PONT), Central-southern European mountain (CSEM), Eurasian (EAS), Holarctic (HOL), Cosmopolitan (COSM) and Adventive (ADV). Criteria proposed by Mueller-Dombois and Ellenberg (1974) and Stevanović (1992) served for the determination of basic life-form groups: phanerophytes (P), chamaephytes (Ch), hemicryptophytes (H), geophytes (G), therophytes (T) and scandentophytes (S).

Collected material is housed in the Herbarium of the Institute of Botany and Botanical Garden "Jevremovac", University of Belgrade (BEOU), the Herbarium of the Natural History Museum in Belgrade (BEO), as well as in the private collection of B. Zlatković (BZ). Nomenclature is given according to Euro+Med or IOPI databases.

RESULTS AND DISCUSSION

Both studied gorges in the valley of the Pčinja river cover an area of 355 km^2, the upper gorge being 146 km^2, and the lower one 215 km^2. The total of 1564 taxa, ranked as species and subspecies, were recorded in the two gorges combined. Out of this number 1057 taxa belong to the upper gorge (UG) flora, and 1174 to the lower gorge (LG) flora, whereas 666 taxa are common to both gorges. Floristic similarity between the two gorges is moderate being 42.75%.

The most abundant life forms in both gorges are hemicryptophytes (UG – 410 vs. LG – 435 taxa) and therophytes (UG – 371 vs. LG – 423 taxa), followed by geophytes, phanerophytes, hemophytes and scandentophytes (Tab.1 A & B). Such a life-form spectrum substantiates the hemicryptophytic-therophytic character of both gorges floras (Tab. 1, Fig. 2A).

Phanerophytes, i.e. trees and scrubs are represented by almost the same number of taxa, i.e. 80 (7.57% of the total flora) in the UG and 83 taxa (7.07% of the total flora) in the LG, whereas the floristic similarity is 45.4%. In both gorges, over 50% of phanerophytes make up scrubs whereas about 45% make up trees. The phanerophyte flora of the gorges is distinguished by the different presence of Mediterranean-submediterranean trees and scrubs (Fig. 2B). The differential species in the LG are *Celtis australis*, *Podocytisus caramanicus* and *Rhus coriaria,* as well as the evergreen species *Phillyrea latifolia, Juniperus excelsa* and *Buxus sempervirens*. Nevertheless, the number of shared Mediterranean-submediterranean phanerophytes in both gorges is high due to species such as *Carpinus orientalis*, *Fraxinus ornus, Quercus pubescens*, *Pyrus spinosa, Coronilla emerus* subsp. *emeroides, Colutea arborescens Pistacia terebinthus, Juniperus oxycedrus*, etc. Phanerophytes of the Central European distribution type are represented in both gorges by approximately the same number of species (UG-33 vs. LG-29 taxa) and a high similarity of 50% in trees and 60% in scrubs. In addition, the high floristic similarity in the gorges has been established for phanerophytes of Eurasian distribution. The relict species of trees and scrubs are particularly significant for both gorges. Their presence highlights the refugial importance of the gorges. Such species in the lower gorge are *Buxus sempervirens*, *Celtis australis*, *Syringa vulgaris, Juniperus excelsa, Staphyllea pinnata, Jasminium fruticans, Rhus coriaria,* while in the upper gorge these are *Acer hyrcanum, Corylus colurna, Ostrya carpinifolia, Myricaria germanica, Laburnum anagyroides*.

Chaemophytes (Fig. 2C) are represented by 102 taxa in the two gorges combined, where a number of species is lower in the UG (52 taxa) than in the LG (84 taxa). The similarity coefficient of chamaephytic flora between the gorges is moderate being 41.71%. In both gorges are dominant Mediterranean woody or semi-woody hemophytes, but their similarity is low, being 31.25%. The most common Mediterranean-submediterranean species in both gorges are *Cytisus triflorus*, *Dianthus gracilis*, *D. pinifolius*, *Dorycnium pentaphyllum* subsp.

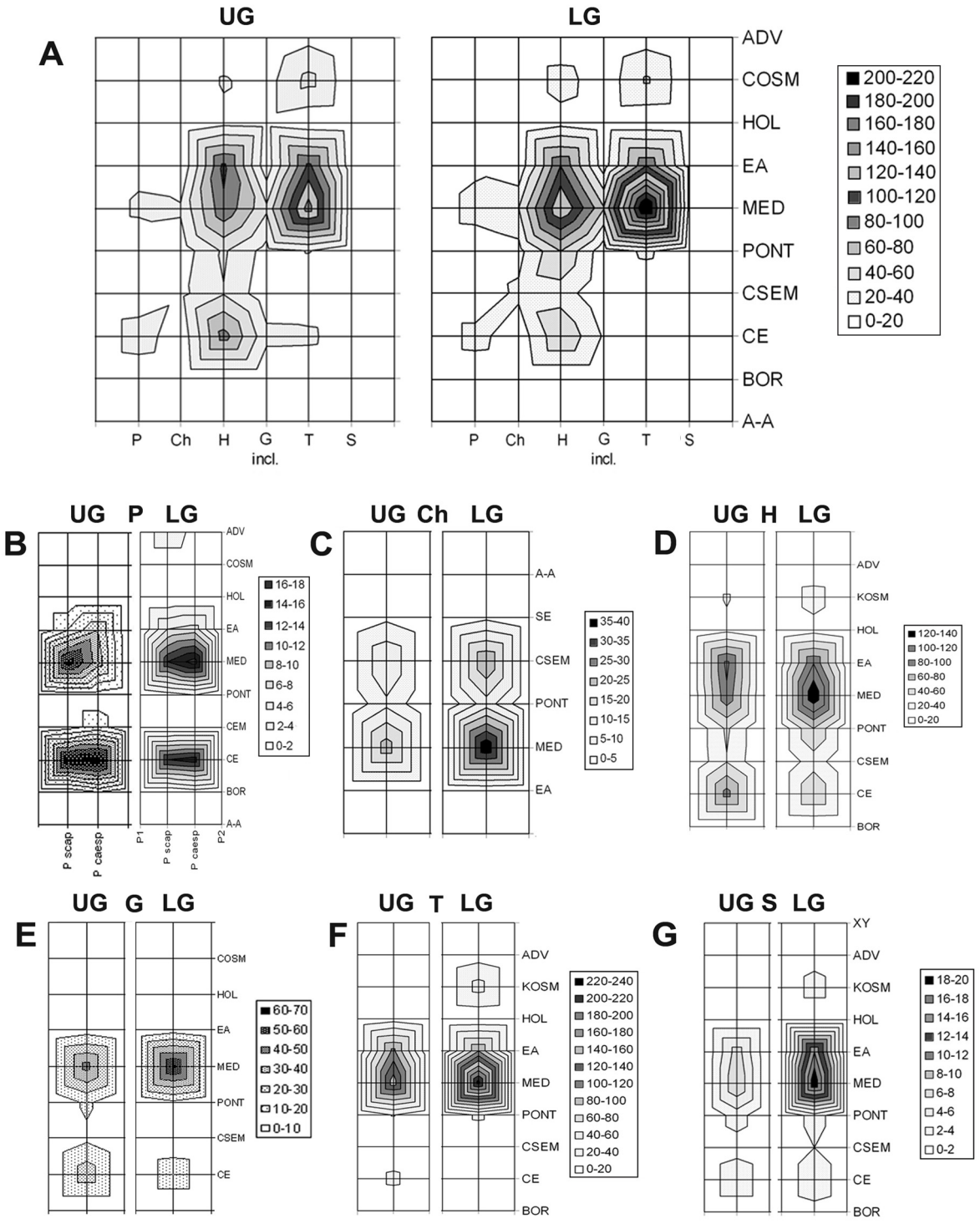

Fig. 2. Combined chorologic and life form spectra of: A – total flora; B – phanerophytes: trees (P scap) and scrubs (P caesp); C – chamaephytes; D – hemicryptophytes; E – gophytes; F – therophytes and G – lianas and climbers (scandentophytes); UG – upper gorge, LG – lower gorge.

Table 1. Numbers and percentage of basic groups of floristic elements and life forms in the gorges of the Pčinja river: UG – upper gorge in Serbia, LG – lower gorge in Macedonia. Abbreviation of the main groups of floristic elements and life forms are given in Materials and Methods.

	P		**Ch**		**H**		**G**		**T**		**S**		**Total**	
UG	**N°**	**%**	**N°**	%	**N°**	**%**	**N°**	**%**	**N°**	**%**	**N°**	**%**	**N°**	**%**
A-A	**0**	**0**	**1**	**1.92**	**0**	**0**	**0**	**0**	0	0	0	0	1	0.1
BOR	2	2.5	0	0	0	0	0	0	1	0.27	0	0	3	0.28
CE	33	41.3	4	7.7	88	21.46	26	22.2	25	6.74	4	14.8	180	17.03
CSEM	4	5	15	28.85	39	9.51	6	5.13	3	0.81	1	3.7	68	6.43
PONT	2	2.5	9	17.3	43	10.49	12	10.3	21	5.66	3	11.1	90	8.52
MED	25	31.3	23	44.23	96	23.41	44	37.6	152	41	8	29.6	348	32.92
EA	12	15	0	0	105	25.61	7	6	105	28.3	7	26	236	22.33
HOL	0	0	0	0	15	3.67	11	9.4	3	0.81	1	3.7	30	2.84
COSM	0	0	0	0	22	5.36	11	9.4	47	12.7	3	11.1	83	7.85
ADV	2	2.5	0	0	2	0.49	0	0	14	3.77	0	0	18	1.7
Total	80	100	52	100	410	100	117	100	371	100	27	100	1057	100
Total (%)		7.57		4.92		38.79		11.07		35.09		2.55		100

	P		**Ch**		**H**		**G**		**T**		**S**		**Total**	
LG	**N°**	**%**	**N°**	**%**	**N°**	**%**	**N°**	**%**	**N°**	**%**	**N°**	**%**	**N°**	%
A-A	0	0	1	1.19	0	0	0	0	0	0	0	0	1	0.09
BOR	1	1.2	0	0	1	0.23	0	0	1	0.24	1	2.56	4	0.34
CE	29	34.9	5	5.95	59	13.56	18	16.4	12	2.84	4	10.3	127	10.82
CSEM	1	1.2	25	29.76	31	7.13	2	1.82	3	0.71	0	0	62	5.28
PONT	3	3.61	12	14.29	60	13.8	7	6.36	24	5.67	3	7.69	109	9.28
MED	31	37.4	40	47.62	141	32.41	62	56.4	229	54.1	16	41	519	44.21
EA	13	15.7	1	1.19	99	22.76	9	8.18	98	23.2	10	25.6	230	19.59
HOL	0	0	0	0	12	2.76	5	4.54	3	0.71	1	2.56	21	1.79
COSM	0	0	0	0	29	6.66	7	6.36	43	10.6	3	7.69	82	6.98
ADV	5	6.02	0	0	3	0.69	0	0	10	2.36	1	2.56	19	1.62
Total	83	100	84	100	435	100	110	100	423	100	39	100	1174	100
Total (%)		7.07		7.15		37.05		9.37		36.03		3.32		100

germanicum and *Fumana procumbens*. However, in the lower gorge typical Mediterranean semi-woody chaemophytes such as *Ephedra foeminea*, *Genista sessilifolia, Astragalus parnassi, Inula aschersoniana, Salvia ringens, Onobrychis hypargirea* and *Phagnalon rupestre graecum* are more numerous. Most of those species reach their northern limit of distribution in this gorge. Chamaephytes of Central-southeuropean mountain distribution rank second, 15 species being in the UG and 25 species in the LG, with low floristic similarity of 29.03%. Such great differences in the number and composition of mountain chamaephytes in the two gorges are primarily a result of habitat specificity, i.e. limestone rocks in the lower gorge and silicate ones in the upper gorge. Otherwise, this group of chaemophytes is distinguished by a high altitudinal distribution range. Such species are *Draba lasiocarpa, Euphorbia myrsinites, Silene saxifraga (parnassica), Chamaecytisus tommasinii, Cerastium banaticum, Chamaespartium sagittale* and *Minuartia falcata*. However, chaemophytes of Central European distribution are present in a small number of species (UG - 4 vs. LG – 5 taxa) and moderate floristic similarity of 50%.

Hemicryptophytes (Fig. 2D) are the most abundant life forms in both gorges with 410 species in the UG and 435 species in the LG, and with moderate similarity of 41.79%. The largest number of hemicryptophytes in both gorges belongs to taxa of Mediterranean-submediterranean distribution, with 96 of such species in the UG, and as many as 141 species in the LG. The similarity coefficient is 42.77%. Widely distributed Eurasian hemicryptophytes were present in almost the same number in both gorges (UG - 105 vs. LG - 99 taxa) having a higher similarity coefficient of 50%. Central European hemicryptophytes are by far more numerous in the UG than in the LG (88 vs. 59 taxa), where floristic similarity is 45%. Strong floristic impacts from the Macedonian-Thracian steppes resulted in the greater presence of hemicryptophytes of Pontic distribution in the LG (60) than in the UG (43), as well as the proportionally lower similarity of 38.35%.

In the flora of both gorges, 171 taxa belonging to geophytes, including hydrogeophytes, were established, 117 growing in the UG and 110 in the LG, with a relatively low similarity of 32.16% (Fig. 2E). Bulbous, rhizomatous and tuberous plants, the distribution areas of which encompass the Mediterranean, Central European and Pontic region, make up 76.7% of the total number of geophytic flora of the gorges studied. In both gorges the most abundant are geophytes of Mediterranean-submediterranean distribution with 44 taxa in the UG and 62 taxa in the LG and a very low similarity of 26.19%. Namely, many typical Mediterranean geophytes, such as *Anemone pavonina, Arrhenatherum palaestinum, Crocus olivieri, Phelypaea boissieri, Ranunculus sprunerianus, Valeriana dioscoridis, Crocus pallasii, Iris sintenisii, Allium ampeloprasum,* inhabit only the lower gorge, which is under direct Mediterranean impact spreading from the south along the Vardar river valley. On the contrary, geophytes of Central European distribution are more numerous in the upper gorge (UG-26 vs. LG-18 taxa), but with a low similarity of 37.5 %. The lowest similarity coefficient between the gorges was recorded for geophytes of Pontic distribution, being only 18.75%.

Therophytes assume second place in presence in ofthe flora inof both gorges, with 371 taxa in the UG and 423 in the LG and a moderate floristic similarity of 48.4% (Fig. 2F). In both gorges, the most abundant are Mediterranean-submediterranean therophytes, with 152 taxa in the UG and 229 in the LG and a moderate similarity of 44.23%. Eurasian therophytes rank second in abundance, with 105 taxa in the UG and 98 taxa in the LG and a high similarity of 54.96%. This was predicted given that they are a widely distributed species. Besides, in both gorges cosmopolitan therophytes are numerous, with 47 and 43 taxa in the upper and lower gorge, respectively, and a still higher similarity of 57.89% as compared to the above-mentioned Eurasian therophytes.

Scandentophytes, i.e. climbers and lianas, are present with a lower number of species in the UG than in the LG (27 vs. 39 taxa) but with a high similarity of 69% (Fig. 2G). Major differences are observed in the

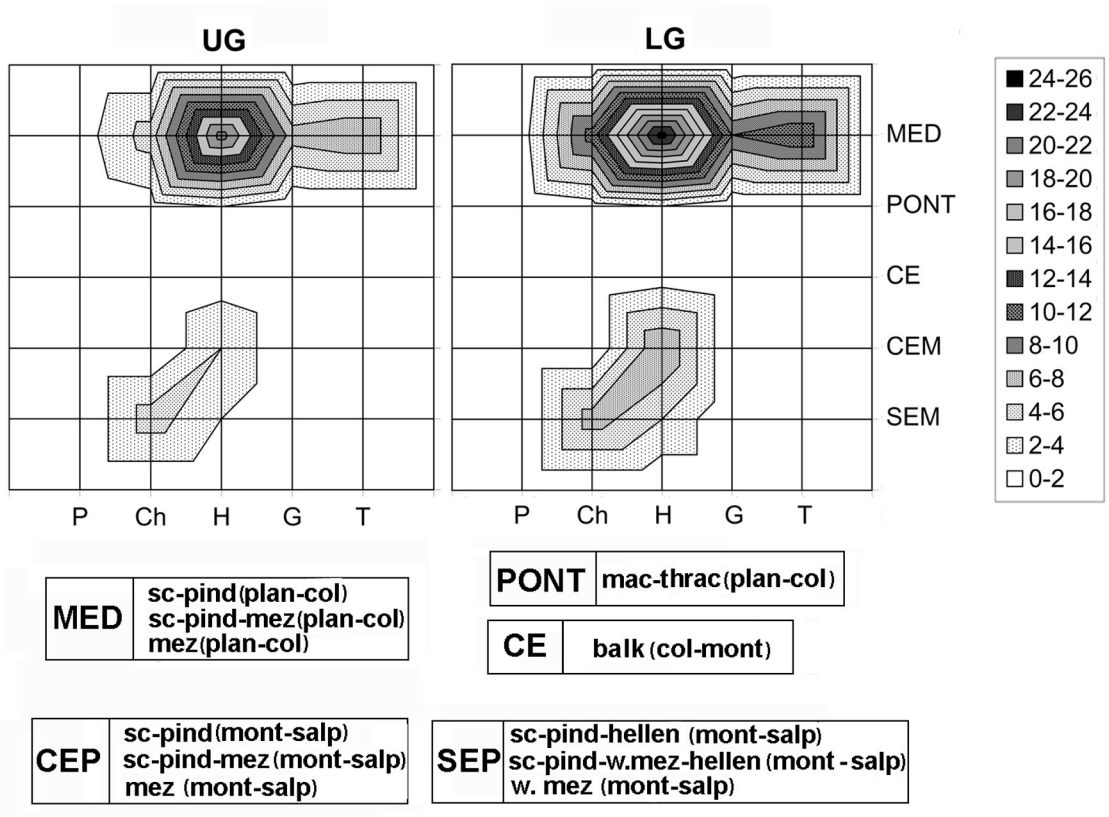

Fig. 3. Combined chorologic and life form spectra of endemic flora in the two gorges of the Pčinja river; UG – upper gorge, LG – lower gorge.

presence of woody Mediterranean-submediterranean lianas and climbers, such as *Asparagus tenuifolius, Periploca graeca, Lonicera etrusca, L. periclymenum*, which occur only in the lower gorge. The similarity coefficient of Mediterranean-submediterranean scandentophytes is small, being 33.3%, whereas that of Central European ones is 100%.

In the flora of both gorges 108 endemic taxa or 6.9% of the total flora were recorded, whereby there are almost less than half the taxa in the UG (58 taxa or 5.49%) than in the LG (86 taxa or 7.32%). The similarity coefficient between the endemic vegetation of the two gorges is only 26.16%. The largest number, 65 species and subspecies or 60.2% of the total of endemics, belongs to Mediterranean-submediterranean taxa s.l. A significantly higher number was recorded in the LG than in the UG (59 vs. 24 taxa), where the similarity was low, being 27.69% (Tab 2.). Among these endemics Scardo-Pindic, Scardo-Pindic-Moesian and lowland to coline (plan-col), and to a lesser extent Illyrian-Balkan floristic elements (Fig. 3), prevail. Central–southern European mountain s.l. endemics rank the second. Their number is approximately the same in both gorges (UG -19 vs. LG - 22 taxa) where the similarity is 28.12%. These endemics mainly inhabit the mountains of the central and eastern parts of the Balkan Peninsula, seldom reaching the mountains of the Central Greece and Peloponnesus. Therefore, they belong to Scardo-Pindic-Moesian, Scardo-Pindic and Moesian, and more seldom, to the Dinaric-Balkan orophytes. The occurrence of these, mainly paleoendemics, resulted of migrations from the mountains into refugial zones, i.e. the surrounding gorges in the course of the glacial-interglacial periods. It is important to point out that strict

Table 2. Number and percentage of basic groups of floristic elements and life forms of endemics in the gorges of the Pčinja river: UG – upper gorge in Serbia, LG – lower gorge in Macedonia. Abbreviations: sc-pind – Scardo-Pindhian; mez –Moesian; mac –Macedonian; thrac – Thracian; hellen – Hellenian; balk - Balkan; plan – lowland; col – colline; mont-montane; salp – subalpine.

	P		**Ch**		**H**		**G**		**T**		**Total**	
UG	N°	%	N°	%	N°	%	N°	%	N°	%	N°	%
SEM	0	0	5	45.45	2	7.14	0	0	1	10	8	13.79
CEM	0	0	0	0	4	14.28	0	0	1	10	5	8.63
CE	1	50	0	0	1	3.57	0	0	0	0	2	3.45
PONT	0	0	1	9.1	2	7.14	0	0	0	0	3	5.17
MED	1	50	5	45.45	19	67.86	7	100	8	80	40	68.96
Total	2	100	11	100	28	100	7	100	10	100	58	100
Total (%)		3.45		18.96		48.27		12.07		17.24		100

	P		**Ch**		**H**		**G**		**T**		**Total**	
LG	N°	%	N°	%	N°	%	N°	%	N°	%	N°	%
SEM	0	0	7	36.84	4	10	0	0	1	6.25	12	13.95
CEM	0	0	0	0	8	20	0	0	2	12.5	10	11.63
CE	0	0	0	0	1	2.5	0	0	1	6.25	2	2.32
PONT	0	0	1	5.26	2	5	0	0	0	0	3	3.49
MED	1	100	11	57.89	25	62.5	10	100	12	76	59	68.60
Total	1	100	19	100	40	100	10	100	16	100	86	100
Total (%)		1.16		22.09		46.51		11.63		18.6		100

endemics, with restricted distribution in one or another gorge only, were not established. The existence of endemo-relict species such as *Ramonda nathaliae, Eryngium palmatum, Achillea ageratifolia, Acer intermedium, Acer heldreichii, Ranunculus psilostachys, Philipea boissieri, Alkanna* spp., *Astragalus* spp., *Scrophularia aestivalis* are worth emphasizing as floristic uniqueness and diversity of the gorges studied.

CONCLUSION

The studied gorges in the valley of the river Pčinja that are 27 km apart, are distinguished by floristic richness, as well as by a marked taxonomic, chorologic and ecologic complexity. Accordingly, they represent centers of diversity of the vascular flora in the central part of the Balkan Peninsula. In the upper

gorge 1.057 taxa, and in the lower gorge 1.174 taxa ranked as species and subspecies, were inventoried. The floristic similarity between the upper gorge in Serbia and the lower gorge and Macedonia is moderate, being 42.75%.

Hemicryptophytes and therophytes prevail in both gorges and are represented by more than 70% of total plant taxa. The highest proportion of these life forms underlines the transitional Mediterranean to temperate character of the flora in these gorges .

The largest number of recorded taxa belongs to Mediterranean-submediterranean plants since both gorges are influenced by the Mediterranean-submediterranean climate conditions spreading from the south, along the valley of the Vardar and Pčinja rivers, towards the continental parts of Serbia. However, the evergreen Mediterranean species of phanerophytes, chamaephytes and scandentophytes grow only in the lower gorge. Thus, the great number of Mediterranean and common xerophyllous floristic elements emphasizes the Mediterranean floristic character of this limestone gorge. On the other hand, the upper silicate gorge is also characterized by a significant number of Mediterranean floristic elements, but it is much more distinguished by the large number of Central European elements in almost all life forms. It is just the ratio of Mediterranean-submediterranean to Central European floristic elements that points to the phytogeographic diversity and differentiation of these two gorges' floras.

Endemic flora in the two gorges combined is represented with 107 taxa or 6.8% of the total flora. However, the number of endemic taxa in the upper gorge (48) is almost half that in the lower gorge (87). The most numerous are Mediterranean-submediterranean and Central European mountain endemics belonging to hemicryptophyte, chamaephyte and therophyte life forms. Based on the chorologic and life-form spectra, both gorges belong to the Mediterranean-submediterranean region, i.e. to the submediterranean subregion of the Macedonian-Thracian province.

However, the flora of these gorges also comprises wide-ranging species, such as Eurasian, Holarctic and cosmopolitan floristic elements, revealing an ever stronger human impact in these habitats.

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