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Autor: Gerdol, Renato
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Gradient analysis of alpine vegetation in the Lagorai range, Dolomites

Renato Gerdol

Faculty of Agricultural Sciences, University of Padova, Via Gradenigo 6, 35121 Padova, Italy

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Abstract

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The environmental uniformity characterizing the northern slope of the Lagorai range at altitudes between 2000 and 2500 m reduces to a considerable extent the range of variation in the floristic composition of plant communities. A set of phytosociological relevés was treated by multivariate ordination techniques (principal component analysis and analysis of concentration) and the results could be clearly interpreted from the ecological viewpoint and correlated with simple abiotic variables. It is shown that the length of the vegetative season is the main factor accounting for most of the floristic variation, followed by the soil-moisture content. The reciprocal ordering based on correspondence analysis permits to define the response of species along gradients of both factors.

Introduction

Alpine vegetation varies in response to the interaction of many factors. These can be roughly categorized as: (i) macroenvironmental factors, e.g. altitude and regional climate; and (ii) microenvironmental factors, e.g. aspect, inclination, soil type and – at least to a certain extent – lithology. While the former are subject to large-scale variations, the latter may determine dramatic changes in the floristic composition of plant communities even within a range of few meters. This is clearly due to the morphologically highly contrasted landscape characterizing the environment in the mountain regions (Aichinger 1933, Wikus 1960, Giacomini et al. 1962, Lippert 1966, Braun-Blanquet 1969, Pignatti E. and S. 1983).

The complex paired relationships among different ecological factors are often difficult to be clearly explained in the absence of data on environmental variables. A detailed sampling of the abiotic environment may meet against great technical obstacles, especially when studying areas far from facilities. In most studies concerned with alpine vegetation the description of the environment is therefore restricted to speditive measurements of simple abiotic variables, such as those included in the heading of the standard Braun-Blanquet tables. In addition, a more detailed sampling, involving for instance soil profiles and topographic surveys, may be performed in selected sites after reducing the

vegetational complexity either by numerical or by intuitive classifications (Braun-Blanquet and Jenny 1926, Giacomini and Pignatti 1955, Komarkova 1980, Gerdol and Piccoli 1982).

The employ of multivariate methods of ordination proved successful for detecting environmental gradients in alpine vegetation. They are both suitable for drawing inferences on the habitat conditions based on the indicator values of plant species and for correlating floristic with abiotic data (Poldini and Feoli 1976, Feoli-Chiapella and Feoli 1977, Feoli and Feoli Chiapella 1980, Grabherr 1982, 1985, Codogno et al. 1984, Tomaselli 1988).

The study area was chosen for a gradient analysis of alpine vegetation on account of its unusual uniformity and of the absence of any considerable disturbance. This greatly reduces the number of environmental factors inducing variations in the vegetation. Furthermore, the response of diagnostic taxa to environmental gradients could be determined with a relatively low degree of uncertainty.

Study area

The Lagorai range represents the southwesternmost outpost of the Dolomites. It is entirely formed of a porphyric acid substratum dating back to the Permian, and therefore contrasts with the typical landscape of the Dolomites, the latter mainly consisting of carbonatic bedrocks. The northern slope of this mountain group is morphologically quite uniform, especially at high altitudes, viz. from 1900–2000 m up to 2500 m, the highest peak reaching 2754 m.

The dominating landform consists of gently inclined outcrops of the porphyric bedrock. Because of the low inclination angle, never exceeding 20°, well below the critical range of 35°–45° for igneous rocks (Gardiner and Dackombe 1983) and the high degree of mechanical resistance against fracturing, the substratum is not covered by debris and also chemical weathering proceeds slowly.

At a lower elevation the vegetation is formed of a sparse woodland of *Pinus cembra* and *Larix decidua* and small mires having *Trichophorum caespitosum* as the dominant vascular species usually growing on a carpet of *Sphagnum compactum*. Above the treeline the plant cover consists of *Carex curvula*-grasslands and *Salix herbacea*-snow beds. The most compact outcrops of bedrock are covered by lichens and are not suitable to be colonized by any type of vascular vegetation.

The slope is locally interrupted by cirques and couloirs, originated by the action of ancient glaciers. Here the landscape consists of a mosaic of more or less stable talus slopes of different ages, surrounded by steep rock faces. Such a morphology gives rise to a much more complex vegetation pattern which is left out from this study.

Climate in the study region is continental cold. At 2000 m the yearly mean temperature averages ca. 2.5 °C and precipitation 1350 mm, the latter having a distinct maximum in summer (Fliri 1975).

Methods

Vegetation was studied by the Braun-Blanquet phytosociological method. All species of vascular plants, lichens and bryophytes occurring in the sampling sites were recorded. Their abundance was estimated by the following scale (van der Maarel 1979): r=1, +=2, 1=3, 2=5, 3=7, 4=8, 5=9.

The abiotic environment was characterized by means of the only two simple variables subject to variations, viz. elevation and inclination, aspect and lithology being constant all over the study area.

The original data set was reduced by eliminating the rare species occurring in no more than one stand. The resulting matrix was numerically classified by average linkage clustering based on the similarity ratio (Orlóci 1978). The matrix of floristic data was subjected to 2 different methods of ordination, viz. (i) centred standardised principal component analysis (PCA) based on the logarithmic transformation of the similarity-ratio matrix between relevés (Feoli-Chiapella and Feoli 1977) and (ii) analysis of concentration (AOC), i.e. a reciprocal ordering of species and relevés based on correspondence analysis (Hill 1974, Feoli and Orlóci 1979).

The patterns resulting from the numerical ordinations were correlated with the environmental variables by means of ellipses of equal concentration (Lagonegro and Feoli 1985). These were drawn around the barycentres of the abiotic variables (p_i , i.e. alternately altitude and inclination) in the space defined by the ordination axes (x_i and y_i).

The barycentre has the following coordinates:

$$x_G = (1/T) \sum_1^n p_i \cdot x_i, \quad y_G = (1/T) \sum_1^n p_i \cdot y_i$$

where

$$T = \sum_1^n p_i$$

and n is the number of relevés.

Nomenclature of species follows Pignatti (1982) for vascular plants, Andrus (1980) for *Sphagnum*, Corley et al. (1981) for the other mosses, Grolle (1983) for hepatics and Poelt (1974) for lichens. Syntaxonomy follows Oberdorfer (1983) when not differently specified.

Results and discussion

Four clusters of relevés are isolated in the classification dendrogram at a similarity level of about 0.30 (Fig. 1). They are in good accordance with the vegetation types

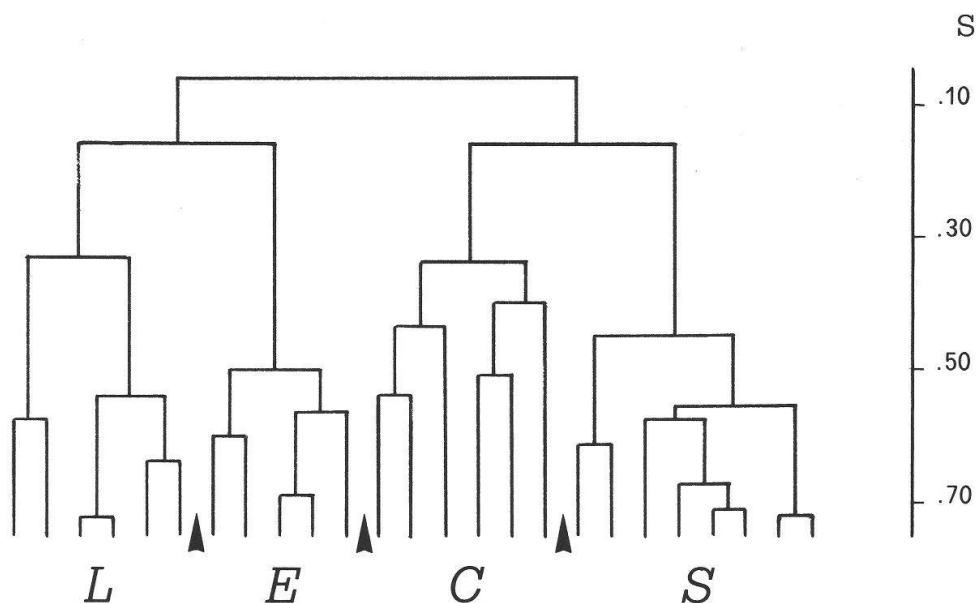


Fig. 1. Dendrogram of classification of the relevés. The sequence of relevés and the symbols for the vegetation types are the same as in Table 1. S = similarity ratio.

Table 1 - Phytosociological table. The abundance values are the van der Maarel's (1979) transformations of the Braun-Blanquet scale. L = Larici-Cembretum; E = Eriophoro-Trichophoretum caepitosi; C = Caricetum curvulae; S = Salicetum herbaceae.

Vegetation type	L	E	C	S
Relevé n.	123456	78901	234567	89012345

Vaccinio-Piceetea

Larix decidua	222333			
Pinus cembra	333333	1		
Picea excelsa	2323			
Rhododendron ferrugineum	537757	2 22	2	
Vaccinium myrtillus	27773	2 2		
Vaccinium gaultherioides	553 33	32333	32	
Calamagrostis villosa	3533			
Homogyne alpina	3 333	32333	53	2 22
Huperzia selago	222322			22
Cetraria islandica	75 233	3		3 2
Cladonia arbuscula	35 23			
Sphagnum girgensohnii	2333	2		
Polytrichum formosum	3222	3		
Juniperus nana	253 3			
Vaccinium vitis-idaea	223			
Pleurozium schreberi	22 2			
Loiseleuria procumbens	52	3		22

Oxycocco-Sphagnetea and Scheuchzerio-Caricetea fuscae

Polytrichum strictum	2	2		
Sphagnum nemoreum	35			
Sphagnum russowii	2 33	35		
Trichophorum caespitosum	2	85785		
Carex stellulata		22		
Selaginella selaginoides	2	222		
Sphagnum compactum	2	75875		
Mylia anomala	2	2		
Eriophorum vaginatum		22 23		
Calliergon sarmentosum		2 22		
Gymnocolea inflata		55		
Viola palustris		2 2		

Juncetea trifidi

Agrostis rupestris	2 22	2 233	33332	2
Phyteuma hemisphaericum	2 222	222 22	2	
Avenula versicolor	22	2 2 2	2 2	
Euphrasia minima	2	22	2	
Carex curvula	3	23 3	555555	2 2
Oreochloa disticha	2		325	
Senecio incanus carniolicus	2		222332	
Saponaria pumila			35	
Primula glutinosa	2		333233	322 222
Phyteuma globulariifolium			22 2	2
Juncus jacquinii			2 2	
Pedicularis kernerii			22	

Vegetation type	L	E	C	S
Relevé n.		11	111111	11222222
	123456	78901	234567	89012345

Salicetea herbaceae

Soldanella pusilla		2	2 2 2	33 23553
Salix herbacea			2352 3	75255732
Luzula alpino-pilosa	22 2		22 2	23375375
Leucanthemopsis alpina			2222 2	522233
Cerastium cerastioides				3 333
Arenaria biflora				355332
Veronica alpina			2	222332
Gnaphalium supinum			2 2	352 222
Sedum alpestre				2 22 2
Sibbaldia procumbens			2	22 22
Cardamine bellidifolia alpina				2322
Polytrichum sexangulare		3		53755878
Kiaeria starkei			33	23 22233
Anthelia juratzkana			252	25 32
Pohlia drummondii			2 22	255223
Solorina crocea			2	2

Companions

Leontodon helveticus	332232	22 22	25 223	3 2
Nardus stricta	32222	35533	2	
Deschampsia caespitosa	2 23	2333	2	2 2
Lophozia wenzelii	2	22	3 3	2 23 2 2
Avenella flexuosa	22233	2 222		
Dicranum scoparium	323333	2	2	
Carex sempervirens	22 23	2 33	2	
Hieracium alpinum	232 2		233 2	
Taraxacum alpinum				22 2222
Potentilla aurea	2222	2		
Soldanella alpina	22 22	2		
Cladonia coccifera	22 2 2		2	
Gentiana punctata	2 2		22 2	
Veratrum album	2222			
Festuca rubra	2 2	22		
Solidago virgaurea alpestris	2 222			
Cephalozia bicuspidata	2 2	22		
Anthoxanthum alpinum	22	2	2	
Polytrichum piliferum			2 232	
Dicranella subulata				2 2 2 2
Dryopteris carthusiana	232			
Sorbus aucuparia	322			
Diplophyllum taxifolium	222			
Polygonum viviparum			2 3 3	
Luzula sudetica	2	22		
Poa alpina				2 23
Campanula barbata	2 2			
Rhynchospora triquetra	2 2			
Carex atrata	2 2			
Alnus viridis	52			
Cladonia elongata	22			
Hylocomium splendens	2 2			
Adenostyles alliariae	22			
Oxalis acetosella	22			
Viola biflora	23			
Aulacomnium palustre	2	2		
Paraleucobryum enerve		2	2	
Pleurocladula albescens	2			3
Potentilla erecta		2 2		
Scapania helvetica		2		2
Racomitrium sudeticum			2 2	
Dicranum fuscescens			2	2
Oligotrichum hercynicum			2 2	

visually recognized in the field. Each of them is phytosociologically characterized by a distinct group of species and can be defined at the association level (Table 1). Syntaxonomy will be further explored in a next contribution.

Cluster L, characterized by Vaccinio-Piceetea species, corresponds to the Larici-Cembretum (sensu Mayer 1974).

Cluster E, characterized by Oxycocco-Sphagnetea and Scheuchzerio-Caricetea species, corresponds to the Eriophoro-Trichophoretum caespitosi.

Cluster C, characterized by Juncetea trifidi species, corresponds to the Caricetum curvulae.

Cluster S, characterized by Salicetea herbaceae species, corresponds to the Salicetum herbaceae.

The ordinations based on the I–II axes of PCA and on the I–III axes of AOC (Fig. 2) gave the best results. Any attempt failed of interpreting the remaining axes in ecological terms. They are therefore not reported.

The first axes of both PCA ($\lambda_1 = 68\%$) and AOC ($R_1 = 0.90$) bring about a comparable ordination of the stands in the sense: Salicetum herbaceae → Caricetum curvulae → Eriophoro-Trichophoretum caespitosi → Larici-Cembretum (Fig. 2). In both cases the centroid of the Salicetum herbaceae and that of the Caricetum curvulae are clearly separated from each other as well as from those of the Eriophoro-Trichophoretum and the Larici-Cembretum. The distance between the latter, on the other hand, is not significant (Table 2, Fig. 3).

Table 2 - Student's t values between the groups of stands corresponding to the different vegetation types. The calculations are based on the I and II components of PCA (upper matrices) and on the I and III canonical variates of AOC (lower matrices).

<u>PCA I</u>	L	E	C	S
Larici-Cembretum	-			
Eriophoro-Trichophoretum	1.31	-		
Caricetum curvulae	7.65	5.87	-	
Salicetum herbaceae	73.33	27.20	4.91	-
<u>PCA II</u>	L	E	C	S
Larici-Cembretum	-			
Eriophoro-Trichophoretum	0.17	-		
Caricetum curvulae	7.29	7.80	-	
Salicetum herbaceae	1.50	1.80	11.40	-
<u>AOC I</u>	L	E	C	S
Larici-Cembretum	-			
Eriophoro-Trichophoretum	2.20	-		
Caricetum curvulae	8.69	7.01	-	
Salicetum herbaceae	30.30	31.54	6.89	-
<u>AOC III</u>	L	E	C	S
Larici-Cembretum	-			
Eriophoro-Trichophoretum	2.46	-		
Caricetum curvulae	5.20	6.50	-	
Salicetum herbaceae	2.83	0.40	7.61	-

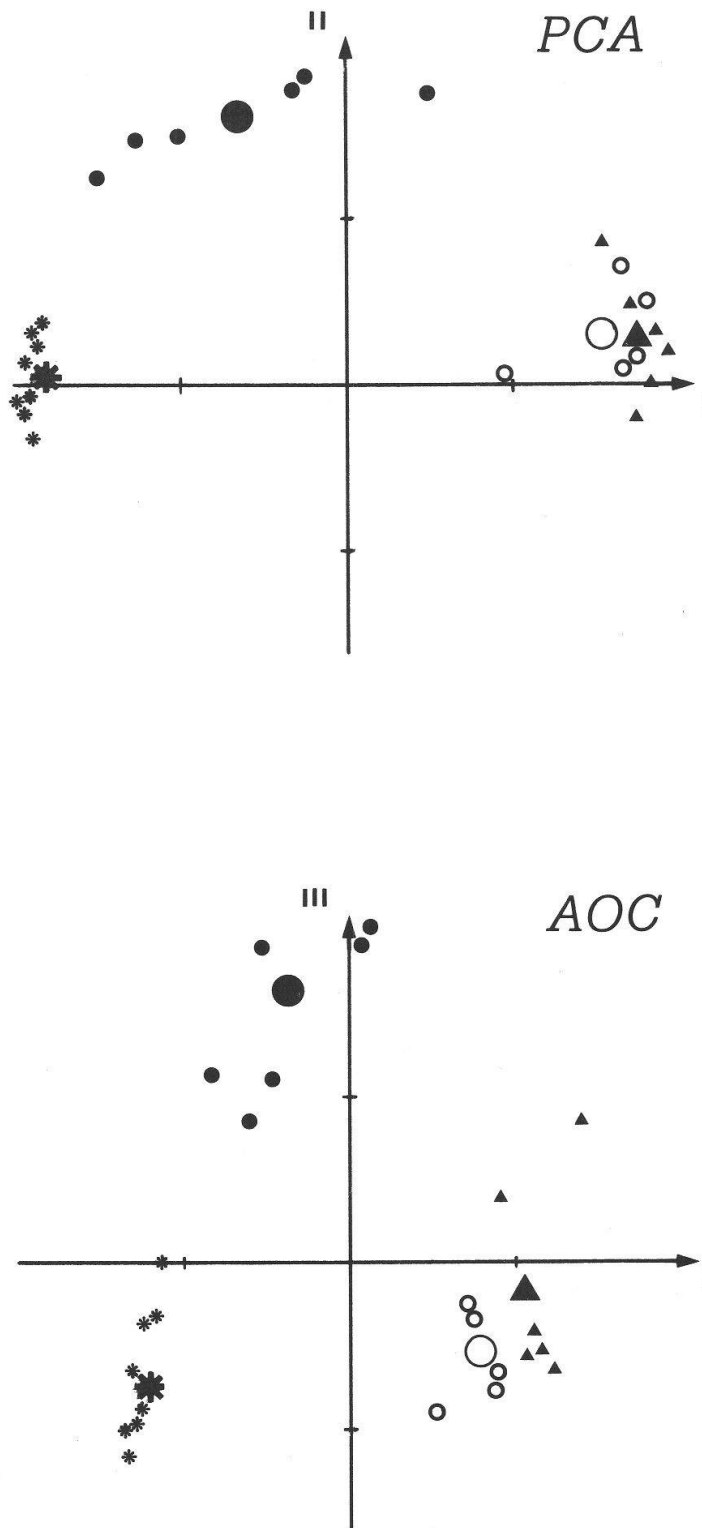


Fig. 2. Ordinations of the relevés by PCA and AOC. The positions of the species in the latter diagram are not indicated. The large symbols indicate the centroids.

- ▲ Larici-Cembretum
- Eriophoro-Trichophoretum caespitosi
- Caricetum curvulae
- * Salicetum herbaceae

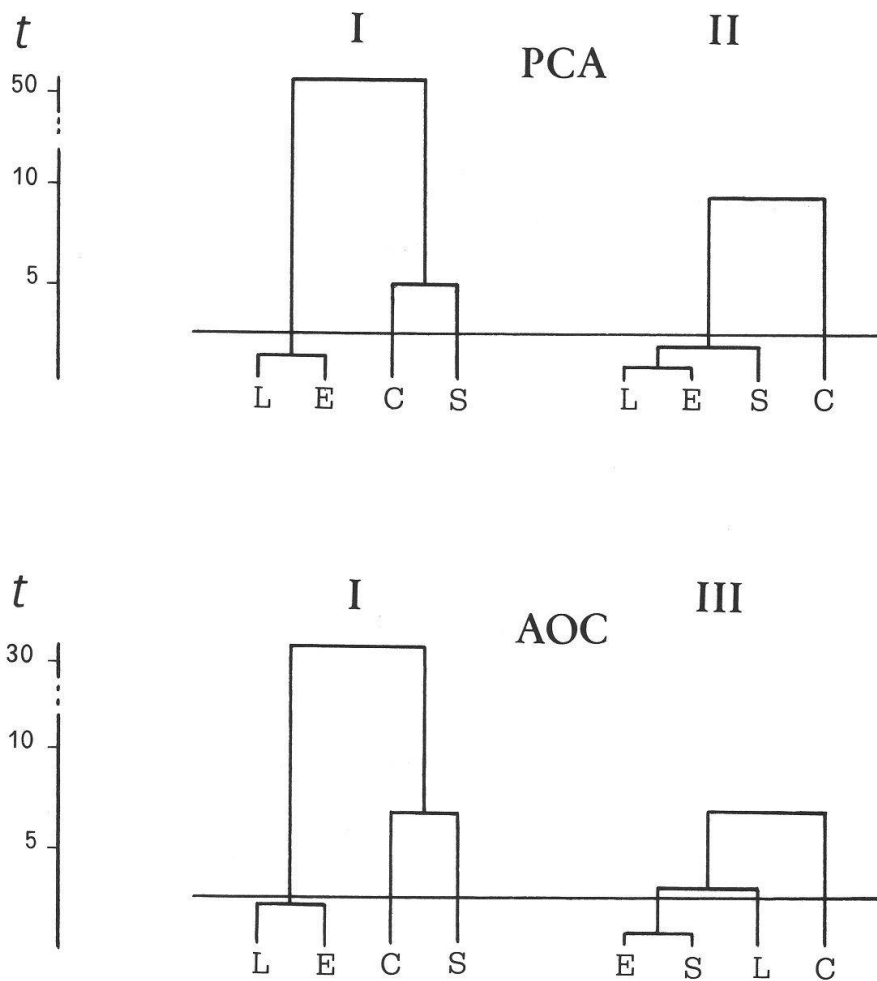


Fig. 3. Classifications of the vegetation types based on the Student's t values (see Table 2). Symbols as in Table 1.

The groups of stands are far less discrete along the second axis of PCA ($\lambda_2 = 18\%$) as well as the third axis of AOC ($R_3 = 0.63$). Only the *Caricetum curvulae* is sharply separated, while the remainder is either indistinct (PCA) or poorly differentiated between *Larici-Cembretum* and *Eriophoro-Trichophoretum* + *Salicetum herbaceae* (AOC; see Table 2, Figs. 2 and 3).

A major difficulty when operating with ordinations based on floristic matrices resides in the ecological characterization of the ordination axes (Orlóci 1978). In this study such a task was made considerably easier by reducing "a priori" the environmental complexity of the sample subjected to the analyses. In fact, no source of floristic variation can be ascribed either to macromorphology or to lithology.

The first ordination axis, accounting for most of the variation both in PCA and in AOC, can be interpreted as an index of length of the vegetative season, increasing in the sense: *Salicetum herbaceae* → *Caricetum curvulae* → *Eriophoro-Trichophoretum caespitosi* + *Larici-Cembretum*. This inference is supported by occasional observations on the duration of the snow cover made in a restricted sector of the study area (Table 3). Recent works, based both on vegetation mapping (Karrer 1980, Heiselmayer 1981), and on gradient analysis (Vetterli 1982), support the well-known opinion (see Ellenberg 1979)

Table 3 - Presence of snow on three different dates in the four vegetation types. The symbol in parentheses indicates isolated snow patches. Observations of the year 1988.

	June 15	July 1	July 15
Larici-Cembretum	(x)		
Eriophoro-Trichophoretum			
Caricetum curvulae	x	x	
Salicetum herbaceae	x	x	x

that the duration of snow cover, in turn conditioned by morphology, is a major factor inducing variations in the vegetation of alpine regions.

The second ordination axis, corresponding respectively to the II principal component of PCA and to the III canonical variate of AOC, can be interpreted on the other hand as an index of the soil-moisture content, increasing in the sense: Caricetum curvulae → Larici-Cembretum → Eriophoro-Trichophoretum caespitosi + Salicetum herbaceae.

A further point to be stressed is the considerable overlap between the results obtained by multivariate techniques based on different assumptions about the mutual relationships among species, viz. the one (PCA) requiring linearity and the other (AOC) not (Gauch 1982, Ezcurra 1987). This can be interpreted as an evidence of the consistency of both methods even when the form of the species responses cannot be exactly defined a priori, as usually happens in plant ecology. AOC has the further advantage of performing a reciprocal ordering of species and relevés. The results can therefore be used for evaluating the response of species along the gradients. This analysis was restricted to the species phytosociologically characterizing the four vegetation types, viz. by excluding the companions (Tables 4 and 5).

Most of the species of the classes Vaccinio-Piceetea, Oxycocco-Sphagnetea and Scheuchzerio-Caricetea fuscae have values on the first canonical variate higher than 0.77 and are almost exclusive of the sites where the vegetative season lasts longer, viz. those of the Larici-Cembretum and of the Eriophoro-Trichophoretum. All of the Salicetea herbaceae species, on the other hand, have values lower than -0.94 and have a clear optimum in the sites where the vegetative season is shortest, viz. those of the Salicetum herbaceae. Most of the Juncetea trifidi species have values comprised between 0.06 and -0.78 and behave intermediately (Table 4).

The remainder includes only 10% of the species, that can be regarded accordingly as more or less euryecious in respect to the duration of the vegetative season. Four of them belong to the Juncetea trifidi, viz. *Euphrasia minima*, *Phyteuma hemisphaericum*, *Avenula versicolor* and *Agrostis rupestris*, and two to the Vaccinio-Piceetea, viz. *Loiseleuria procumbens* and *Homogyne alpina*.

The ordering of the species along the third axis, corresponding to a gradient of soil-moisture content, is more loosely correlated with the syntaxonomical grouping (Table 5). The Juncetea trifidi species are distinctly concentrated at the "xeric end" of the gradient with positive values. All of the Oxycocco-Sphagnetea and Scheuchzerio-Caricetea species have, on the other hand, negative values though the "moist end" of the

Table 4 - Reciprocal ordering of species and relevés according to decreasing values of the first canonical variate of AOC. Abbreviations for the vegetation types as in Table 1.

Relevé n.	11	1111	121	2212	221
	2411253930876944851627035				
Vegetation type	LLLLLEEELECCCCSSSSSSSS				
1.27 Calamagrostis villosa	3335				
1.27 Picea excelsa	2323				
1.26 Sphagnum nemoreum	53				
1.22 Vaccinium myrtillus	737722	2			
1.21 Polytrichum formosum	3222	3			
1.21 Sphagnum girgensohnii	2333		2		
1.20 Vaccinium vitis-idaea	2	32			
1.17 Larix decidua	23332		2		
1.14 Pinus cembra	333331		3		
1.13 Mylia anomala	2	2			
1.11 Juniperus nana	33	5		2	
1.10 Rhododendron ferrugineum	77573222	5	2		
1.09 Polytrichum strictum	2		2		
1.06 Sphagnum russowii	3	3	3	52	
1.05 Cladonia arbuscula		325		3	
1.02 Pleurozium schreberi	2	2		2	
0.99 Carex stellulata			22		
0.96 Calliergon sarmentosum			2	22	
0.93 Sphagnum compactum	2		7875	5	
0.93 Selaginella selaginoides			22	22	
0.93 Trichophorum caespitosum	2		8785	5	
0.90 Huperzia selago	22232		2	22	
0.89 Vaccinium gaultherioides	333	533335223			
0.88 Eriophorum vaginatum		2	23	2	
0.80 Cetraria islandica	3325		3	7	3
0.78 Gymnocolea inflata			5	5	
0.77 Viola palustris			2	2	
0.69 Euphrasia minima		2	22	2	
0.65 Loiseleuria procumbens		2	3	5	22
0.65 Phyteuma hemisphaericum	2	22	22	22	2
0.60 Avenula versicolor		2	2222	22	
0.40 Homogyne alpina	33333333	2	325	22	
0.24 Agrostis rupestris	22	32232	233	33	2
0.06 Saponaria pumila			53		
-0.08 Oreochloa disticha			2	23	5
-0.18 Senecio incanus carniol.	2			332222	
-0.20 Carex curvula			23335555552		2
-0.23 Pedicularis kernerii			2	2	
-0.69 Phyteuma globulariifolium			2	2	2
-0.74 Primula glutinosa		2	32333332222		2
-0.78 Juncus jacquinii			22		
-0.94 Solorina crocea			2	2	
-0.99 Luzula alpino-pilosa	22	2	2	2	223573573
-1.02 Anthelia juratzkana			5	22253	2
-1.04 Leucanthemopsis alpina			22222523		3
-1.11 Soldanella pusilla		2	2223335532		
-1.15 Salix herbacea			2332575537252		
-1.18 Kiaeria starkei			3	3	2323232
-1.19 Pohlia drummondii			2	22	522352
-1.21 Sibbaldia procumbens				2	22
-1.24 Gnaphalium supinum				2235222	2
-1.30 Polytrichum sexangulare		3		53578857	
-1.33 Veronica alpina				2223	2
-1.43 Arenaria biflora				3323	55
-1.44 Sedum alpestre				2	22
-1.45 Cardamine bellidif. alpina				2	2
-1.46 Cerastium cerastioides				3333	

Table 5 - Reciprocal ordering of species and relevés according to decreasing values of the third canonical variate of AOC. Abbreviations for the vegetation types as in Table 1.

Relevé n.	1 2 111122 11 1 21122
	7648940251936141372528530
Vegetation type	CCCCCLLSSEESLLESLESESS
3.98 <i>Saponaria pumila</i>	53
3.78 <i>Pedicularis kernerii</i>	2 2
3.13 <i>Oreochloa disticha</i>	235 2
2.54 <i>Senecio incanobarnioli</i>	332222 2
1.96 <i>Phyteuma globulariifolium</i>	222 2
1.65 <i>Carex curvula</i>	5555553 2 23 2 3
1.58 <i>Juncus jacquinii</i>	2 2
1.54 <i>Loiseleuria procumbens</i>	22 52 3
1.15 <i>Primula glutinosa</i>	323332 32 2 2 2 2
0.75 <i>Cetraria islandica</i>	32 75 3 332
0.74 <i>Agrostis rupestris</i>	23 3332 23222 2 3
0.73 <i>Euphrasia minima</i>	2 2 2 2
0.71 <i>Avenula versicolor</i>	2 2 22 22 2
0.69 <i>Solorina crocea</i>	2 2
0.68 <i>Huperzia selago</i>	22 22 223 2
0.42 <i>Anthelia juratzkana</i>	252 25 3 2
0.41 <i>Leucanthemopsis alpina</i>	22222 52 3 3 22
0.37 <i>Pleurozium schreberi</i>	22 2
0.34 <i>Phyteuma hemisphaericum</i>	2 222 2 2 22 22
0.25 <i>Cladonia arbuscula</i>	35 3 2
0.22 <i>Vaccinium gaultherioides</i>	23 55 33 33 3 33 2
0.05 <i>Salix herbacea</i>	23532 75 5 7 3 252
0.03 <i>Juniperus nana</i>	25 3 3
0 <i>Homogyne alpina</i>	2 35 32233 3333 3 2
-0.25 <i>Pohlia drummondii</i>	2 2 2 5 2 2 253
-0.26 <i>Gnaphalium supinum</i>	2 2 2 35 2 2 2 2
-0.26 <i>Rhododendron ferrugineum</i>	2 53 2 5772 72
-0.29 <i>Sibbaldia procumbens</i>	2 22 2 2
-0.30 <i>Pinus cembra</i>	33 333 31
-0.35 <i>Kiaeria starkei</i>	33 23 2 2 3 23
-0.36 <i>Selaginella selaginoides</i>	2 2 2 2
-0.36 <i>Larix decidua</i>	22 333 2
-0.41 <i>Soldanella pusilla</i>	22 2 33 3 5 25 23
-0.48 <i>Luzula alpino-pilosa</i>	222 2223 5 2 3 7 375
-0.50 <i>Vaccinium vitis-idaea</i>	2 2 3 2
-0.56 <i>Veronica alpina</i>	2 22 3 2 23
-0.60 <i>Sphagnum russowii</i>	2 5 3 33
-0.61 <i>Polytrichum strictum</i>	2 2
-0.76 <i>Sphagnum nemoreum</i>	35
-0.76 <i>Vaccinium myrtilus</i>	2 2 737 72
-0.77 <i>Calliergon sarmentosum</i>	22 2
-0.80 <i>Sphagnum girgensohnii</i>	2 333 2
-0.86 <i>Picea excelsa</i>	233 2
-0.87 <i>Eriophorum vaginatum</i>	23 2 2
-0.87 <i>Calamagrostis villosa</i>	335 3
-0.91 <i>Trichophorum caespitosum</i>	85 2 7 8 5
-0.92 <i>Sphagnum compactum</i>	75 2 8 7 5
-0.94 <i>Gymnocolea inflata</i>	5 5
-0.95 <i>Viola palustris</i>	2 2
-0.95 <i>Polytrichum formosum</i>	222 33
-1.02 <i>Mylia anomala</i>	2 2
-1.09 <i>Carex stellulata</i>	2 2
-1.16 <i>Polytrichum sexangulare</i>	53 5 8 73758
-1.17 <i>Arenaria biflora</i>	3 3 3 2 55
-1.22 <i>Cardamine bellidif. alpina</i>	2 2 23
-1.24 <i>Sedum alpestre</i>	2 2 2 2
-1.28 <i>Cerastium cerastioides</i>	3 3 33

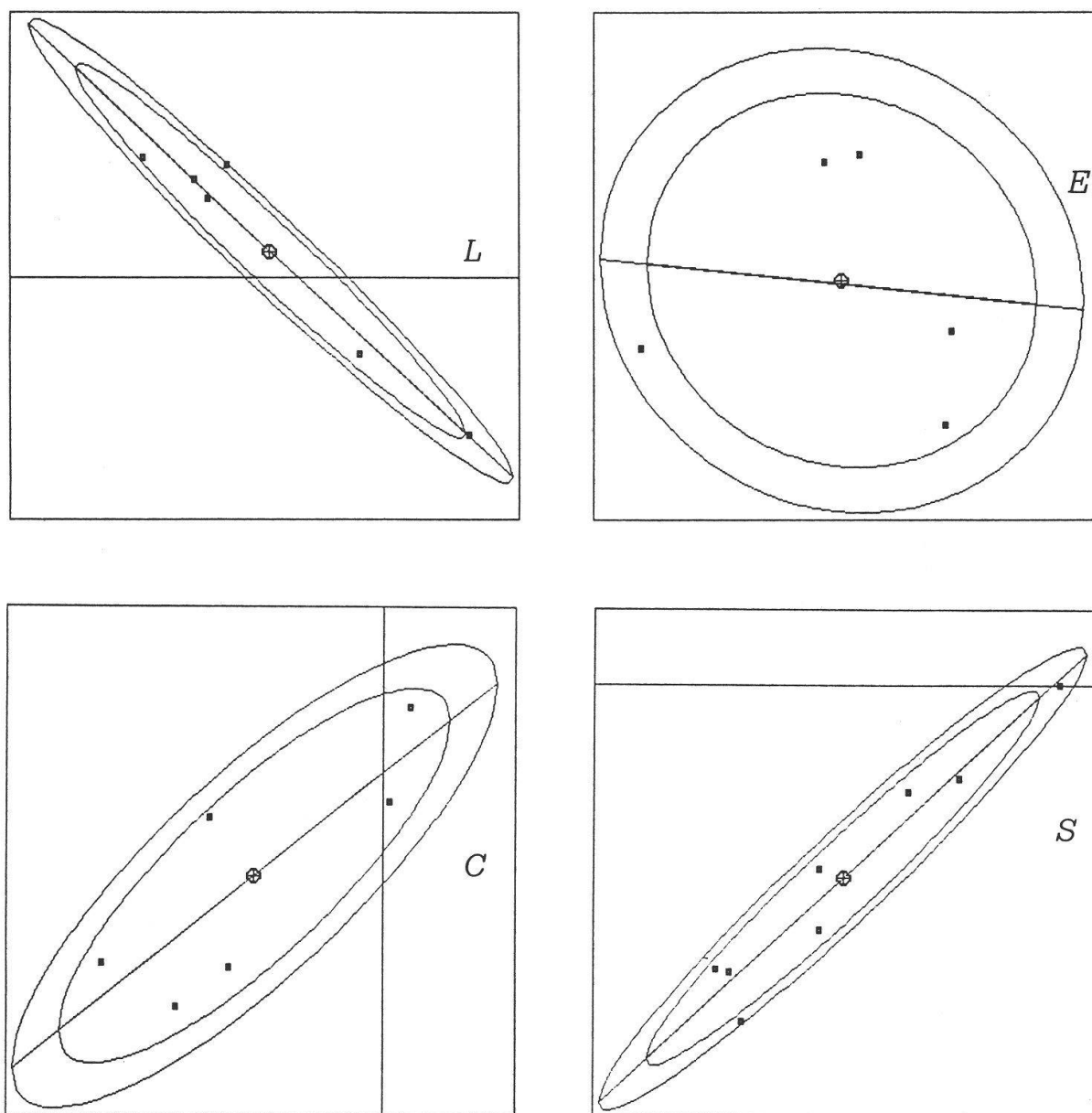


Fig. 4. Ellipses of equal concentration drawn around the barycentres of altitude in the space defined by the I and III canonical variates of AOC. Symbols as in Table 1.

gradient is occupied by some *Salicetea herbaceae* species. The *Vaccinio-Piceetea* species are widely spread along the gradient. Some of them, having positive values, show a clear xerophilous tendency as happens for *Loiseleuria procumbens* and *Cetraria islandica*. Others such as *Calamagrostis villosa* and *Polytrichum formosum* reveal as relatively hygrophilous. The phytosociological grouping as a whole can be therefore considered less informative with respect to the soil-moisture content than to the duration of the vegetative season.

The habitat in the four vegetation types is clearly defined by two variables as simple as altitude and inclination (Table 6). The *Larici-Cembretum* apparently develops at the lowest mean altitude corresponding, on an average, to the treeline in the study area. The *Eriophoro-Trichophoretum*, on the other hand, penetrates into the alpine vegetation

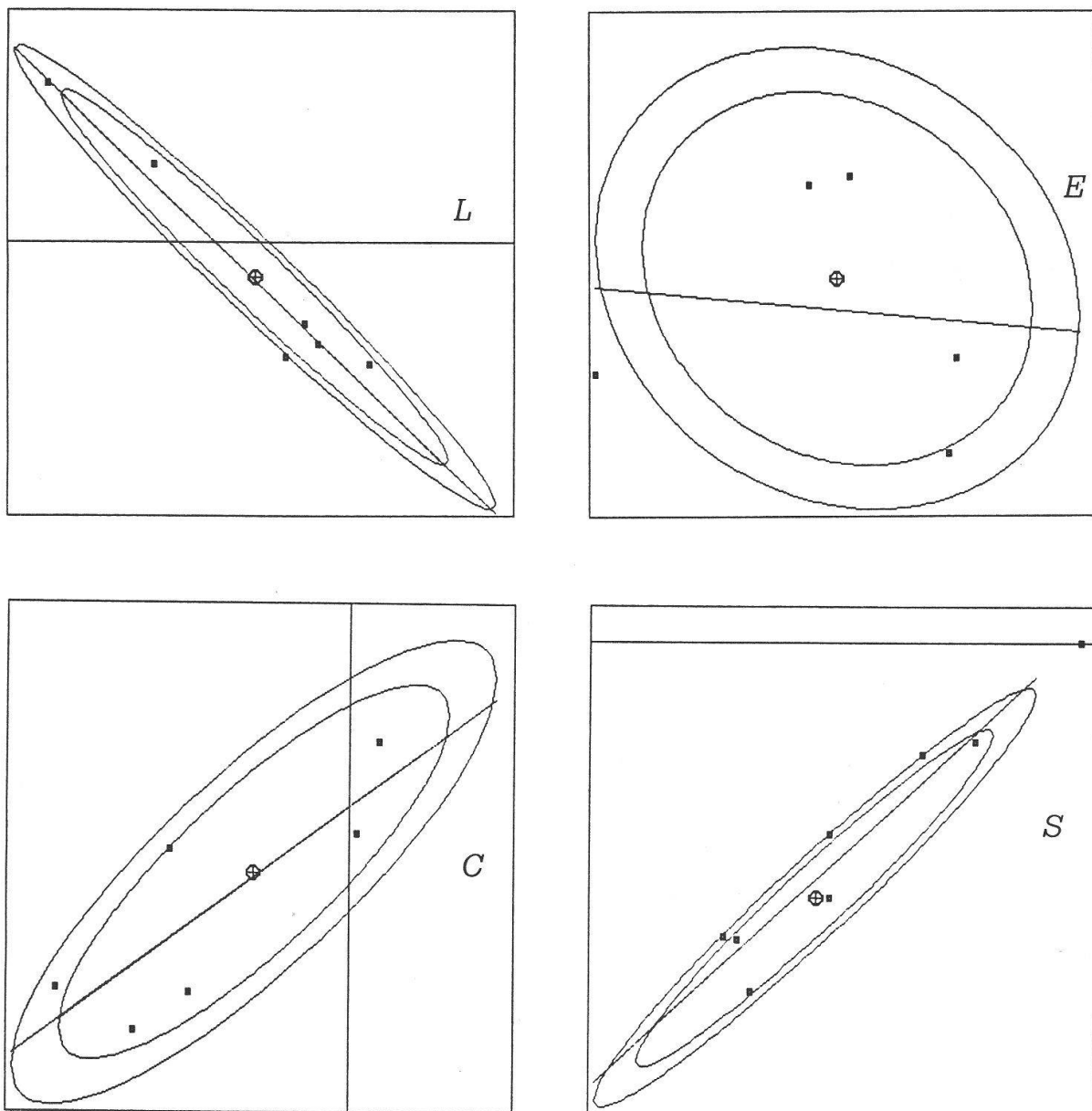


Fig. 5. Ellipses of equal concentration drawn around the barycentres of inclination in the space defined by the I and III canonical variates of AOC. Symbols as in Table 1.

belt, whereas both the *Caricetum curvulae* and the *Salicetum herbaceae* are restricted to the latter. Their stands have correspondingly a higher mean elevation (Table 6). While the *Larici-Cembretum* and the *Caricetum curvulae* are usually located on inclined slopes (mean inclination angle ca. 10°), both the *Eriophoro-Trichophoretum* and the *Salicetum herbaceae* develop on a flat or very little inclined terrain (Table 6). Such a morphology can either favour, at lower elevations, water stagnation and consequently peat accumulation or, at higher elevations, a long duration of snow cover.

The ellipses of equal concentration allow to correlate both abiotic variables with the floristic data, the latter being previously synthesized by the ordinations, and to evaluate how far the environment in the different vegetation types can be regarded as uniform. The habitat is homogeneous in all types as far as altitude is concerned (Fig. 4). When

Table 6 - Means and standard deviations of altitude and inclination measured in the four vegetation types.

	Altitude (m)	Inclination (°)
Larici-Cembretum	2085 ± 92	10.5 ± 2.3
Eriophoro-Trichophoretum	2154 ± 102	2.4 ± 1.8
Caricetum curvulae	2383 ± 72	9.0 ± 3.9
Salicetum herbaceae	2395 ± 76	3.1 ± 3.4

considering inclination, on the other hand, the habitat of the *Caricetum curvulae* is uniform, while those of the *Eriophoro-Trichophoretum*, of the *Larici-Cembretum* and of the *Salicetum herbaceae* are not, since some of the corresponding stands are left outside the ellipses even at the 1%-probability level (Fig. 5).

This means that the habitat conditions determining the distributional pattern of plants within a given elevation range cannot be completely accounted for by inclination. Micromorphology seems to play a role to this regard and may be responsible for a certain amount of within-group floristic variation detected both in the *Larici-Cembretum* and in the *Salicetum herbaceae*. Within the former the convex slopes more exposed to the wind action are invaded by xerophilous species such as *Loiseleuria procumbens* and lichens (Table 1, rel. 1–2). Within the latter association shallow depressions usually corresponding to small faults may hinder snow melting with respect to the surrounding terrain, even if their bottom is somewhat inclined. In such habitats (Table 1, rel. 24–25) the mosses better adapted to a short-lasting vegetative season such as *Polytrichum sexangulare* (Dierssen 1984) tend to outcompete *Salix herbacea* and most of the other vascular species.

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