

P. L. NIMIS, L. LOSI

LICHENS AS PHYTOCLIMATICAL INDICATORS IN THE TRIESTE KARST*

*I LICHENI COME INDICATORI FITOCLIMATICI NEL CARSO TRIESTINO**

Abstract — Three biotopes of the Trieste Karst have been compared on the basis of chorological spectra relative to their lichen florulas, subdivided according to main substrate types: bark, soil, sandstone, limestone. Lichen species with similar distribution patterns tend to have similar ecological requirements. They seem to respond well to differences in air humidity and temperature. Therefore, lichen species can be used as phytoclimatical indicators.

Key words: Lichens, Phytogeography, Trieste.

Riassunto breve — *Gli spettri corologici relativi alle florule licheniche di tre biotopi del Carso Triestino, suddivisi per tipo di substrato (scorza, suolo, calcare, arenaria) sono stati analizzati tramite metodi di analisi multivariata. Specie licheniche con areali simili tendono ad avere simili esigenze ecologiche. In particolare, i licheni sembrano essere molto sensibili a differenze in temperatura ed umidità atmosferica, il che permette la loro utilizzazione quali indicatori ecologici.*

Parole chiave: Licheni, Fitogeografia, Trieste.

Introduction

Aim of this paper is to test the use of lichens for the phytogeographical and phytoclimatical characterization of different biotopes. In particular, the study aims to quantify the degree of correlation between lichen species with similar ranges and biotopes characterized by different ecological conditions.

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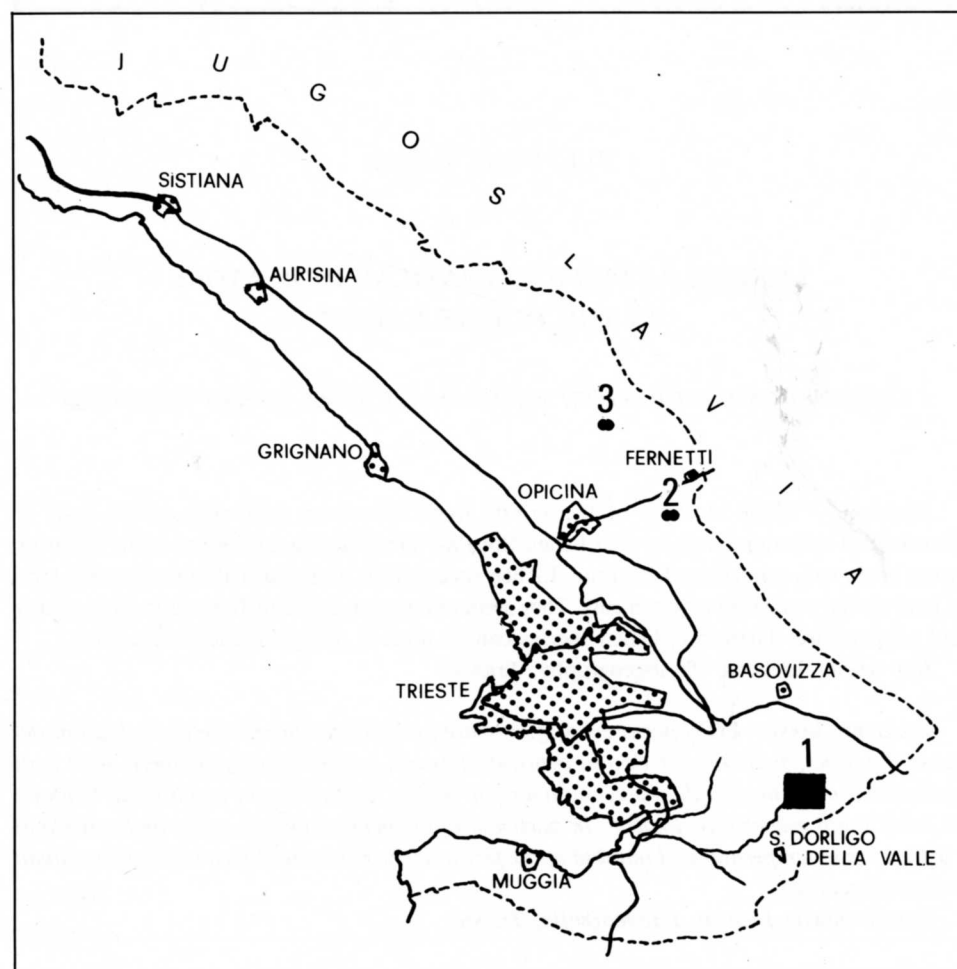


Fig. 1 - Location of study areas.
- Localizzazione delle aree studiate.

The analysis is performed on the basis of species lists relative to three biotopes located in the Karst region surrounding the town of Trieste (fig. 1): the Rosandra-Valley (NIMIS & LOI, 1981), the Doline of Percedol (NIMIS & LOI, 1983; NIMIS, 1983) and the Doline of Ferneti (LOSI, 1983). Each area is described in terms of a chorological spectrum relative to the whole of its lichen flora and by other spectra referring to sub-lists of species growing on four main substrate types: bark, soil,

limestone, sandstone (the latter present only in the Val Rosandra).

The basic assumption underlying the present study is that species with similar distribution patterns tend to have similar ecological requirements, above all in respect with climate. Consequently, differences in chorological spectra between different biotopes could be utilized for their phytoclimatical characterization. This is an extension to lichen species of a kind of analysis already attempted by FEOLI CHIAPELLA & FEOLI (1983) for the phanerogamic flora of M. Paularo (Carnian Alps) and by NIMIS (1983b) for the phanerogamic flora of Sicily.

Description of study areas

A first general remark concerning the ecological characterization of the three biotopes is that they are far from presenting homogeneous ecological conditions all over their respective surface. They are representative of two main geomorphological units in the landscape system of the Karst region: dolines and a karst valley. Microclimatical conditions in different parts of a doline (POLLI, 1961) or at the two side slopes of the valley (POLLI, 1981) are generally very different. The climatic diagrams of the three biotopes are in fig. 2⁽¹⁾. The temperature curves refer to the bottom and outer margin of the two dolines (the former is colder than the latter) and to two stations located at the two side slopes of Val Rosandra, one South-exposed, the other North-exposed. From the three climatic diagrams it is evident how the Doline of Percedol is the coldest among the three biotopes, Val Rosandra the warmest, whereas the Doline of Ferneti is characterized by temperatures that are intermediate between those of the two former biotopes.

Further data on the three biotopes are given below:

Doline of Percedol:	Elevation: 270 m (bottom) - 304 m (margins).
	Diameter: 400-270 m.
	Surface: ca. 0.02 Km ² .
	Nr. of Lichens: 106 (NIMIS & LOI, 1983).
Doline of Ferneti:	Elevation: 269.3 m (bottom) - 315/320 m (margins).
	Diameter: 0.5 Km (E-W) - 0.38 Km (N-S).
	Surface: 0.04 Km ² .

(1) Data sources: POLLI, 1983 (Percedol); COLAUTTI, 1984 (Ferneti); COLAUTTI, 1975 (Val Rosandra).

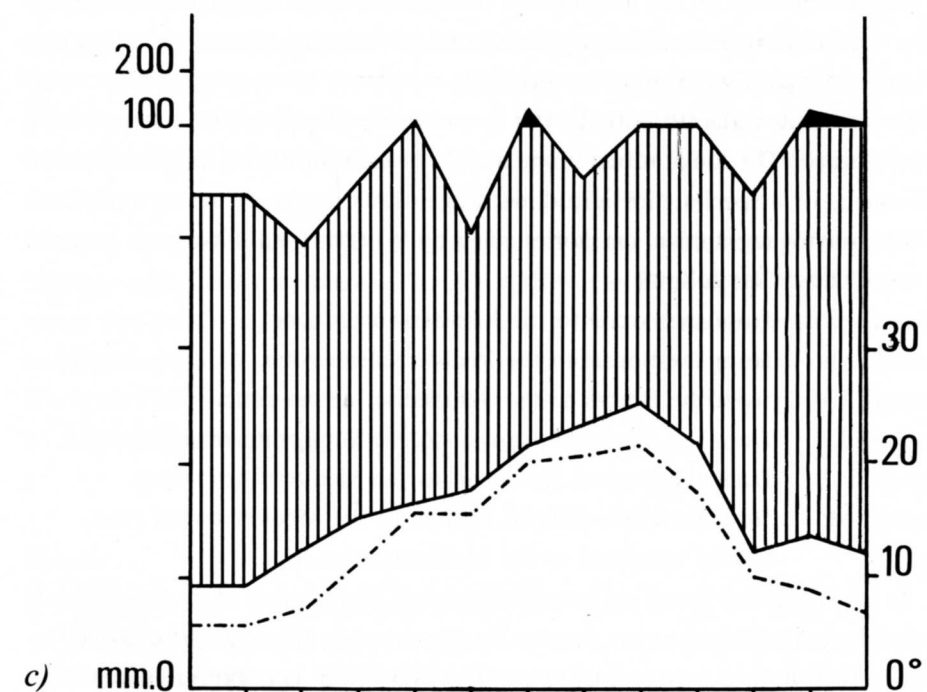
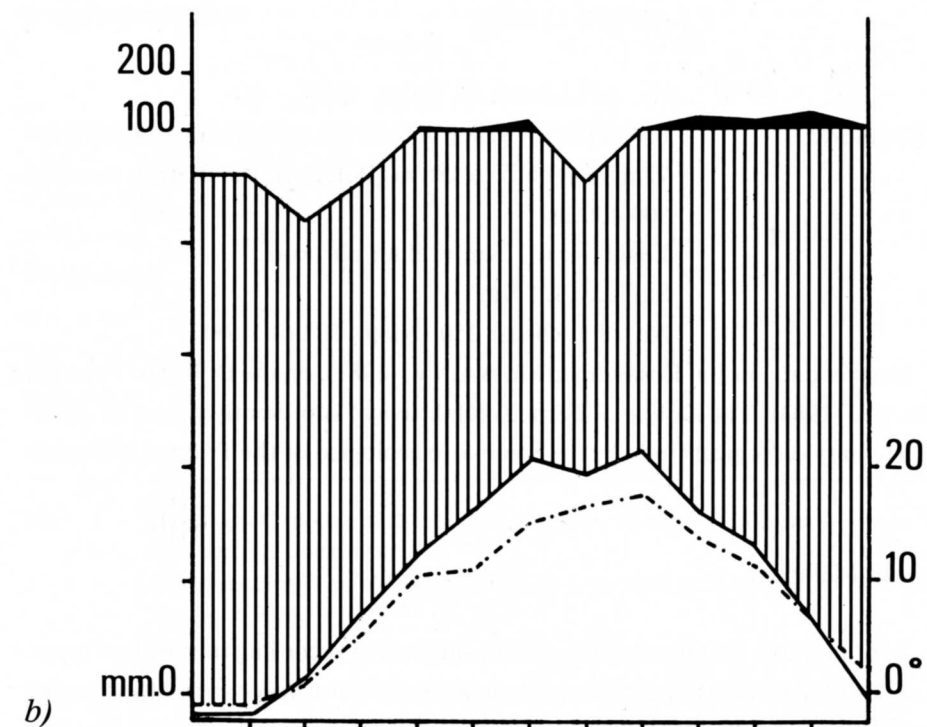
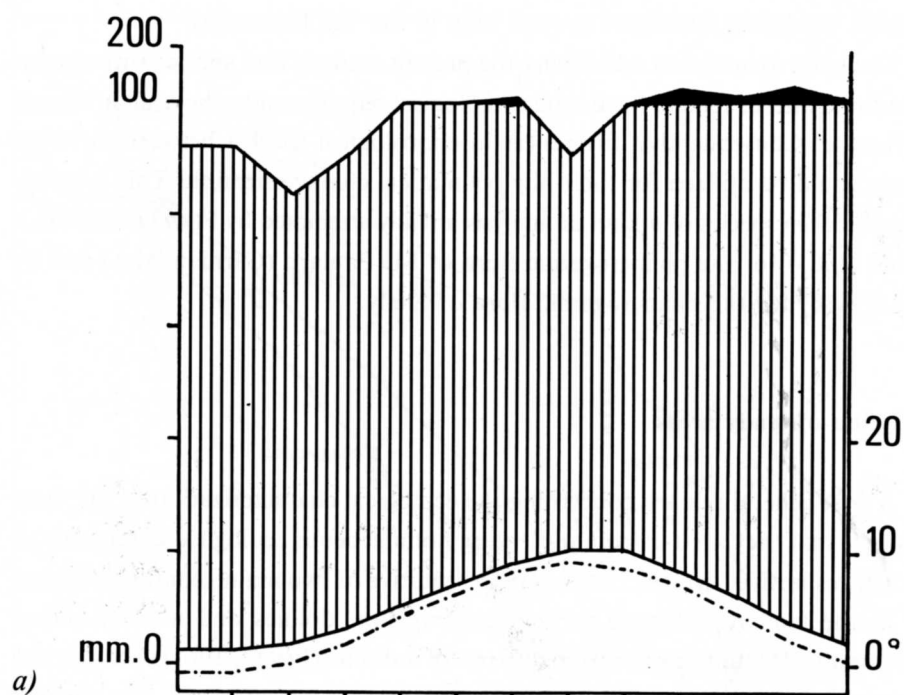


Fig. 2 - Climatic diagrams of the three biotopes:

a) Doline of Percedol

b) Doline of Ferneti

c) Val Rosandra

(Dotted line represents temperatures measured at the bottom, continuous line at the upper margin of the dolines in 2a and 2b. Dotted line in fig. 2c refers to temperatures at the North exposed side of the Valley, continuous line at the South-exposed side).

- Diagrammi climatici dei tre biotopi:

a) Dolina di Percedol

b) Dolina di Ferneti

c) Val Rosandra

(la linea tratteggiata riporta le temperature misurate al fondo, quella continua le temperature misurate al margine superiore delle doline in 2a e 2b. La linea tratteggiata in fig. 2c si riferisce alle temperature misurate al lato esposto a N, quella continua alle temperature misurate al lato S della Val Rosandra).

Nr. of Lichens: 83 (LOSI, 1983).

Val Rosandra: Elevation: the valley bottom has an elevation ranging from 72 m (Bagnoli) to 186 m (Botazzo); the Plateau opens at 300-400 m.

Lenght: ca. 1 Km (italian portion).

Surface: 1.4 Km².

Nr. of Lichens: 250 (NIMIS & LOI, 1981).

Further data on Val Rosandra are in AA.VV. (1981), on the Doline of Percedol in AA.VV. (1983). The Doline of Ferneti (Gabrovica) is presently object of an interdisciplinary ecological study by the Seminario ecologico of the Trieste University.

Data and Methods

Tab. I reports the chorological spectra subdivided according to substrate types.

The subdivision of species into phytogeographical categories is based on the system proposed by WIRTH (1980), in which two main criteria are adopted: the first is to give information on the longitudinal distribution range in Europe, by specifying the vegetation belts in which a given species is occurring, the second takes into account the longitudinal range, by specifying whether a given species has a range shifted westwards (atlantic, subatlantic) or eastwards (continental) in respect with Central Europe. The longitudinal range mainly gives information on the thermal requirements of a species, the latitudinal range on its degree of aeroxerophytism.

The phytogeographical categories given by WIRTH (1980) have been grouped into seven classes, as follows:

Arkt-med: from the Arctic to the Mediterranean zone.

Bor-med: from the Boreal to the Mediterranean zone.

Bor-smed: from the Boreal to the Submediterranean zone.

Mieur-smed: from the Central European to the Submediterranean zone.

Mieur-med: from the Central European to the Mediterranean zone.

S'mieur-med: from Southern Central Europe to the Mediterranean zone.

Med: chiefly restricted to the Mediterranean zone.

In tab. I a further group has been distinguished, including all of the lichen species with main distributional center located in the atlantic provinces of Europe, independently from their longitudinal range. The data in tab. I are expressed in percen-

	Val Rosandra				D. Percedol		D. Ferneti		
	E	L	S	EG	E	L	E	EG	L
med	5	14	7	15	—	—	—	—	3
s'mieur-med	4	18	5	17	—	—	—	17	10
mieur-med	23	41	18	18	28	39	13	—	35
mieur-smed	6	7	5	4	—	5	5	—	3
bor-smed	13	—	—	9	5	8	10	33	—
bor-med	51	10	28	22	55	34	59	17	31
arkt-med	8	10	37	25	12	14	13	33	18
atl/subatl	21	1	—	—	31	14	22	—	7

Table I - Chorological spectra of the three biotopes, subdivided by substrate. For abbreviations see fig. 3 and text.

- *Spettri corologici dei 3 biotopi, suddivisi per substrato. Per le abbreviazioni vedi fig. 3 e il testo.*

tages over the total lichen florula of each biotope or of each habitat in the three biotopes. This because each of the three biotopes is considered as an independent Operational Geographic Unit.

Data elaboration is based on Complete Linkage Clustering with Jaccard's Coefficient (ANDERBERG, 1973) and on Concentration Analysis (AOC). The basic algorithm of AOC is described by FEOLI & ORLOCI (1979). Other related algorithms, which have given rise to AOC, are outlined by ORLOCI (1978). The basic model of AOC:

$$X^2 = R_1^2 F + \dots R_k^2 F$$

specifies the partitioning of the interaction chi square associated with a $s \times k$ contingency table into components. The R_i are known as Canonical Correlations. If the group structure is significantly and reasonably sharp, it makes sense to search for intrinsic variables $Y_1 \dots Y_i$ which partition the compositional gradient into Canonical Variates. The results may be visualized in a scatter diagram that gives the position of the s_i and k_i according to the Canonical Variates.

Results

The dendrogram of the chorological spectra is in fig. 3. Three main clusters are formed, as follows:

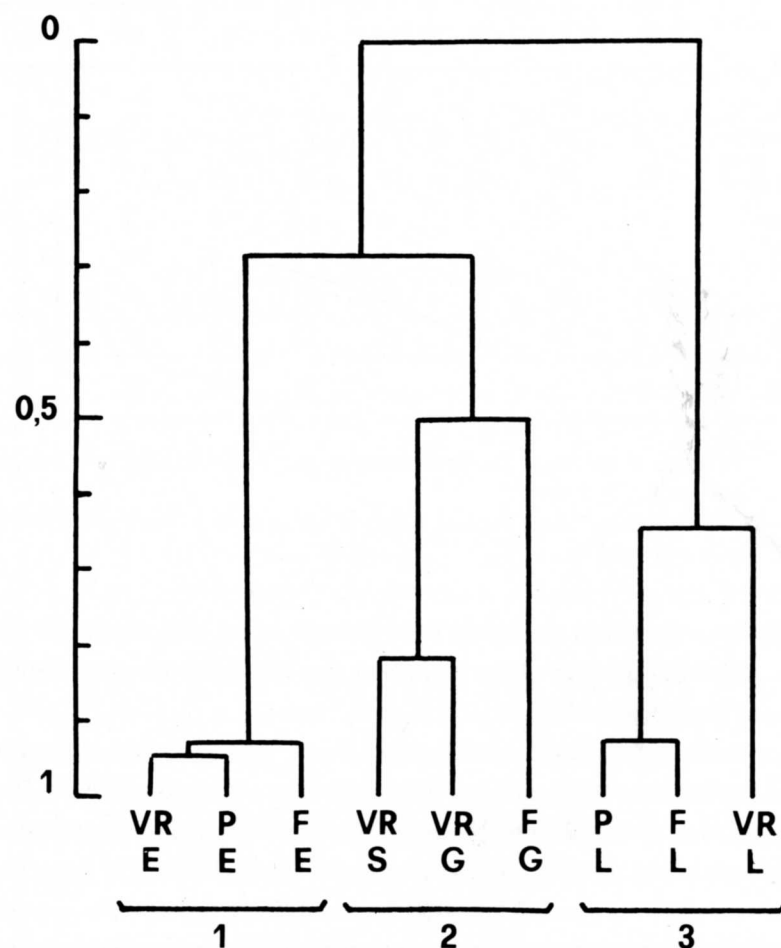


Fig. 3 - Dendrogram of the chorological spectra. Symbols as in fig. 4.

- Dendrogramma degli spettri corologici. I simboli sono come in fig. 4.

Cluster 1: includes epiphytic lichens from all of the three biotopes. The relative spectra are characterized by the prevalence of species ranging from the boreal to the mediterranean zones and by the scarcity of southern european elements.

Cluster 2: includes epigaeic species from Percedol and Val Rosandra, plus epilithic species on sandstone (Val Rosandra). The relative spectra are intermediate between those of Cluster 1 and those of Cluster 3.

Group	level	med	s'mieur	mieur	mieur	bor	bor	arkt
VR-EPIPHYTES	.930 7.314	.129 1.220	.354 .507	2.420 1.020	.179 .289	3.000 1.180	1.940 4.740	.349 .185
VR-LIMESTONE	6.091 56.969	.374 3.540	1.950 2.790	4.220 1.770	.173 .281	.002 .000	.532 1.300	.881 .466
VR-SANDSTONE	.033 4.324	.180 1.700	.590 .845	1.820 .763	.178 .289	.002 .000	1.180 2.880	2.580 1.370
VR-EPIGAEIC	4.179 14.825	.334 3.160	1.300 1.860	1.820 .763	.143 .231	2.250 .885	.884 2.160	1.680 .886
P-EPIPHYTES	9.339 20.489	.000 .000	.000 .000	2.230 1.190	.000 .000	1.250 .491	2.320 5.660	.838 .443
P-LIMESTONE	18.253 1.997	.000 .000	.000 .000	4.360 1.970	.000 .000	.527 .207	1.460 3.580	1.030 .545
P-EPIPHYTES	.323 32.949	.000 .000	.000 .000	1.310 .551	.178 .289	2.500 .938	2.480 6.080	.907 .480
F-EPIGAEIC	140.273 .818	.000 .000	2.010 2.870	.000 .000	.000 .000	8.250 3.240	.716 1.750	2.300 1.220
F-LIMESTONE	6.697 2.395	.000 .729	1.180 1.690	3.530 1.480	.107 .173	.000 .000	1.310 3.190	1.260 .664

Table II - Contribution of phytogeographical categories to the chi square accounted for by the first two Canonical Variates in AOC and their levels of influence partitioned by substrate types, subdivided by biotopes.

- Contributo delle categorie fitogeografiche al chi quadrato delle prime 2 variabili canoniche in AOC ed i loro livelli di influenza, suddivisi per tipo di substrato, riferiti ai biotopi.

Cluster 3: includes species on limestone from all of the three biotopes. They are characterized by higher frequencies of southern species, particularly in the Val Rosandra.

The results of the numerical classification show that the distribution ranges of lichen species are related with the specific heat of the various substrates: this is minimal for bark (northern species) and maximal for limestone (southern species), soil and sandstone being in an intermediate position.

Differences between biotopes have been studied on the basis of the results of AOC. AOC has produced the Canonical Variates which partition the total interac-

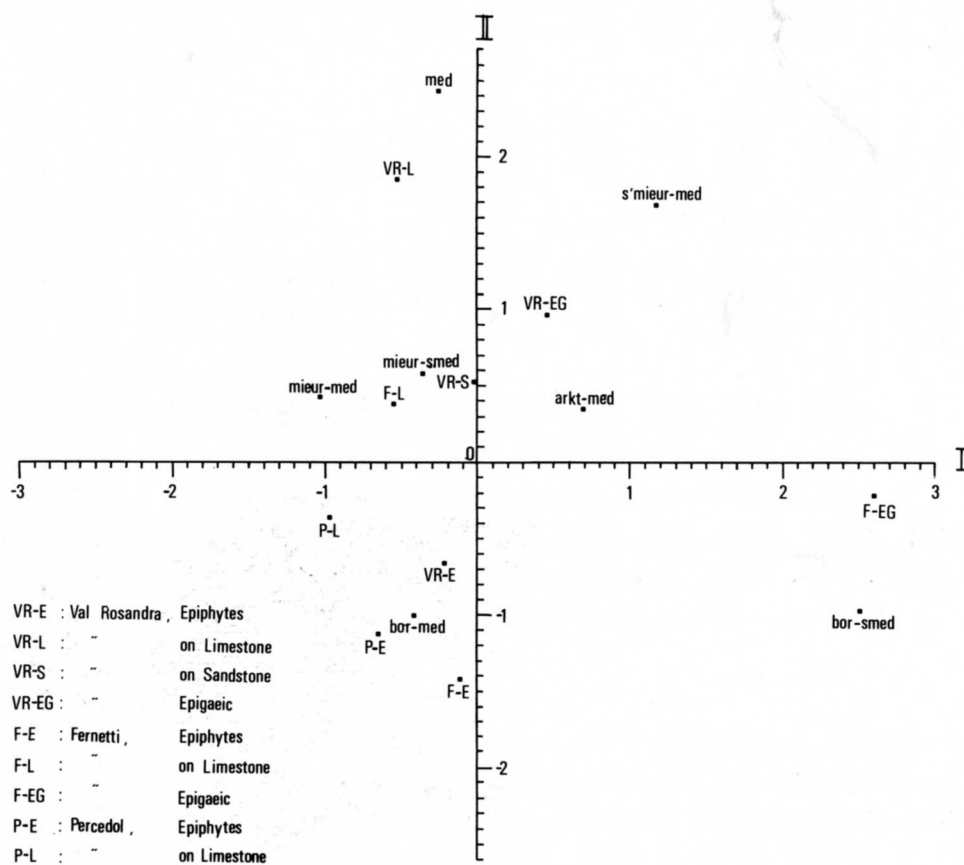


Fig. 4 - Scatter diagram obtained by AOC on the matrix of tab. II.

- Analisi della concentrazione (AOC) sui dati in tab. II. Distribuzione dei punti secondo la I e II variabile canonica.

	Group level	VR-E	VR-L	VR-S	VR-EG	P-E	P-L	F-E	F-EG	F-L
med	.589 40.200	.160 .518	1.200 4.210	.041 .556	.892 1.920	.000 .000	.000 .000	.000 .000	.000 .000	.259 .178
s'mieur-med	18.100 28.000	.080 .257	1.120 3.940	.024 .328	.624 1.340	.000 .000	.000 .000	.000 .000	5.570 .484	.713 .489
mieur-med	46.100 6.270	.340 1.000	1.520 5.330	.047 .632	.546 1.170	1.260 2.150	2.720 1.040	.109 1.260	.000 .000	1.340 .916
mieur-smed	.712 1.440	.202 .654	.504 1.770	.037 .501	.346 .744	.000 .000	.000 .000	.119 1.390	.000 .000	.327 .224
bor-smed	91.900 10.900	.299 .968	.000 .000	.000 .000	.481 1.030	.397 .676	.234 .000	.147 1.710	10.200 .885	.000 .000
bor-med	11.100 51.000	.555 1.800	.391 1.370	.062 .838	.543 1.170	2.110 3.600	1.870 .711	.420 4.880	2.540 .221	1.010 .691
arkt-med	17.000 3.660	.080 .262	.524 1.840	.111 1.480	.831 1.780	.618 1.050	1.060 .404	.124 1.440	6.600 .574	.784 .537

Table III - Contributions of substrate types, subdivided by biotopes, to the chi square accounted for by the first two Canonical Variates and their levels of influence, partitioned among phytogeographical categories.

- Contributo dei tipi di substrato suddivisi per biotopi, al chi quadrato espresso dalle prime 2 variabili canoniche ed i loro livelli di influenza, suddivisi per categorie fitogeografiche.

tion chi square into two major and one lesser component. The first of these accounts for 45.2% of the total interaction chi square, the second for 34.6%, the third for 20.2%, independently from the first two. The scatter diagram of phytogeographical categories and substrates, according to the Ist and IInd Canonical Variates is in fig. 4. Tab. II gives the contribution of phytogeographical categories to the chi square accounted for by the first two Canonical Variates and their levels of influence partitioned by substrate types in the three biotopes. Tab. III gives the contribution of substrate types, subdivided by biotopes, to the chi square accounted for by the first two Canonical Variates and their levels of influence, partitioned among phytogeographical categories.

The first Canonical Variate clearly separates epigaeic lichens of the doline of Ferneti, that are correlated with species whose ranges extend from the boreal to the submediterranean zones, from all the others (tab. I; fig. 4). The joint distribution of phytogeographical categories and substrate types along the second Canonical Variate clearly reveals a trend from northern ranges (negative scores) to southern ranges (positive scores). At the negative side of the second Canonical Variate is the group of species whose ranges extend from the boreal to the mediterranean zones. They are correlated with the epiphytic habitats from all of the three biotopes. Along the second Canonical Variate the phytogeographical categories are disposed in a sequence characterized by a progressive narrowing of the northern limits of the ranges. Among the phytogeographical categories that have a greater contribution to the chi square on the second Canonical Variate, the sequence is as follows (from the negative to the positive side): bor-med, mieu-med, s'mieu-med, med.

At the positive side of the second Canonical Variate are species that do not reach the boreal zone: they are most correlated with epi-endolithic habitat on limestone. The epigaeic lichens from Val Rosandra are affected both by the first and the second Canonical Variates (tab. II/III): they are related both with northern species, ranging from the boreal to the submediterranean zones, and with mediterranean species.

Finally, the group of species with very broad distribution, from the arctic to the mediterranean zones, has a low contribution to the chi square both on the first and the second Canonical Variates and is mostly correlated with epilithic habitat on sandstone.

The above presented results were based on multivariate analysis of data concerning the longitudinal distribution ranges of the various species; therefore, they should be considered as reflecting differences in temperature between biotopes and

between substrate types within a single biotope. Tab. I gives also the percentages of species with atlantic-subatlantic distribution, i.e. of species that are linked with climates characterized by high air humidity. These are most frequent on bark in all of the three biotopes. They also occur on limestone, above all in the doline of Percedol, and are very scarcely represented on soil, sandstone and limestone in the Val Rosandra. From the data in tab. I, the doline of Percedol is the biotope with highest incidence of aerohygrophytic species, the Val Rosandra the one with lowest incidence. This is well in accordance with climatical data from the three biotopes (fig. 1).

Discussion

A first remark concerning the above presented results concerns the low discriminant power that epiphytic lichens have in respect with the three biotopes. This is mainly due to the presence in all of the three biotopes of mature woody stands whose microclimatical conditions are buffered in respect with macroclimatical differences among the biotopes. The species occurring on trees are mostly characterized by ranges going from the boreal to the central european zones. This is well in accordance with the central european character of the phanerogamic flora of mature woody stands on the Karst Plateau (POLDINI, 1982). Most of the epiphytic lichen species occurring in mature woods within the study area reproduce by means of soredia (NIMIS, 1982). Vegetative reproduction should be considered as a relatively recent feature in lichens (POELT, 1970), a fact that is well related with the presence of such species in woody stands of relatively recent origin. Apothecia-bearing species, on the contrary, are most frequent on isolated trees, above all at the south exposed side of the bole (NIMIS, 1982; NIMIS & DE FAVERI, 1981) and along the coastal strip, where mediterranean influences in the epiphytic lichen flora are more marked. Finally, the peculiar microclimate of woody stands is reflected in the high frequency of atlantic-subatlantic species in their lichen florulas, a fact that indicates higher air humidity in respect with the surrounding areas, independently from the climatical conditions prevailing in the three biotopes.

As far as the epi-endolithic lichens on limestone are concerned, their phytogeographical characterization seems to reflect well the main climatical differences among the biotopes. Those in the Doline of Percedol are characterized in a northern sense (many species extend up to the boreal zone and truly mediterranean species

are very scarcely represented), whereas the epi-endolithic lichens in the Val Rosandra mostly consist of mediterranean species, or of species that do not reach the boreal zone. The doline of Ferneti has an epi-endolithic lichen flora that in phytogeographically intermediate between the former two. Also this fact is well in accordance with microclimatical and phytogeographical-phytosociological data regarding the phanerogamic flora of the three biotopes: the doline of Percedol is almost completely covered with *Asaro-Carpinetum* (LAUSI, 1971; POLDINI, 1982), a closed wood with clear central european affinities, whereas the Val Rosandra is one of the biotopes in the Trieste Karst in which mediterranean affinities are most evident (POLDINI, 1981). The Doline of Ferneti is only half-covered with woody stands and its phanerogamic flora is less characterized in a central european sense than the one in the Doline of Percedol (POLDINI, in litt.). Furthermore, the presence of calcareous rocks exposed to direct sunlight is maximal in the Val Rosandra, where south exposed subvertical cliffs are one of its major geomorphological features and minimal in the Doline of Percedol, because of the prevalence of woody vegetation. The latter biotope is the only one in which air humidity is sufficiently high to allow the presence of a group of subatlantic species growing on limestone (tab. I).

The epigaeic lichen floras in the Val Rosandra and in the Doline of Ferneti are characterized by interesting differences in their phytogeographical affinities: the mediterranean element is still well represented in Val Rosandra, whereas in the Doline of Ferneti most of the epigaeic lichens consist of species whose southern distributional limit lies in the submediterranean zone. Most of the epigaeic lichens in the Doline of Ferneti occur within the *Carici-Centaureetum rupestris* (POLDINI, 1981), whereas in the Val Rosandra, besides this grassland association located in the higher parts of the valley, at the margins of the Karst Plateau, another association dominated by grasses is most frequent on south exposed slopes, the *Lactuco-Ischaemetum* (POLDINI, 1976). The phytogeographical affinities of the former are mainly central european-illyric, those of the latter are chiefly mediterranean. The lichen synusia commonly occurring in the *Carici-Centaureetum* is the *Cladonietum convolutae* (NIMIS & LOI, 1981), whereas the *Lactuco-Ischaemetum* has a lichen component in which species of the *Toninion coeruleonigrantis* are most frequent. The latter foederatio has its main distributional center from the Steppes of Central Asia to continental Central Europe (ALBERTSON, 1946; GAMS, 1938), extending up to the sagebrush grasslands of Central North America (NIMIS, 1981a; 1981b). This finds a correspondence in the phytogeographical characterization of the *Lactuco-Ischaemetum*

as given by POLDINI (1975), according to whom this association has clear affinities both in a mediterranean and a parasteppic sense. Also in this case the phytogeographical differences between lichen florulas of different biotopes find a correspondence in the phytogeographical characterization of the phanerogamic component and are referable to microclimatical differences between the biotopes.

Finally, the correlation between species with broad distribution, from the arctic to the mediterranean zone and the sandstone substrate, is simply due to the prevalence of nitrophytic species on the latter, as already discussed by NIMIS & LOI (1982).

Conclusions

The distribution patterns of lichen species proved to be well correlated with ecological differences among the biotopes. In particular, these organisms tend to respond to differences in temperature and air humidity, a fact that is readily understandable considering their peculiar physiological adaptations. A general remark concerns the Trieste Karst as a study area. This region is clearly transitional, from the climatical point of view, between a maritime-mediterranean climate and a continental-prealpine climate type. This is the main reason why small changes in geomorphology (and hence in microclimates) correspond with marked differences in vegetation. This fact was already known for the phanerogamic vegetation (POLDINI, 1972; 1980; LAUSI, 1971). The present study confirms that the same phenomenon can be observed as far as lichen species are concerned.

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RIASSUNTO — Gli spettri corologici di tre biotopi del Carso Triestino, basati sulla distribuzione delle specie di licheni in essi presenti e suddivisi a seconda del substrato (scorza, suolo, calcare, arenaria), sono stati soggetti ad analisi multivariata al fine di quantificare le correlazioni tra affinità fitogeografiche delle florule licheniche e le caratteristiche microclimatiche dei tre biotopi (Dolina di Percedol, Dolina Gabrovica di Ferneti, Val Rosandra).

Gli spettri corologici dei licheni epifiti non risultano discriminanti tra i biotopi, a causa del microclima particolare dell'ambiente boschivo. Quelli dei licheni epilitici ed epigei riflettono assai bene le principali differenze microclimatiche tra i biotopi, con una prevalenza di specie meridionali in Val Rosandra (il biotopo più caldo e meno umido), di specie settentrionali nella Dolina di Percedol (il biotopo più freddo e più umido). Le specie ad affinità suba-

tlantiche sono maggiormente frequenti tra i licheni epifiti ed il loro numero decresce dalla dolina di Percedol alla Val Rosandra, in corrispondenza con una diminuzione dell'umidità atmosferica.

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Authors' address - Indirizzo degli Autori:

- Dr. Pier Luigi NIMIS
 — Dr. Luisa LOSI
 Dipartimento di Biologia,
 Sez. Geobotanica ed Ecologia Vegetale
 dell'Università degli Studi
 Via Valerio 30, I-34127 TRIESTE