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VASCULAR FLORA OF THE GEOMORPHOLOGICAL NATURE MONUMENT CRVENO JEZERO (DALMATIA, CROATIA)

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The vascular flora of the geomorphological natural monument Crveno jezero, located in the Dalmatian hinterland, was studied during 2017 for the first time. A total of 149 plant taxa belonging to 52 families were recorded, with *Asteraceae*, *Fabaceae*, *Lamiaceae*, and *Poaceae* being the most abundant families. The dominance of Mediterranean, South-European, and Eurasian floral elements indicates that the study area is under the influence of both oceanic and continental climates, which is in accordance with the specific location of the study area. We noted a diversity of life form strategies, with the five main strategies having a share of at least 10% of the total number of species. Most species in the study area had competitive or stress-tolerant strategies, as well as the capacity for vegetative propagation, which was to be expected in this fairly unfavorable environment. No fewer than 15 recorded species are protected by law, including 11 endemic species, which represent 7.4% of the total flora. Most of the endemic species are Illyrian-Adriatic and Illyrian-Balkanic endemics. The results of the present study greatly contribute to the knowledge of the flora of Crveno jezero and the Imotski region, and they can be used as a basis for the future conservation of the area.

Keywords: Imotski, Dinaric karst, floral elements, life forms, biodiversity, Illyrian-Adriatic endems, Illyrian-Balkanic endems, collapse doline, screes

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Tijekom 2017. istraživana je vaskularna flora geomorfološkog spomenika prirode Crveno jezero u Dalmatinskoj zagori. Bilo je to prvo istraživanje flore Crvenog jezera, u kojem je zabilježeno 149 biljnih vrsta unutar 52 porodice, među kojima su najčešće bile *Asteraceae*, *Fabaceae*, *Lamiaceae* i *Poaceae*. Dominantnost mediteranskog, južnoeuropskog i euroazijskog flornog elementa ukazuje da je istraživano područje pod utjecajem oceanske i kontinentalne klime, što je u skladu s jedinstvenim položajem područja. Zabilježili smo raznolikost životnih oblika; svaki od pet glavnih oblika imao je udio od najmanje 10% u ukupnom broju vrsta. Većina vrsta na istraživanom području ima kompetitivnu ili stres-tolerantnu strategiju, kao i sposobnost vegetativnog razmnožavanja, što je u skladu s ovim prilično negostoljubivim staništem. Zakonom je zaštićeno 15 zabilježenih vrsta, uključujući 11 endema (koji predstavljaju 7,4% ukupne flore). Većina endema su ilirsko-jadranski i ilirsko-balkanski endemi. Rezultati ovog istraživanja uvelike pridonose poznavanju flore Imotskog područja te se mogu koristiti kao osnova za buduću zaštitu područja.

Ključne riječi: Imotski, dinarski krš, florni elementi, životni oblici, biodiverzitet, ilirsko-jadranski endemi, ilirsko-balkanski endemi, ponikva, točilo

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INTRODUCTION

Crveno jezero (Red Lake) near the town of Imotski is a unique feature in the Dinaric karst, an interesting result of the interaction of karst relief and water flow, and is today one of the world's deepest karstic cryptodepressions filled with water (Zwicker *et al.*, 2008; Andrić *et al.*, 2013; Andrić & Bonacci, 2014). With an area of 0.138 km^2, it is located in the Dalmatian hinterland (Dalmatinska zagora), 1.5 kilometers northwest of the town of Imotski, Croatia, and is part of the Dinaric mountain range (Fig. 1). Since 1964 it has been classified as a geomorphological natural monument (Zwicker *et al.*, 2008), and since 2014, Crveno jezero and the nearby Plavo jezero (Blue Lake) have also been a part of the Natura 2000 ecological network (Croatian agency for the environment and nature, 2017).

In the area around Imotski Field (Imotsko polje), there are seven intermittent lakes periodically or constantly filled with water (Lovrić & Rac, 1987). The only lake that is constantly filled with water is Crveno jezero, because the water here is deep enough never to dry out (on average 250 m), and this lake is interconnected with other lakes and streams through many gaps and passages through the karstic relief. The lake itself is in a collapse doline surrounded by steep cliffs, mostly limestone but partly dolomite (Andrić & Bonacci, 2014). Insoluble deposits of bauxite minerals give the cliffs the characteristic reddish-brown color after which the lake was named. Different habitats found around the lake are shown in Fig. 2.

The area of Imotsko polje, including Crveno jezero, is located in the sub-Mediterranean vegetation belt characterized by dry, hot summers and colder winters than eumediterranean winters, with more precipitation and, unlike eumediterranean, deciduous vegetation belonging to the class *Quercetea pubescentis* (Vukelić, 2012). In the area of Imotski, the average annual amount of sunlight ranges from 2200 to 2500 hours. The average annual air temperature is 11–15 °C, with the lowest daily temperature in January below 0 °C, and the maximum daily temperature in July and August above 35 °C. The annual rainfall varies from 750 to 2350 mm, with an average of 1300–1500 mm, and precipitation can include snow which may be up to 40 cm deep but does not last longer than a few days (Zaninović *et al.*, 2008, Nikolić *et al.*, 2009).

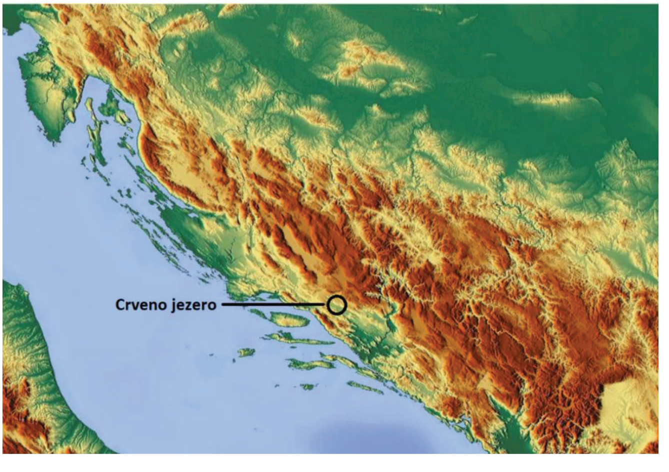

Fig. 1. The position of Crveno jezero in the Dinaric mountain range (map downloaded from https://www.dinarskogorje.com/)

Fig. 2. Different habitats found around Crveno jezero. (upper left) *Quercus ilex* trees on the northern vertical cliffs; (upper right) succession stages, including scrub and encroached dry rocky habitats; (lower left) large scree habitat on the southeastern side; (lower right) view of the lake from the northern side

Although biological research of the lake began in the first half of the 19th century, until today, no data has been published on the flora of the lakes around Imotski. Most research conducted on Crveno jezero was hydrological, hydromorphological, or zoological, and Crveno jezero is best known for being the *locus classicus* of the endemic fish species *Delminichthys adspersus* Heckel, 1843.

The aim of this study was to investigate and make a list of vascular flora of Crveno jezero as well as to carry out biological, ecological, and geographical analysis of the flora.

MATERIALS AND METHODS

Field research was carried out during the vegetation season of 2017, partly within the expedition "Crveno jezero 2017" led by ADIPA (Society for Research and Conservation of Croatian Natural Diversity). The flora of all habitats inside the geomorphological natural monument Crveno jezero was systematically investigated; some of the taxa were identified in the field and collected for pressing, while the rest were collected, pressed, and later identified using standard floristic literature (Pignatti, 1982; Jávorka & Csapody; 1991, Domac; 1984, Alegro *et al.*, 2003, Martinčič *et al.*, 2007; Rothmaler, 2007; Eggenberg & Möhl, 2013). The nomenclature and systematics follow Nikolić (2020).

Even though a vegetation analysis was not carried out, the plants were divided into three groups according to habitat types. We recognized three main habitats: forest, succession stages (maquis, scrub, and encroached dry rocky habitats), and exposed rocks and screes. For each habitat type, life forms, floristic elements, ecological indicator values, and plant life strategies were analyzed. Life forms and floristic elements were designated according to Landolt *et al.* (2010), Pignatti (1982), and

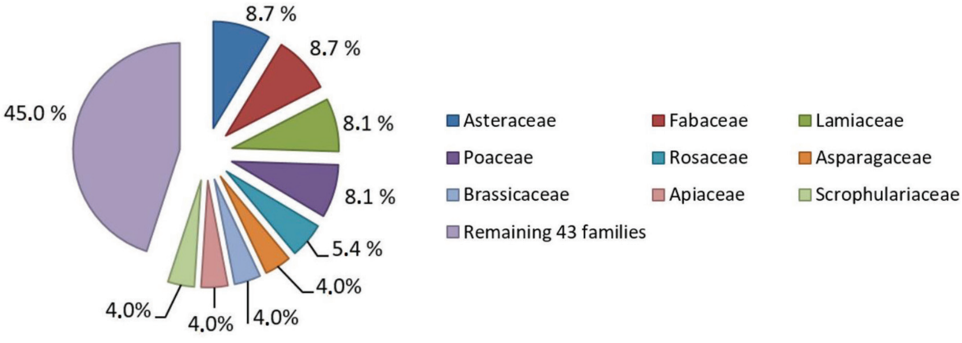

Fig. 3. The spectrum of plant families in Crveno jezero flora

Hess *et al.* (2010). For life forms, the following abbreviations were used: P (Phanerophyta), Ch (Chamaephyta), H (Hemicryptophyta), T (Therophyta), and G (Geophyta). Chorological analysis, i.e., the analysis of floristic elements, was carried out according to Horvatić (1963) and Horvatić *et al.* (1967–1968), and the abbreviations used in the list are indicated in **bold type**: Mediterranean plants (**med**) [within is a category **med*** – Illyrian-Adriatic plants], South European plants (**s-eur**), Eurasian plants (**eu-as**), Southeastern European plants (**se-eur**), Central European plants (**ce-eur**), Illyrian-Balkanic plants (**il-balk**), Eastern European-Pontic plants (**ee-pont**), European plants (**eur**), widespread plants, i.e., cosmopolites (**cosm**), and cultivated and adventive plants (**adv**).

Ecological indicator values for climate and soil were determined for most of the recorded species (130/149) according to Landolt *et al.* (2010) and Ellenberg & Leuschner (2010), and the CSR strategy types followed Landolt *et al.* (2010).

Data on endemic taxa were obtained from Nikolić *et al.* (2015). Threat categories were defined according to Nikolić & Topić (2005), and the recorded threatened plants belonged to one of the following categories: VU, vulnerable, NT, near threatened taxa, and DD, data deficient taxa. No other threat categories were present. Protected species were defined according to the Ordinance on Strictly Protected Species (2013). Data on invasive species were obtained from Nikolić *et al.* (2014) and adjusted to the current state in the Flora Croatica Database (Nikolić 2020).

RESULTS

Vascular flora of Crveno jezero was systematically investigated for the first time and a total of 149 taxa belonging to 52 families were recorded. The taxa were classified into subclasses and families according to the APG IV system (Chase *et al.*, 2016) (Appendix 1). Among the 52 families, the families with the highest number of taxa were *Asteraceae*, *Fabaceae* (both 8.7%), *Lamiaceae*, and *Poaceae* (both 8.1%) (Fig. 3).

Chorological analysis

The chorological analysis showed that the majority of plants found around Crveno jezero belonged in two categories: circum-Mediterannean (41.6%) and South European plants (31.5%) (Fig. 4). Following them were Eurasian plants (10.1%), whereas the other floral elements were represented with <5% in the investigated flora.

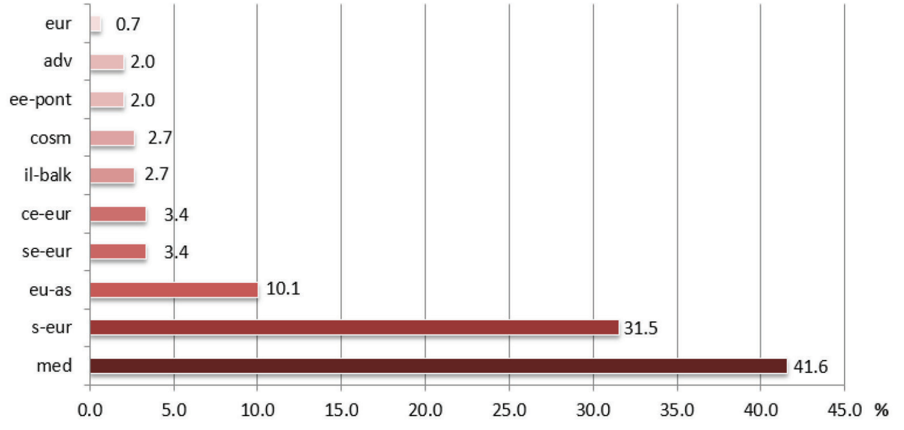

Fig. 4. The chorological spectrum of Crveno jezero flora. eur = European, adv = cultivated and adventive, ee-pont = Eastern European-Pontic, cosm = cosmopolites, il-balk = Illyrian-Balkanic, ce-eur = Central European, se-eur = Southeastern European, eu-as = Eurasian, s-eur = South European, med = Mediterranean plants

Analysis of ecological parameters

Ecological parameters for climate and soil properties were analyzed for plants with sufficient data (130 of 149 plant species; Appendix 1).

Temperature and continentality. The results of the analysis of indicator values for light showed that the majority of species (> 50%) were adapted to living in warm and very warm hilly regions (Fig. 5), and the results were similar for all three investigated habitat types.

The climatic conditions of the investigated area were reflected in the high percentage of species belonging to the subcontinental (39.7%) and suboceanic-subcontinental climate type (31.7%). One fifth of all species (20.6%) belonged to the suboceanic climate type, whereas a lower proportion of species belonged to the continental (7.1%) and the oceanic climate type (0.8%).

Light. The results of the analysis of indicator values for light, shown for three habitat types, are presented in Fig. 6. Heliophytes, represented by columns 4 and 5 in Fig. 6, were most commonly found in succession stages (80.4%), followed by rocky habitats and screes (69.3%). In rocky habitats and screes, we recorded many species adapted to semi-shade conditions (27.6%). In the forest, the proportion of species adapted to these conditions was as high as 50%, followed by species adapted to high amount of light (39.1%).

Soil moisture, airiness, and humus content. The majority of species were found to be adapted to dry or very dry soils (71.2% in succession stages and 76.9% in rocky habitats). Among the species found in rocky habitats, 4.2% had high indicator values for soil moisture, indicating that they inhabit microlocalities that are damper within this rocky and mostly dry habitat. The highest soil moisture indices were found in connection with species recorded in the forest. Only 31.3% of the species in the forest were adapted to dry or very dry soils, and 22.2% of species were adapted to moderately moist to moist soils.

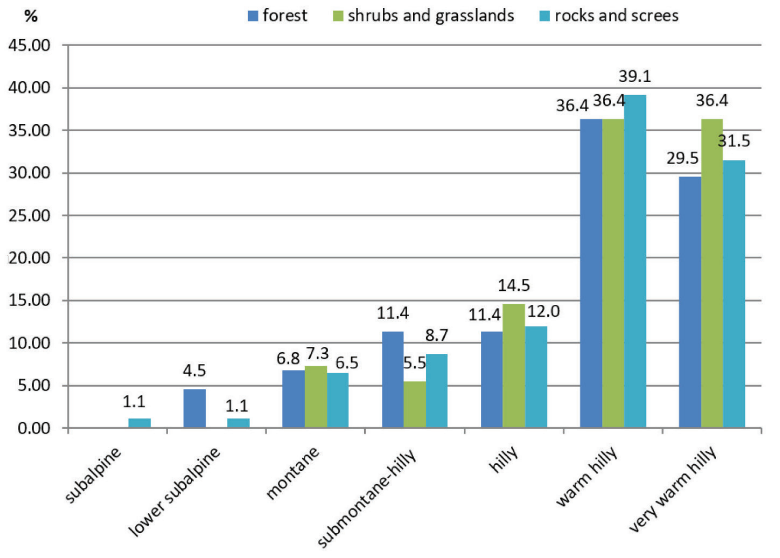

Fig. 5. Temperature values in the three investigated habitat types according to Ellenberg & Leuschner (2010)

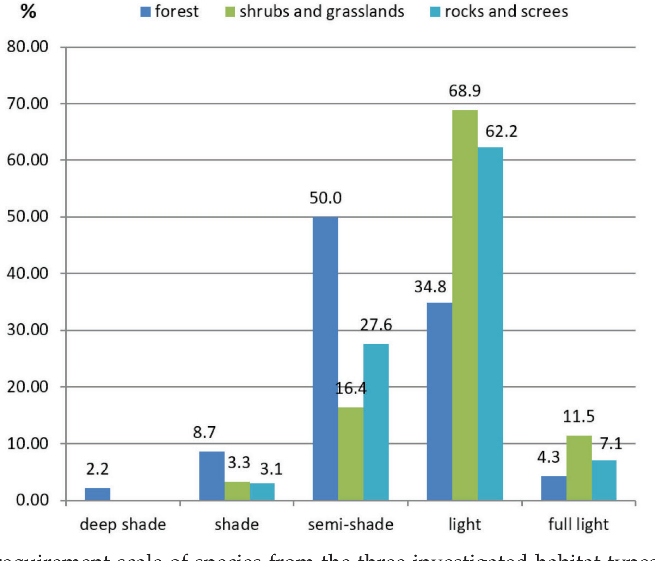

Fig. 6. Light requirement scale of species from the three investigated habitat types of Crveno jezero flora: **1** (deep shade plants), **2** (shade plants), **3** (semi-shade plants), **4** (light plants), **5** (full light plants)

Soil pH and nitrogen content. More than half of the species preferred living in neutral to alkaline soils (pH 5.5–8.5), followed by species of mildly acidic to neutral soils (pH 4.5–7.5), and lastly, species of alkaline (pH 6.5–8.5) and acidic soils (pH 3.5–6.5) (Fig. 7).

The majority of the recorded species (54.3%) were found to live in nitrogen-poor habitats, followed by habitats moderately rich in nitrogen (34.6%). Ten species that preferred soils rich in nitrogen were recorded, whereas four species preferred soils poor with nitrogen (Fig. 8).

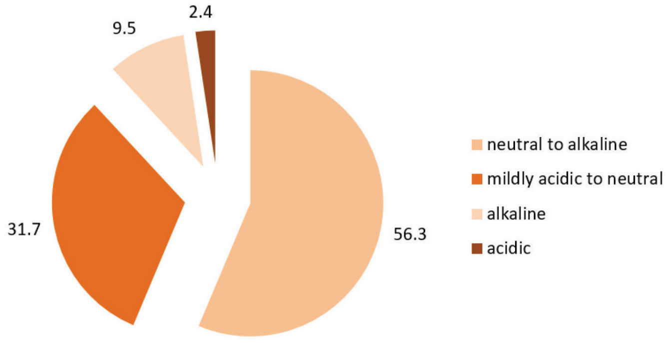

Fig. 7. Soil pH requirements of the plants of Crveno jezero

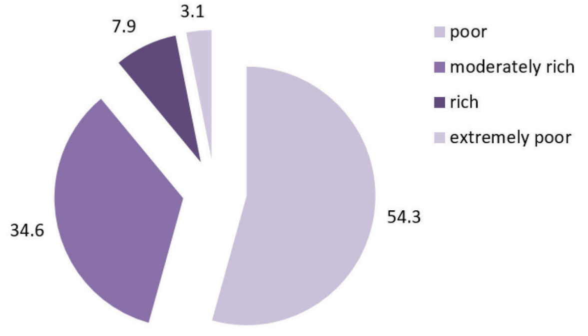

Fig. 8. Nitrogen requirements of the plants of Crveno jezero

Analysis of life strategies

The analyzed life strategy parameters are presented in detail in Appendix 1.

Life forms. The life form spectrum of the total flora showed the dominance of Hemicryptophyta (42.3%) followed by Phanerophyta (21.5%). The remaining three life forms were present with a similar proportion (Chamaephyta 13.4%, Therophyta 12.8%, and Geophyta 10.1%). According to habitat types, forests had the highest proportion of phanaerophytes (> 40%), followed by hemicryptophytes (> 25%), whereas they had a very low proportion of therophytes (< 5%). On the other hand, scrubs and maquis, as well as rocks and screes had the highest proportion of hemicryptophytes (ca. 45%), but they differed in the proportion of other life forms, with scrub and maquis having a higher proportion of therophytes, chamaephytes, and geophytes, and rocks and screes having a higher proportion of phanaerophytes (Fig. 9).

CSR strategies. The differences in CSR strategies among species of the three main habitat types are shown in Fig. 10. We found that stress-tolerant competitors (CCS and CSS) prevailed in all three habitat types. In rocky habitats, the second most common strategy was CSR (21.5%), followed by CCC (19.4%). In scrub and scree habitats, the second most common strategy was also CSR (33.4%), whereas the third most common strategy was RRR (11.7%). In forest habitats, stress-tolerant competitors were followed by competitors (32.6%) and plants with the CSR strategy (26.1%). The least number of taxa had competitive-ruderal and ruderal-stress tolerant strategies (2.2% in forest habitats, 9.8% in scrubs and screes, and 14.1% in rocky habitats).

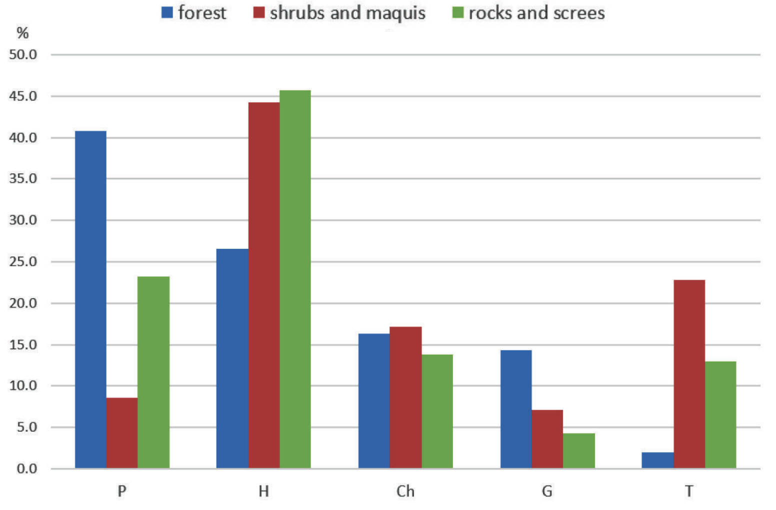

Fig. 9. Life form spectrum of Crveno jezero flora across the investigated habitat types. T, Terophyta; G, Geophyta; H, Hemicryptophyta; Ch, Chamaephyta, P, Phanaerophyta

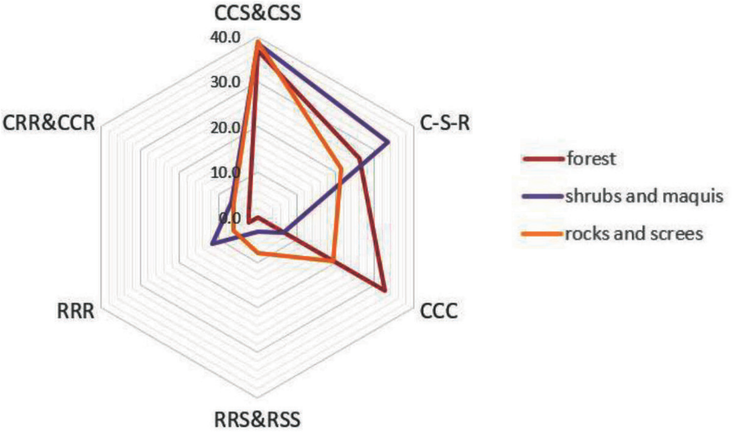

Fig. 10. The web of CSR strategies for plants found in the three investigated habitat types. C, competitive; S, stress-tolerant; R, ruderal

Vegetative propagation. The means of vegetative propagation were analyzed for 144 species. We found that 44 plants did not propagate vegetatively, whereas among the remaining 100 that did propagate in this manner, the majority used basal, lateral shoots. Fifteen species spread asexually by rhizomes, five by layering, and two by stolons. Eight species belonging to the *Poaceae* family formed tussocks. Four species of the flora of Crveno jezero had bulbs, whereas one species spread using bulbils.

Seed dispersal (sexual propagation). In case of sexual propagation, the seeds or fruits of most of the investigated species were dispersed by animals (88 species) and wind (74 species). Comparing the forest to the open, rocky habitats, we could see that zoochory was more dominant in forests, whereas anemochory was a strategy more used by the plants of open habitats (Fig. 11).

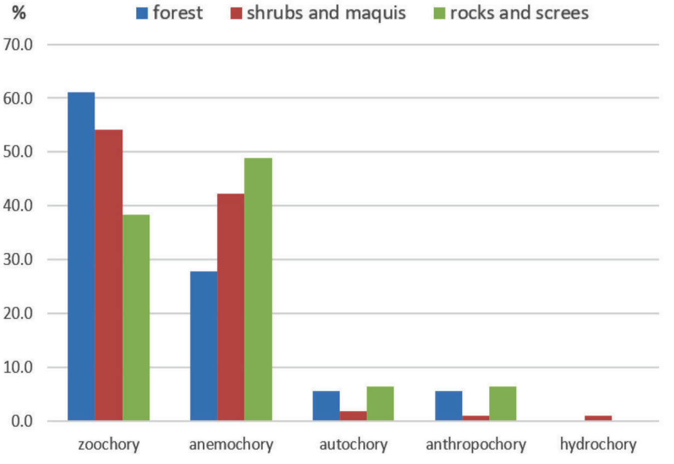

Fig. 11. Comparison of preferred seed dispersal techniques among the three investigated habitat types

Pollination. The most common mean of pollination, observed in 90 taxa from Crveno jezero flora, was entomophily (73.8%). Plants of these habitats were found to be adapted to pollination by various insect groups, most commonly by different Hymenoptera (including bees, bumblebees, and wasps) and flies (Diptera), whereas some species were pollinated by beetles (Coleoptera) and butterflies (Lepidoptera). In addition to entomophily, anemophily was present in 17 species, and autogamy in 15 species.

Endemic, endangered, protected, and invasive species

Fourteen species found on Crveno jezero (9.4%) are strictly protected by law (Ordinance on Strictly Protected Species, 2013) (Tab. 1). A total of 11 species or 7.4% of the total flora are endemic (Nikolić *et al.*, 2015). Among them, most belonged to the groups of Illyrian-Adriatic and Illyrian-Balkanic endemic species. According to the Croatian Red List of Vascular Plants, one species was considered to be directly threatened (vulnerable category: *Ophrys sphegodes*), and eight more species were in the lower categories of concern: four near threatened species and four data deficient species.

Two invasive species were recorded in the investigated area: *Ailanthus altissima* (Mill.) Swingle, originating in Asia, and *Conyza canadensis* (L.) Cronquist, originating in North America.

DISCUSSION

The phytogeographic position of Crveno jezero and the diversity of its habitats have resulted in a great wealth of flora inhabiting this rocky, steep terrain. With an area of only 0.138 km^2, this geomorphological natural monument is home to 149 species of vascular plants. The observed order of species-richest plant families concurs with the most common plant families in the Croatian flora, as well as in the investigated area (Nikolić, 2013).

As large areas around the lake predominantly offer skeletal habitats with little amount of soil as substrate, the dominance of species of cliffs and screes was expected and recorded. Screes are a type of frequently disturbed habitat in which the high

Tab. 1. List of the strictly protected species of vascular flora found on Crveno jezero. **endemic species**: + = endemic to Croatia, IL-ADR = Illyric-Adriatic endems, IL-BALK = Illyric-Balkanic endems. **Red List**: VU = vulnerable, NT = Near Threatened, DD = Data Deficient.

No.	TAXON	ENDEMIC	RED LIST	PROTECTED
1	*Achillea virescens* (Fenzl) Heimerl	IL-BALK		+
2	*Centaurea glaberrima* Tausch	+	NT	+
3	*Centaurea spinosociliata* Seenus ssp. *cristata* (Bertol.) Dostál	IL-ADR	NT	+
4	*Cerinthe glabra* Mill.		DD	+
5	*Onosma echioides* (L.) L. ssp. *dalmatica* (Scheele) Peruzziet N. G. Passal	IL-ADR		+
6	*Dianthus sylvestris* Wulfen in Jacq. ssp. *tergestinus* (Rchb.) Hayek	IL-ADR		+
7	*Anthyllis vulneraria* ssp. *praepropera* (A.Kern.) Bornm.	IL-ADR		
8	*Genista sylvestris* Scop. ssp. *dalmatica* (Bartl.) H. Lindb.	IL-ADR		+
9	*Iris pseudopallida* Trinajstić	IL-BALK		+
10	*Teucrium arduini* L.	IL-BALK	DD	+
11	*Ophrys sphegodes* Mill.		VU	+
12	*Platanthera clorantha* (Custer) Rchb.		NT	+
13	*Achnatherum calamagrostis* (L.) P.Beauv.		DD	+
14	*Rhamnus intermedia* Steud. et Hochst.	+	NT	+
15	*Linaria* cf. *microsepala* A. Kern.	IL-ADR	DD	+

level of stress and disturbance determines which species will be able to inhabit this unwelcoming terrain. One of the first communities in plant succession on frequently disturbed habitats are plants that grow on silt, sand, rock dust, and small to medium rocks. Plants adapted to this habitat are able to stabilize the unstable substrate and compensate for the lack of organic matter by having a strong, branched root system (Wellstein *et al.*, 2003). One of such plants is *Rumex scutatus*, found on steep cliffs and screes around Crveno jezero. Its root system is adapted so that it anchors the plant with one main root, and spreads lateral roots through the layers of rock dust and skeletal soil (Wellstein *et al.*, 2003). Another species with similar characteristics that we recorded on the slopes of Crveno jezero is *Achnatherum calamagrostis*. It is a tussock-forming tall grass which inhabits steep limestone screes and rocks and prepares the soil for less resistant species which are currently unable to inhabit this steep terrain. In total, 15 species of Crveno jezero flora belonged to plants of screes, moving pebbles/sands, rocks, and cliffs. These plants inhabit the most unfavorable habitats with low amounts of soil.

The distribution of life forms showed the diversity of plant adaptations to the ecological conditions of the area. The five main life form strategies were all represented by 10% or more in the total number of species. The dominance of hemicryptophytes in the species-richest habitats, i.e., rocks and succession stages, indicated that a high proportion of the recorded species hide their buds near or on the soil surface to survive unfavorable conditions. Hemicryptophytes as a group have a wide variety of manners of vegetative propagation (Raunkier, 1934), and are therefore the dominant group of plants inhabiting frequently disturbed habitats (Wellstein, 2003). Chapman & Crow (1981) showed that hemicryptophytes are well adapted to fire, as they attempt to compensate for fire-induced losses through their increased growth rates after fires and through vegetative propagation and germination of dormant seeds. The following most common life form observed in the present study was phanerophytes, and aside from being abundant in forest habitats, they were often found inhabiting open, rocky habitats scarce with soil. Half of the phanerophytes in rocky habitats were nanophanerophytes, indicating that the stressful conditions of nutrient-poor soil, exposure to wind, and the existence of a dry and a cold period selected for smaller, more robust trees (Raunkiaer, 1934). The high proportion of nanophanerophytes and hemicryptophytes as well as the presence of geophytes in all habitat types indicated that the plants of Crveno jezero are adapted to frequent fires (Cain, 1950).

More than half of the recorded plant species inhabited nitrogen poor or moderately rich soil, and the affinity for humus soils was very low for the majority of plants inhabiting this area. Among the plant species recorded, a high proportion of plants were observed to reproduce vegetatively. This ensures the survival of a larger number of offspring, and it is a common strategy in areas where seed propagation is uncertain due to reduced availability of soil for seed germination or due to potential hazards such as fire (Grime, 2001). Considering the low number of therophytes (19 taxa) in relation to the high number of taxa spreading vegetatively (100 taxa), and taking into account that the soil of the studied area was mostly nutrient-poor, we concluded that vegetative propagation is an efficient adaptation to the limitations in distribution, germination, and survival of seeds in these conditions. Some of the taxa recorded were specifically adapted to such conditions, e.g., *Poa bulbosa* var. *vivipara* uses surely the safest way of reproduction, as sprouted young plants separate from the mother plant only after the development of first leaflets and rootstocks. Most recorded taxa were found to have some type of storage organ or tissue, which indicated the presence of unfavorable, dry periods and lack of available nutrients throughout the year. This corresponds to our findings that most taxa were adapted to low soil moisture variability and to moderately dry or dry soil.

Among the researched taxa, competitive, stress-tolerant, and CSR strategies predominated. Considering that the ability of vegetative propagation increases the competitive ability of plants, we could relate the high proportion of plants spreading vegetatively with a high proportion of plants using the competitive strategy. The species of rocky habitats were more commonly characterized by the stress-tolerant strategy, whereas the species of forest habitats were more commonly characterized by the competitive strategy. Competitors are long-lasting, tall, often woody plants, whereas stress-tolerant plants are mostly bushy plants with small, evergreen leaves, more commonly found in rocky and more exposed habitats. A lower proportion of species had ruderal or competitive-ruderal strategy. The possible reason for this could be the lower chance of their seeds germinating in these conditions, especially because of the low level of nitrogen in the soil, as opposed to the other strategies' dispersal techniques.

A great impact of both continental and oceanic climate type could be seen in the high proportion of species belonging to the Mediterranean, as well as South-European and Eurasian floral elements. The subcontinental climate type is characterized by low air humidity values, high temperature variations, and relatively cold winters, whereas in the suboceanic-subcontinental climate type, these values are somewhat milder. Despite this area being separated from the Adriatic Sea by the mountain mass of Biokovo, a high proportion of species belonging to the suboceanic climate type was recorded. This indicated a partial penetration of suboceanic climatic conditions to this area, with lower temperature variations and milder winter conditions. Radić (1979) wrote that there are two possible ways these influences could spread to the area of Imotski: over the lower peaks of Biokovo Mountain (north of Brela and Dupci mountain pass), or from the south of Biokovo, through the canyon of Vrljika River.

The observed dominance of taxa adapted to higher temperatures and higher solar radiation is in accordance with the climate conditions in the area of Crveno jezero, where during the long and hot summer period, temperatures often exceed 35 °C. This area is one of the warmest areas in Croatia, with the average annual air temperature of 13–14 °C, and the annual sunlight hours ranging from 2200 to 2500. Species adapted to lower temperatures were mostly found in forest habitats, overshadowed by trees and hidden from direct sunlight and warming, as well as in rock crevices.

Most species of the Crveno jezero flora were adapted to growth in pH neutral to alkaline as well as nitrogen-deficient soil, whereas no taxa that preferred living in acidic soils were recorded. This distribution corresponds to the geological data for this area, which indicates the predominance of alkaline limestones and dolomites (Velić & Vlahović, 2009). The soil around Crveno jezero probably remains alkaline because it is very shallow, and more bases are being replaced from the parent material than are being washed away by water.

Among the investigated species' ways of spreading diaspores, zoochory and anemochory were predominant. According to Cavallero *et al.* (2012), endozoochory is a safe dispersal technique in which the seed has the highest chances for germination because it is encoated in a fecal medium that protects it from disturbing abiotic or biotic conditions in its earliest phases of development. As the studied area tends to dry out during the peak of the vegetation period, this method ensures the survival of endozoochoric species' seeds. These plants were most common in forest habitats, where they are less exposed to wind, and where there are more animal species that are possible seed dispersers. On the other hand, the most common habitats around Crveno jezero are cliffs, which is why a high number of anemochoric species was observed. Species of rocky habitats are not as protected by the surrounding flora as species of forest habitats; they are more exposed to wind and therefore more frequently rely on wind as a dispersal tool. The formation of a very high amount of low-weight seeds ensures them independence of animals as dispersers. The majority of plants recorded at Crveno jezero are pollinated by insects, followed by wind pollination and autogamy. The high proportion of entomophily among the plants of Crveno jezero indicated high species richness (Regal, 1982, Kühn *et al.*, 2006).

Fourteen protected species were found in the investigated area, most of which are Illyrian-Adriatic and Illyrian-Balkanic endemic plants. Eleven endemic species (7.8% of the total flora) were recorded, which is three times higher than the average percentage of endemic species of Adriatic islands (2.6%) (Nikolić *et al.*, 2008). Two invasive species were recorded in the area (*Ailanthus altissima* and *Conyza canadensis*), but because of the low number of individuals recorded, they currently do not present a great threat to the natural flora. Nevertheless, both of these species are widespread invasive species in Croatia and are highly adaptable and tolerant to different habitats, which is why their presence in the studied area needs to be monitored in the future.

The high proportion of endemic species, the presence of Illyrian-Adriatic and Illyrian-Balkanic endems, and diversity of habitats and microlocalities indicated low anthropogenic influence in the studied area, and for the maintenance of this state, the researched area needs to keep being monitored in the future.

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APPENDIX 1.

The list of vascular flora of Crveno jezero with the associated indices; 1, 2, 3 – forest, succession stages (maquis, shrubbery, and encroached dry rocky habitats), and exposed rocks and screes, respectively; FE, floral elements: Mediterranean plants (**med**) [within is the category **med*** – Illyrian-Adriatic plants], South European plants (**s-eur**), Eurasian plants (**eu-as**), Southeastern European plants (**se-eur**), Central European plants (**ce-eur**), Illyrian Balkanic plants (**il-balk**), Eastern European-Pontic plants (**ee-pont**), European plants (**eur**), cosmopolites (**cosm**), and cultivated and adventive plants (**adv**).

Taxon	Family	1	2	3	FE
Allium commutatum Guss.	*Amaryllidaceae*			+	med
Cotinus coggygria Scop.	*Anacardiaceae*			+	s-eur
Pistacia lentiscus L.	*Anacardiaceae*			+	med
Pistacia terebinthus L.	*Anacardiaceae*	+		+	med
Bunium ferulaceum Sibth. et Sm.	*Apiaceae*		+	+	s-eur
Eryngium amethystinum L.	*Apiaceae*		+	+	med
Opopanax chironium (L.) Koch	*Apiaceae*	+		+	med
Orlaya daucorlaya Murb.	*Apiaceae*		+		med
Orlaya grandiflora (L.) Hoffm.	*Apiaceae*		+		s-eur
Smyrnium perfoliatum L.	*Apiaceae*			+	med
Arum italicum Mill.	*Araceae*	+			med
Hedera helix L.	*Araliaceae*		+		eur
Asparagus acutifolius L.	*Asparagaceae*	+			med
Muscari comosum (L.) Mill	*Asparagaceae*		+		s-eur
Ornithogalum comosum L.	*Asparagaceae*		+		se-eur
Ornithogalum pyramidale L.	*Asparagaceae*		+		s-eur
Ruscus aculeatus L.	*Asparagaceae*	+			med
Scilla autumnalis L.	*Asparagaceae*		+	+	med
Asplenium ceterach L.	*Aspleniaceae*			+	s-eur
Asplenium trichomanes L.	*Aspleniaceae*			+	cosm
Achillea virescens (Fenzl) Heimerl	*Asteraceae*		+		il-balk
Anthemis austriaca Jacq.	*Asteraceae*		+	+	s-eur
Centaurea glaberrima Tausch	*Asteraceae*		+	+	med

Taxon	Family	1	2	3	FE
Centaurea rupestris L.	*Asteraceae*		+	+	med*
Centaurea spinosociliata Seenus ssp. *cristata* (Bertol.) Dostál	*Asteraceae*		+	+	med*
Conyza canadensis (L.) Cronquist	*Asteraceae*			+	adv
Crepis neglecta L.	*Asteraceae*		+	+	med
Hieracium glaucum All.	*Asteraceae*	+			se-eur
Inula verbascifolia (Willd.) Hausskn.	*Asteraceae*			+	med
Lactuca perennis L.	*Asteraceae*		+		s-eur
Leontodon crispus Vill.	*Asteraceae*		+	+	s-eur
Picris hispidissima (Bartl.) Koch	*Asteraceae*		+	+	med*
Scolymus hispanicus L.	*Asteraceae*		+		med
Ostrya carpinifolia Scop.	*Betulaceae*	+	+	+	med
Cerinthe glabra Mill.	*Boraginaceae*			+	s-eur
Onosma echioides (L.) L. ssp. *dalmatica* (Scheele) Peruzziet N. G. Passal	*Boraginaceae*	+	+	+	med*
Aethionema saxatile (L.) R. Br.	*Brassicaceae*			+	s-eur
Alyssoides utriculata (L.) Medik.	*Brassicaceae*	+		+	s-eur
Alyssum simplex Rudolphi	*Brassicaceae*		+	+	med
Arabis collina Ten.	*Brassicaceae*			+	med
Arabis hirsuta (L.) Scop.	*Brassicaceae*			+	cosm
Arabis turrita L.	*Brassicaceae*			+	s-eur
Campanula glomerata L.	*Campanulaceae*	+		+	eu-as
Campanula pyramidalis L.	*Campanulaceae*			+	med*
Campanula sibirica L.	*Campanulaceae*	+	+	+	se-eur
Lonicera etrusca Santi	*Caprifoliaceae*	+			med
Lonicera xylosteum L.	*Caprifoliaceae*	+		+	eu-as
Cerastium semidecandrum L.	*Caryophyllaceae*		+	+	s-eur
Dianthus sylvestris Wulfen in Jacq. ssp. *tergestinus* (Rchb.) Hayek	*Caryophyllaceae*		+	+	med*
Petrorhagia saxifraga (L.) Link	*Caryophyllaceae*		+	+	med
Silene italica (L.) Pers.	*Caryophyllaceae*		+	+	s-eur
Euonymus europaeus L.	*Celastraceae*			+	eu-as
Euonymus verrucosa Scop.	*Celastraceae*			+	ee-pont
Fumana ericifolia Wallr.	*Cistaceae*	+	+		med
Helianthemum nummularium (L.) Mill. ssp. *obscurum* (Čelak.) Holub	*Cistaceae*		+		ce-eur
Hypericum perforatum L.	*Clusiaceae*			+	s-eur
Convolvulus cantabrica L.	*Convolvulaceae*		+	+	s-eur
Cornus mas L.	*Cornaceae*	+		+	s-eur
Sedum acre L.	*Crassulaceae*		+	+	eu-as
Sedum ochroleucum Chaix	*Crassulaceae*		+	+	s-eur
Sedum rubens L.	*Crassulaceae*		+	+	s-eur
Sedum telephium L. ssp. m*aximum* (L.) Krock.	*Crassulaceae*			+	ce-eur
Cupressus sempervirens L.	*Cupressaceae*	+		+	med
Juniperus oxycedrus L.	*Cupressaceae*	+		+	med
Carex hallerana Asso	*Cyperaceae*			+	s-eur
Tamus communis L.	*Dioscoreaceae*	+			s-eur
Cephalaria leucantha (L.) Roem. et Schult.	*Dipsacaceae*			+	med
Dryopteris pallida (Bory) C.Chr. ex Maire et Petitmengin	*Dryopteridaceae*			+	med
Euphorbia characias L. ssp. *wulfenii* (Hoppe ex Koch) A.M.Sm.	*Euphorbiaceae*			+	il-balk
Anthyllis vulneraria L. ssp. *praepropera* (A.Kern.) Bornm.	*Fabaceae*		+		med*
Argyrolobium zanonii (Turra) P. W. Ball	*Fabaceae*		+	+	med
Coronilla emerus L. ssp. *emeroides* Boiss. et Spruner	*Fabaceae*	+		+	med
Genista sylvestris Scop. ssp. *dalmatica* (Bartl.) H. Lindb.	*Fabaceae*	+		+	med*
Hippocrepis comosa L.	*Fabaceae*		+	+	s-eur
Lathyrus cicera L.	*Fabaceae*		+	+	med
Lotus corniculatus L. ssp. *hirsutus* Rothm.	*Fabaceae*	+	+		s-eur
Medicago prostrata Jacq.	*Fabaceae*		+	+	s-eur
Trifolium stellatum L.	*Fabaceae*		+	+	med
Vicia cracca L.	*Fabaceae*			+	eu-as
Vicia sylvatica L.	*Fabaceae*	+			eu-as
Quercus ilex L.	*Fagaceae*	+		+	med
Quercus pubescens Willd.	*Fagaceae*	+	+	+	s-eur
Geranium columbinum L.	*Geraniaceae*		+	+	eu-as
Geranium molle L.	*Geraniaceae*		+	+	cosm
Iris pseudopallida Trinajstić	*Iridaceae*			+	il-balk
Acinos arvensis (Lam.) Dandy	*Lamiaceae*		+	+	med

Taxon	Family	1	2	3	FE
Ajuga chamaepitys (L.) Schreb.	*Lamiaceae*		+	+	med
Lamium galeobdolon (L.) L.	*Lamiaceae*	+			eu-as
Lamium purpureum L.	*Lamiaceae*	+			eu-as
Marrubium incanum Desr.	*Lamiaceae*		+	+	med*
Salvia officinalis L.	*Lamiaceae*			+	med
Satureja montana L.	*Lamiaceae*		+	+	s-eur
Stachys thirkei K.Koch	*Lamiaceae*			+	med
Teucrium arduini L.	*Lamiaceae*			+	il-balk
Teucrium chamaedrys L.	*Lamiaceae*	+	+	+	s-eur
Teucrium flavum L.	*Lamiaceae*	+	+	+	med
Teucrium polium L. ssp. *capitatum* (L.) Arcang.	*Lamiaceae*		+	+	med
Ficus carica L.	*Moraceae*			+	med
Fraxinus ornus L.	*Oleaceae*	+	+	+	s-eur
Phillyrea latifolia L.	*Oleaceae*	+	+	+	med
Ophrys sphegodes Mill.	*Orchidaceae*	+			s-eur
Platanthera chlorantha (Custer) Rchb.	*Orchidaceae*	+			eu-as
Pinus nigra J.F.Arnold ssp. *nigra*	*Pinaceae*	+		+	s-eur
Plantago lanceolata L.	*Plantaginaceae*		+		cosm
Rumex scutatus L.	*Polygonaceae*			+	s-eur
Polypodium cambricum L.	*Polypodiaceae*			+	med
Cyclamen hederifolium Aiton	*Primulaceae*	+		+	med
Achnatherum calamagrostis (L.) P.Beauv.	*Poaceae*			+	s-eur
Aegilops neglecta Req. ex Bertol.	*Poaceae*		+	+	med
Avena barbata Pott ex Link	*Poaceae*		+	+	ee-pont
Dactylis glomerata L.	*Poaceae*		+	+	eu-as
Festuca rupicola Heuff.	*Poaceae*	+	+	+	se-eur
Helictotrichon convolutum (C.Presl) Henrard	*Poaceae*	+	+	+	med
Koeleria pyramidata (Lam.) P.Beauv.	*Poaceae*		+	+	ce-eur
Koeleria splendens C.Presl	*Poaceae*		+	+	s-eur
Poa bulbosa L.	*Poaceae*		+		eu-as
Sesleria autumnalis (Scop.) F.W.Schultz	*Poaceae*	+		+	med
Sesleria robusta Schott, Nyman et Kotschy	*Poaceae*		+	+	med
Stipa pennata L. ssp. *eriocaulis* (Borbás) Martinovský et Skalický	*Poaceae*		+	+	med*
Clematis flammula L.	*Ranunculaceae*		+	+	med
Clematis viticella L.	*Ranunculaceae*			+	s-eur
Frangula rupestris (Scop.) Schur.	*Rhamnaceae*	+		+	med*
Paliurus spina-christi Mill.	*Rhamnaceae*		+	+	s-eur
Rhamnus intermedia Steud. et Hochst.	*Rhamnaceae*			+	s-eur
Amelanchier ovalis Medik.	*Rosaceae*			+	s-eur
Potentilla heptaphylla L.	*Rosaceae*		+	+	ce-eur
Prunus mahaleb L.	*Rosaceae*	+		+	s-eur
Prunus spinosa L.	*Rosaceae*			+	eu-as
Rosa arvensis Huds.	*Rosaceae*	+			ce-eur
Rubus ulmifolius Schott	*Rosaceae*	+		+	med
Sanguisorba minor Scop. ssp. *muricata* Briq.	*Rosaceae*	+			s-eur
Sorbus torminalis (L.) Crantz	*Rosaceae*	+			eu-as
Asperula aristata L.f.	*Rubiaceae*			+	s-eur
Galium lucidum All.	*Rubiaceae*		+	+	s-eur
Osyris alba L.	*Santalaceae*	+	+		med
Thesium divaricutum Jan. ex Mert. et Koch	*Santalaceae*			+	med
Acer monspessulanum L.	*Sapindaceae*	+			s-eur
Cymbalaria muralis P.Gaertn., B.Mey. et Scherb.	*Scrophulariaceae*			+	s-eur
Linaria cf. *microsepala* A. Kern.	*Scrophulariaceae*			+	med*
Scrophularia canina L.	*Scrophulariaceae*		+	+	s-eur
Verbascum orientale (L.) All.	*Scrophulariaceae*			+	ee-pont
Veronica austriaca L.	*Scrophulariaceae*	+		+	se-eur
Veronica chamaedrys L.	*Scrophulariaceae*	+		+	eu-as
Ailanthus altissima (Mill.) Swingle	*Simaroubaceae*			+	adv
Smilax aspera L.	*Smilacaceae*	+			med
Celtis australis L.	*Ulmaceae*			+	s-eur
Parietaria judaica L.	*Urticaceae*	+		+	s-eur
Valeriana tuberosa L.	*Valerianaceae*		+		med
Vitis vinifera L. ssp. *vinifera*	*Vitaceae*			+	adv