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PLANT DIVERSITY OF THE STIROVACA MEADOWS -NORTH VELEBIT NATIONAL PARK, CROATIA

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ABSTRACT

Stirovaca is located in Croatia, in the south-east part of Velebit National Park; it consists of dense forest stands and several meadow openings. The flora of the Stirovaca meadows has never before been systematically studied.

Here, we report the results of a floristic study of plant diversity of the Stirovaca meadows. It was established that there were 134 species of wild vascular plants (132 species and 2 subspecies), classified into 97 genera and 38 families. The families with the greatest number of species and subspecies were Asteraceae (13.4 %), Poaceae (8.2 %), Lamiaceae (5.9 %) and Rosaceae (5.2 %). In the life-forms spectrum *Hemicryptophyta* prevailed (66.4 %) which is characteristic of meadowland flora in areas with continental climates. An analysis of the floristic elements showed the greatest presence of Eurasian (35.0 %) and South European floristic elements (23.1 %). Vegetation succession in the last 60 or so years has progressed very considerably, at the expense of meadowland.

The results of this research show that the Stirovaca meadows are an essential enrichment of plant and landscape diversity, indicating the need to preserve and protect the area investigated.

KEYWORDS:
Plant biodiversity, Meadow, Stirovaca, Vascular flora, Velebit

INTRODUCTION

In the Dinarides, the upland massif of Velebit stands out in terms of length. Its extraordinary natural values and beauties were recognised long since. In 1978 Velebit was included into the network of world biosphere reserves as part of the UNESCO programme Man and the Biosphere. Three years later, Velebit was proclaimed a nature park. It actually has two national parks – North Velebit National Park, formed in 1999, while in the south there is Paklenica National Park, which achieved that status in 1949. As a whole, Velebit is part of the European Ecological Network Natura 2000 [1].

North Velebit National Park occupies an area of 109 km^2 and is mainly built of sedimentary carbonate rocks, limestones and dolomites. Water partially dissolves the carbonate rocks, creating a special form of relief – karst [2, 3]. In the Velebit area, various kinds of climate are encountered: sub-Mediterranean, continental and mountainous, producing a harsh climate and unpredictable weather conditions [4]. One of the main climate characteristics is the bura, a strong wind that blows from land out to sea [5].

The geographical position of North Velebit National Park and its geological and climatic characteristics are reflected in the great richness of the plant world. In spite of numerous investigations of the flora and vegetation of the Park [6, 7, 8, 9, 10, 11], no exploration of the flora of the Stirovaca meadows has yet been conducted.

The objective of the present study was to establish the abundance and diversity of the wild vascular flora of Stirovaca meadows. This should be able to contribute not only to the better understanding of the plant diversity of the meadows in the Park but also to the preservation and protection of the environment of North Velebit National Park, a natural heritage that belongs to the world.

MATERIALS AND METHODS

Study area. The Stirovaca area is in the south-east part of Velebit NP, and consist of dense forest stands with several openings of meadowland, of which the best known is the Stirovaca valley, from which the whole area has taken its name (Figure 1).

From a geomorphological sense, Stirovaca is a karstic depression, on the border between karst polje and large karst uvala. Its lowest point lies at about 1045 m asl, and extends over an area of about 8 km length and 1-2 km broad [12]. It extends between 44°39'58.2" N and 44°38'05.6" N and 44°39'39.5" E and 44°38'16.3"E. It has an elongated shape in the north to south direction and is surrounded in all sides by the steep slopes of the neighbouring mountains.

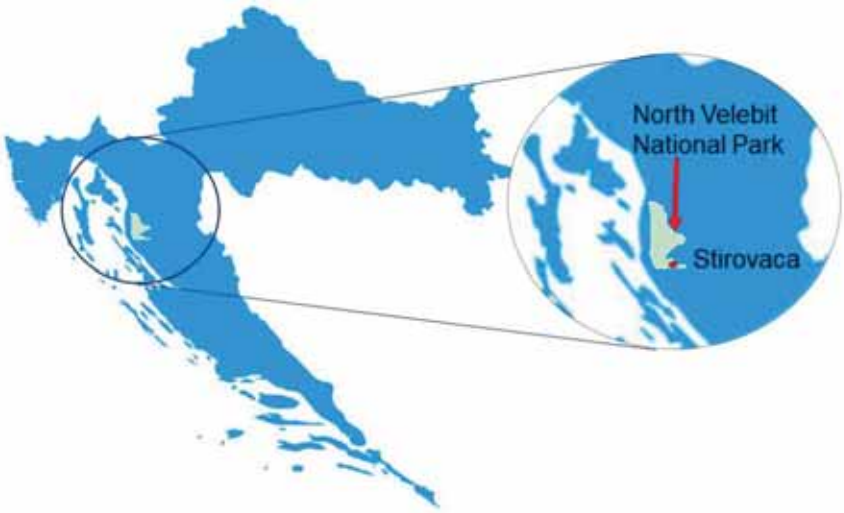

FIGURE 1
The position of Stirovaca in Croatia and inside North Velebit National Park

The hydrogeological characteristics of the rocks and the geological makeup are the basis for the differences that make Stirovaca essentially distinct from the other parts of North Velebit National Park. Several streams flow through the valley of Stirovaca, in places disappearing streams as well, which keep the surrounding meadows moist. Depending on the particular hydrological conditions, particularly at the time of snowmelt, the streams flood the meadows and create a flood zone.

Prevailing in the Stirovaca area are brown soils on limestones and dolomites, acidic brown soils on sandstones, loess soils, black soils on limestones, acid brown podsols, rendzinas and podsols. In a smallish part of Stirovaca there are undeveloped or only weakly developed soils created by the relocation of soil material during unusually strong torrential flows of the watercourses and the action of ice and snow. All types of soil at Stirovaca have a humus content above 10 %, which places them among humus-rich soils [13].

Data collection. Investigation of the floristic composition of the Stirovaca meadows was conducted during the vegetation seasons of 2018 and 2019. Wild vascular plants were inventoried in the field and where necessary photographed and herbarium specimens were prepared. A GPS device (Garmin Vista e-Trex) was used for geocoding finding sites. Determination of the plant material was done either directly in the field or at a later date in the laboratory. The standard determination keys were used for this purpose [14, 15, 16, 17, 18]. Nomenclature is harmonised with the Flora Croatica Database [19]. Herbarium specimens were deposited in the ZAGR herbarium, while digitised herbarium sheets are accessible via the portal ZAGR Virtual Herbarium (http://herbarium.agr.hr/) [20].

A list of species and subspecies is given in alphabetical order in the framework of higher taxonomic groups in line with *Pteridophyte Phylogeny* Group [21] and *Angiosperm Phylogeny* Group IV [22]. Raunkiaer's life forms are determined after Pignatti and the following abbreviations are used: Ch – *Chamaephyta*, G – *Geophyta*, H – *Hemicryptophyta*, T – *Therophyta* [23]. Their affiliations to floristic elements were analysed according to Flora Croatica Database [19] and Pignatti et al. [24]. The following abbreviations are given for floristic elements: med – Mediterranean, s-eu – South European, se-eu – Southeast European, eu – European, c-eu – Central European, eu-as – Euroasian, circ – Circumholarctic, cosmop – Cosmopolites and adv – Adventive and Cultivated taxa.

Threatened plants were analysed according to Flora Croatica Database [19] and Red Book of Vascular Flora of Croatia [25] making use of the following categories: EN – Endangered, NT – Near Threatened, LC – Least Concern, DD – Data Deficient. Endemicity (END) and invasiveness of species (INV) are taken from Flora Croatica Database [19]. The statutory protection status in Croatia is in line with the Ordinance on Strictly Protected Species and is marked with an asterisk (*) [26].

Remote sensing. Mapping of the habitats in the Stirovaca area was carried out with the remote sensing method, using archival and recent orthophotographic images in the programme Quantum GIS 3.10.2. Coruña. Analysis of date from archival images of 1962 (TIF file, resolution 1.0 m) and digital orthophotographic images of 2018 (resolution 0.5 m) led to the production of a digital map that gives an overview of successional changes in the last 56 years. Interpretation of raster images from different time periods enabled the formation of ultimate vector shapefile layers and the area was computed in m^2. In the making of the map of habitat and vegetation

succession changes the HTRS96/CroatiaTM, EPSG: 3765 coordinate reference system (CRS) was employed.

RESULTS

During floristic investigation of the Stirovaca meadows, in all, 134 wild vascular plants were determined (132 species and 2 subspecies). The species *Dactylorhiza incarnata* is endangered (EN), while the species *Chenopodium bonus-henricus*, *Orchis mascula* and *Trollius europaeus* are near threatened (NT). There are four statutorily protected species from the orchid group *Dactylorhiza fuchsii*, *D. incarnata*, *Gymnadenia conopsea* and *Orchis mascula,* as well as the species *Rorippa lippizensis*. which is protected because of its status as endemic. There are the invasive species *Erigeron annuus* and *Juncus tenuis* (Table 1).

TABLE 1
Wild vascular flora of the Stirovaca meadows
(Abbreviations and asterisks explained in Materials and Methods)

Taxon	Life form	Floristic element	Status
FERNS			
Equisetaceae			
Equisetum arvense L.	G	circ	
Equisetum palustre L.	G	circ	
MONOCOTS			
Melanthiaceae			
Veratrum album L.	G	eu-as	DD
Colchicaceae			
Colchicum autumnale L.	G	c-eu	
Orchidaceae			
Dactylorhiza fuchsii (Druce) Soó	G	eu-as	*
Dactylorhiza incarnata (L.) Soó	G	eu-as	EN*
Gymnadenia conopsea (L.)	G	eu-as	*
Orchis mascula (L.) L.	G	eu	NT*
Iridaceae			
Crocus vernus (L.) Hill	G	s-eu	
Amaryllidaceae			
Allium carinatum L.	G	s-eu	
Allium ursinum L.	G	eu-as	
Asparagaceae			
Muscari botryoides (L.) Mill.	G	s-eu	
Juncaceae			
Juncus articulatus L.	G	circ	
Juncus effusus L.	H	cosmop	
Juncus tenuis Willd.	H	adv	INV
Luzula campestris (L.) DC.	H	eu	
Luzula forsteri (Sm.) DC.	H	s-eu	
Luzula sylvatica (Huds.) Gaudin	H	s-eu	
Cyperaceae			
Carex caryophyllea Latourr.	H	eu-as	
Carex digitata L.	H	eu-as	
Carex elata All.	H	eu	
Carex flacca Schreb.	G	eu	
Carex hirta L.	G	eu	
Poaceae			
Agrostis gigantea Roth	H	circ	
Aira elegantissima Schur	T	s-eu	
Briza media L.	H	eu-as	
Dactylis glomerata L.	H	eu-as	
Festuca pratensis Huds.	H	eu-as	
Festuca rupicola Heuff.	H	c-eu	
Nardus stricta L.	H	s-eu	
Phleum pretense L.	H	circ	
Poa alpina L.	H	circ	

Poa annua L.	T	cosmop	LC
Poa pratensis L.	H	circ	
EUDICOTS			
Ranunculaceae			
Anemone nemorosa L.	G	circ	
Caltha palustris L.	H	circ	
Ranunculus acris L.	H	cosmop	
Ranunculus lanuginosus L.	H	eu	
Ranunculus thora L.	G	s-eu	
Trollius europaeus L.	H	eu-as	NT
Crassulaceae			
Sedum sexangulare L.	Ch	c-eu	
Fabaceae			
Chamaespartium sagittale (L.) Gibbs	Ch	c-eu	
Lathyrus pratensis L.	H	eu-as	
Lotus corniculatus L.	H	eu-as	
Medicago lupulina L.	T	eu-as	
Trifolium montanum L.	H	s-eu	
Vicia cracca L.	H	eu-as	
Polygalaceae			
Polygala alpestris Rchb.	H	s-eu	
Polygala vulgaris L.	H	eu-as	
Rosaceae			
Alchemilla xantochlora Roth.	H	c-eu	
Filipendula ulmaria (L.) Maxim.	H	eu-as	
Fragaria vesca L.	Ch	eu-as	
Geum rivale L.	H	circ	
Potentilla australis Krašan	H	med	
Potentilla erecta (L.) Raeuschel	H	eu-as	
Sanguisorba minor Scop.	H	eu-as	
Oxalidaceae			
Oxalis acetosella L.	G	circ	
Clusiaceae			
Hypericum perforatum L.	H	eu-as	
Violaceae			
Viola arvensis Murray	T	eu-as	
Viola reichenbachiana Jord. ex Boreau	H	eu-as	
Viola tricolor L.	T	eu-as	
Euphorbiaceae			
Euphorbia amygdaloides L.	Ch	eu	
Euphorbia carniolica Jacq.	H	s-eu	
Onagraceae			
Epilobium angustifolium L.	H	circ	
Malvaceae			
Malva moschata L.	H	s-eu	
Cistaceae			
Helianthemum nummularium (L.) Mill.	Ch	eu	
Brassicaceae			
Arabis hirsuta (L.) Scop.	H	eu	
Barbarea vulgaris R. Br.	H	cosmop	
Cardamine hirsuta L.	T	cosmop	
Cardamine trifolia L.	H	med	
Rorippa lippizensis (Wulfen) Rchb.	H	s-eu	END*
Polygonaceae			
Rumex acetosa L.	H	circ	
Rumex crispus L.	H	cosmop	
Caryophyllaceae			
Silene dioica (L.) Clairv.	H	eu-as	
Silene vulgaris (Moench) Garcke	H	eu-as	
Stellaria graminea L.	H	eu-as	

Stellaria nemorum L. ssp. *glochidiosperma* Murb.	H	eu	
Amaranthaceae			
Chenopodium bonus-henricus L.	H	circ	NT
Primulaceae			
Primula elatior (L.) L.	H	c-eu	
Primula vulgaris Huds.	H	eu	
Ericaceae			
Vaccinium myrtillus L.	Ch	circ	
Rubiaceae			
Galium mollugo L.	H	s-eu	
Galium palustre L.	H	eu	
Galium verum L.	T	eu	
Gentianaceae			
Gentiana cruciata L.	H	eu-as	
Gentiana tergestina Beck	H	med	
Gentianella anisodonta (Borbás) Á. Löve et D. Löve	H	med	
Gentianella ciliata (L.) Borkh.	T	s-eu	
Boraginaceae			
Myosotis sylvatica Hoffm.	H	eu-as	
Symphytum tuberosum L.	G	s-eu	
Plantaginaceae			
Plantago argentea Chaix	H	s-eu	
Plantago media L.	H	eu-as	
Scrophulariaceae			
Rhinanthus alectorolophus (Scop.) Pollich	T	c-eu	
Rhinanthus angustifolius C. C. Gmel.	T	eu-as	
Veronica beccabunga L.	Ch	eu-as	
Veronica chamaedrys L.	H	s-eu	
Veronica urticifolia Jacq.	H	s-eu	
Lamiaceae			
Ajuga reptans L.	Ch	eu	
Clinopodium vulgare L.	H	circ	
Lamium maculatum L.	H	eu-as	
Mentha longifolia (L.) Huds.	H	eu-as	
Prunella laciniata (L.) L.	H	s-eu	
Prunella vulgaris L.	H	circ	
Salvia pratensis L.	H	s-eu	
Thymus pulegioides L.	Ch	eu-as	
Campanulaceae			
Campanula glomerata L.	H	eu-as	
Campanula scheuchzeri Vill.	H	s-eu	
Phyteuma spicatum L.	H	c-eu	
Asteraceae			
Achillea millefolium L.	H	eu-as	
Aposeris foetida (L.) Less	H	s-eu	
Buphthalmum salicifolium L.	H	s-eu	
Carduus carduelis (L.) Gren.	H	se-eu	
Centaurea bracteata Scop.	H	s-eu	
Centaurea fritschii Hayek	H	eu-as	
Centaurea jacea L.	H	eu-as	
Cicerbita alpina (L.) Wallr.	H	eu	
Cirsium arvense (L.) Scop.	G	eu-as	
Crepis foetida L.	T	s-eu	
Erigeron annuus (L.) Pers.	T	adv	INV
Leucanthemum vulgare Lam.	H	eu-as	
Petasites albus (L.) Gaertn.	G	c-eu	
Prenanthes purpurea L.	H	eu	
Scorzonera purpurea L. ssp. *rosea* (Waldst.et Kit.) Nyman	H	s-eu	DD
Taraxacum officinale Weber	H	circ	
Taraxacum palustre (Lyons) Symons	H	eu-as	

Tussilago farfara L.	G	eu-as
Caprifoliaceae		
Knautia dinarica (Murb.) Borbás	H	s-eu
Scabiosa lucida Vill.	T	s-eu
Apiaceae		
Angelica sylvestris L.	H	eu-as
Anthriscus sylvestris (L.) Hoffm.	H	eu-as
Astrantia major L.	H	s-eu
Carum carvi L.	H	eu-as
Heracleum sphondylium L.	H	eu-as
Laserpitium krapfii Crantz	H	s-eu

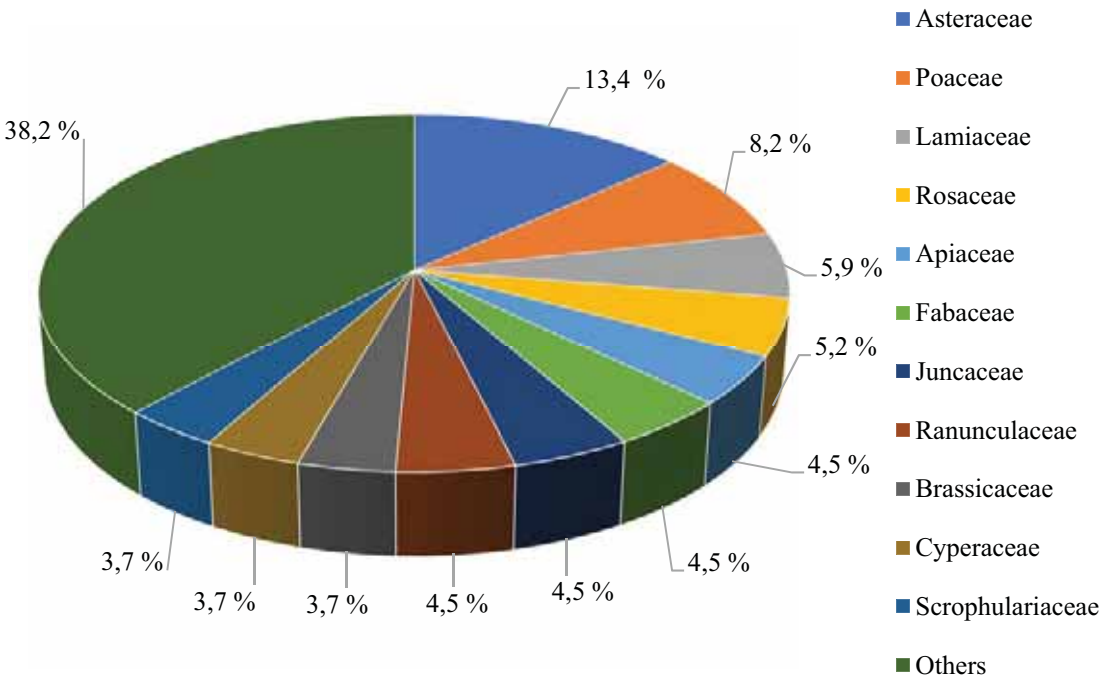

FIGURE 2
The most represented families (with 5 or more species and subspecies) in the composition of the flora of the Stirovaca meadows

All species and subspecies recorded in the area of the Stirovaca meadows, 134 of them, are classified into 97 genera and 38 families. Most of the plants determined – 100 species and subspecies belong to eudicotyledons (74.6%). There are 32 species in the monocotyledon group and just two species belong among the ferns. The most common family in the flora investigated is Asteraceae (18 species and subspecies), after which come Poaceae (11 species), Lamiaceae (8 species) and Rosaceae (7 species). In all 12 families were recognised as being significant by being represented by five or more species and subspecies (Figure 2).

In the life-forms spectrum, the group Hemicryptophyta prevailed, with 89 species and subspecies, constituting 66.4 % of the total flora of the Stirovaca meadows (Figure 3).

Through analysis of the floristic elements it was established that the greatest number of taxa, 46, belonged to the Eurasian floristic element (35.0 % of the total), then the southern European floristic element (23.1 %), plants of Circumholarctic distribution (13.4 %) and the European floristic element (12.0 %) (Figure 4).

Progressive vegetation succession has advanced over the last 60 or so years. By analysis of the period of time from 1962 to 2018, it was determined that the meadowland area in the Stirovaca valley has diminished by 10,035 m^2 (Figure 5).

DISCUSSION AND CONCLUSION

The meadows of Stirovaca in North Velebit National Park have never previously been systematically examined with respect to their flora, and so this paper is the first detailed inventory and analysis of the flora.

The flora of Stirovaca encompasses all told 134 species and subspecies of wild vascular plants. Only partially represented are species that are characteristic of mountain area meadows, and the major part consists of species that are less typical of meadow communities. This can be explained by the position of the Stirovaca meadows. They are meadows that are relatively small in area and are surrounded with a dense complex of forest and virgin forest ecosystems. The closeness of spruce and beech-and-fir forests has a great impact on the flora of the meadowland. Here we are primarily faced with meadows in an area that to a great extent is not subject to the adverse effects of Velebit climate, like strong winds and blizzards. Then, in the area of Stirovaca, there is a lack of any clearly defined transitional zone of vegetation between the meadow and the forest areas, which resuls in the floristic composition of the meadows having forest floor species (*Vaccinium myrtillus*, *Astrantia major*, *Prenanthes purpurea*, *Allium ursinum*, *Oxalis acetosella*, *Petasites albus* and others) [5].

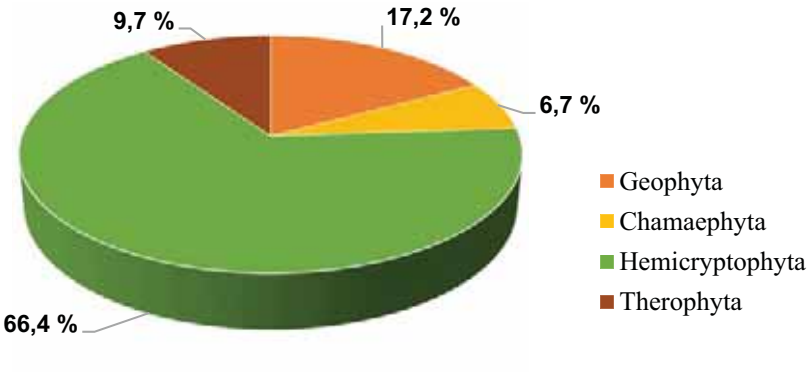

FIGURE 3
Life forms spectrum of the flora of Stirovaca meadows

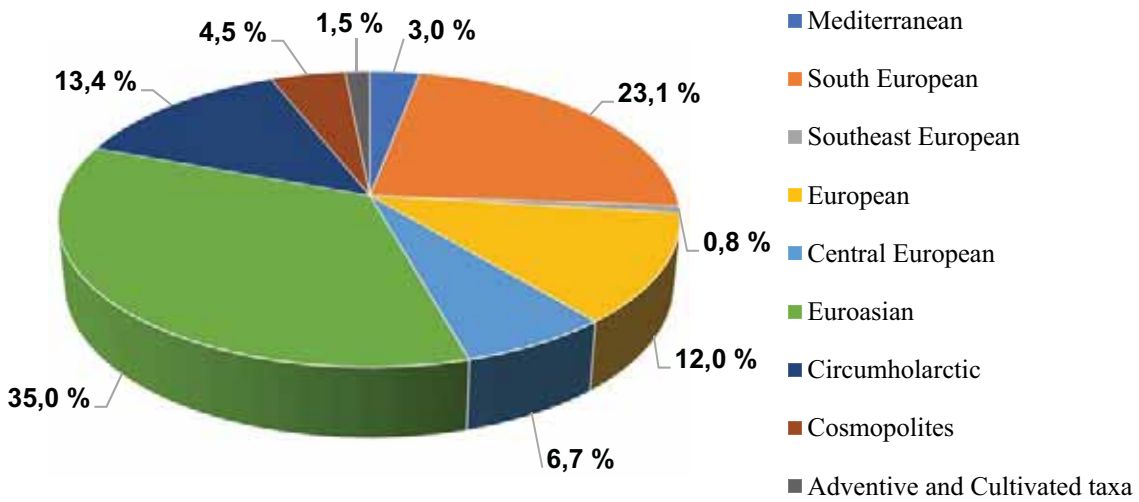

FIGURE 4
Spectrum of floristic elements of the flora of Stirovaca meadows

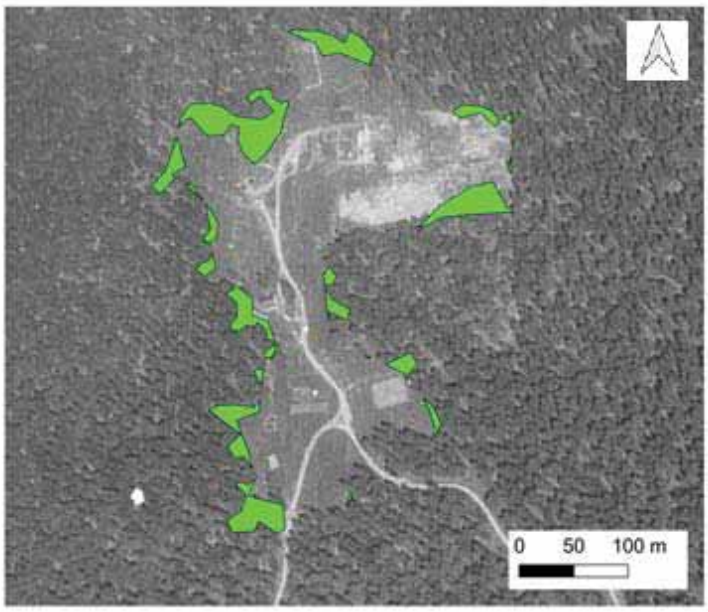

FIGURE 5
Vegetation succession in the Stirovaca area

This investigation has inventoried all kinds of moist and aquatic habitats, for example, *Agrostis gigantea*, *Caltha palustris*, *Equisetum arvense*, *E. palustre*, *Fragaria vesca* and *Veronica beccabunga*, which can be explained by the particular hydrogeological conditions that prevailed in the area of Stirovaca.

Next, the extensive distribution and abundance of several species of Orchidaceae were noticed, to be precise, of *Dactylorhiza fuchsii*, *D. incarnata*, *Gymnadenia conopsea* and *Orchis mascula*. These species in meadow flora composition in Croatia on the whole appear in smaller numbers, while in the Stirovaca meadows they are represented by considerably more specimens. It is worthy of emphasis that in global terms, there are ever fewer populations of the species *Dactylorhiza incarnata* (EN) and this species is not listed only in the Red Book of Vascular Flora of Croatia, but also in the IUCN Red List of Threatened Species in the category Least Concern (LC) [25, 27].

It has to be pointed out that in the past Stirovaca was a busy area for economic activities. Because of the high quality forests and access to potable water, in 1870 a sawmill was built with an attached housing settlement. Apart from sawmill workers, forestry employees lived here, as well as herdsmen. During World War II, the sawmill was destroyed by fire and stopped working, and so the residential settlement vanished too [28]. These anthropogenic influences can today be seen in the composition of meadow flora, where species typical of nitrogen rich habitats grow sporadically: *Chenopodium bonus-henricus*, *Rumex acetosa* and *Rumex crispus*.

Two introduced species in the category of invasive neophytes are recorded in the composition of the flora of Stirovaca (*Erigeron anuus* and *Juncus tenuis*) but they are low in abundance and accordingly are no threat to the ecosystem [29].

It is worth paying particular attention on the Stirovaca meadows to the preservation and protection of the population of the inventoried species *Gentiana cruciata*, which is host plant to the globally threatened butterfly *Phengaris alcon* during the oviposition process [30].

Since in this research it has been established that the process of succession has advanced, the meadows of Stirovaca can be counted among threatened habitats. Because of the progressive succession they are being overgrown, which can lead to an important reduction of meadow areas and thus to an essentially lower plant diversity.

It can be concluded that the meadows of Stirovaca are an essential enrichment of plant and landscape diversity for, in spite of the relatively small number of threatened and endemic species, the abundance and diversity of the other wild plants are very great.

Richness and diversity of the plant world, the basic characteristic of Stirovaca, are a rich feature of the world natural heritage. Accordingly, it is necessary to go on carrying out the inventorying and monitoring of the conditions so as to be able to ensure the preservation and protection of the Stirovaca environment and of North Velebit National Park as a whole.

ACKNOWLEDGEMENTS

We would like to thank the Ministry of Environmental Protection and Energy of the Republic of Croatia for permission to collect plant material for the purposes of research in the area of North Velebit National Park.

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Received: **02.08.2021**
Accepted: **15.10.2021**

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