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Gradient analysis of alpine vegetation in the Lagorai range, Dolomites

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Abstract

Gerdol R. 1990. Gradient analysis of alpine vegetation in the Lagorai range, Dolomites. *Bot. Helv.* 100: 167–181.

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

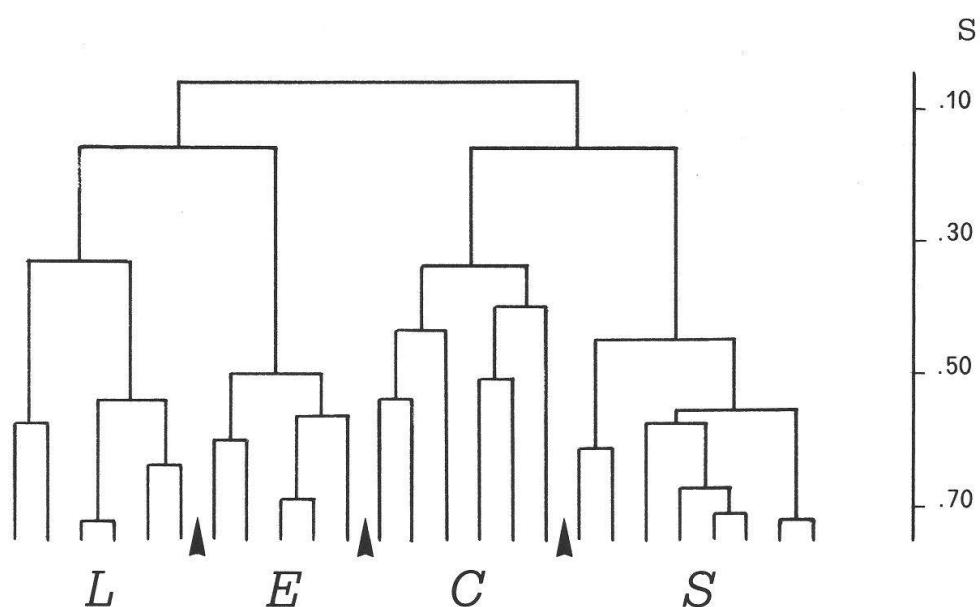


Fig. 1. Dendrogram of classification of the relevés. The sequence of relevés and the symbols for the vegetation types are the same as in Table 1. S=similarity ratio.

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.		11 123456	111111 78901	11222222 234567 89012345

Vaccinio-Piceetea

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

Oxycocco-Sphagnetea and Scheuchzerio-Caricetea fuscae

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

Juncetea trifidi

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

Vegetation type	L	E	C	S
Relevé n.		11 123456	111111 78901	11222222 234567
<u>Salicetea herbaceae</u>				89012345
<i>Soldanella pusilla</i>		2	2 2	33 23553
<i>Salix herbacea</i>			2352 3	75255732
<i>Luzula alpino-pilosa</i>	22 2		22 2	23375375
<i>Leucanthemopsis alpina</i>			2222 2	522233
<i>Cerastium cerastoides</i>				3 333
<i>Arenaria biflora</i>				355332
<i>Veronica alpina</i>		2		222332
<i>Gnaphalium supinum</i>		2 2		352 222
<i>Sedum alpestre</i>				2 22 2
<i>Sibbaldia procumbens</i>		2		22 22
<i>Cardamine bellidifolia alpina</i>				2322
<i>Polytrichum sexangulare</i>	3			53755878
<i>Kiaeria starkei</i>		33		23 22233
<i>Anthelia juratzkana</i>		252		25 32
<i>Pohlia drummondii</i>		2	22	255223
<i>Solorina crocea</i>		2		2
Companions				
<i>Leontodon helveticus</i>	332232	22 22	25 223	3 2
<i>Nardus stricta</i>	32222	35533	2	
<i>Deschampsia caespitosa</i>	2 23	2333	2	2 2
<i>Lophozia wenzelii</i>	2	22	3 3	2 23 2 2
<i>Avenella flexuosa</i>	22233	2 222		
<i>Dicranum scoparium</i>	323333	2	2	
<i>Carex sempervirens</i>	22 23	2 33	2	
<i>Hieracium alpinum</i>	232 2		233 2	
<i>Taraxacum alpinum</i>				22 2222
<i>Potentilla aurea</i>	2222		2	
<i>Soldanella alpina</i>	22 22		2	
<i>Cladonia coccifera</i>	22 2 2			2
<i>Gentiana punctata</i>	2 2		22 2	
<i>Veratrum album</i>	2222			
<i>Festuca rubra</i>	2 2		22	
<i>Solidago virgaurea alpestris</i>	2 222			
<i>Cephalozia bicuspidata</i>	2 2		22	
<i>Anthoxanthum alpinum</i>		22	2	2
<i>Polytrichum piliferum</i>			2 232	
<i>Dicranella subulata</i>				2 2 2 2
<i>Dryopteris carthusiana</i>	232			
<i>Sorbus aucuparia</i>	322			
<i>Diplophyllum taxifolium</i>	222			
<i>Polygonum viviparum</i>			2 3 3	
<i>Luzula sudetica</i>	2		22	
<i>Poa alpina</i>				2 23
<i>Campanula barbata</i>	2 2			
<i>Rhytidiodelphus triquetrus</i>	2 2			
<i>Carex atrata</i>	2 2			
<i>Alnus viridis</i>	52			
<i>Cladonia elongata</i>	22			
<i>Hylocomium splendens</i>	2 2			
<i>Adenostyles alliariae</i>	22			
<i>Oxalis acetosella</i>	22			
<i>Viola biflora</i>	23			
<i>Aulacomnium palustre</i>	2	2		
<i>Paraleucobryum enerve</i>		2		2
<i>Pleurocladula albescens</i>		2		3
<i>Potentilla erecta</i>		2 2		
<i>Scapania helvetica</i>		2		2
<i>Racomitrium sudeticum</i>			2 2	
<i>Dicranum fuscescens</i>			2	2
<i>Oligotrichum hercinicum</i>			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	-

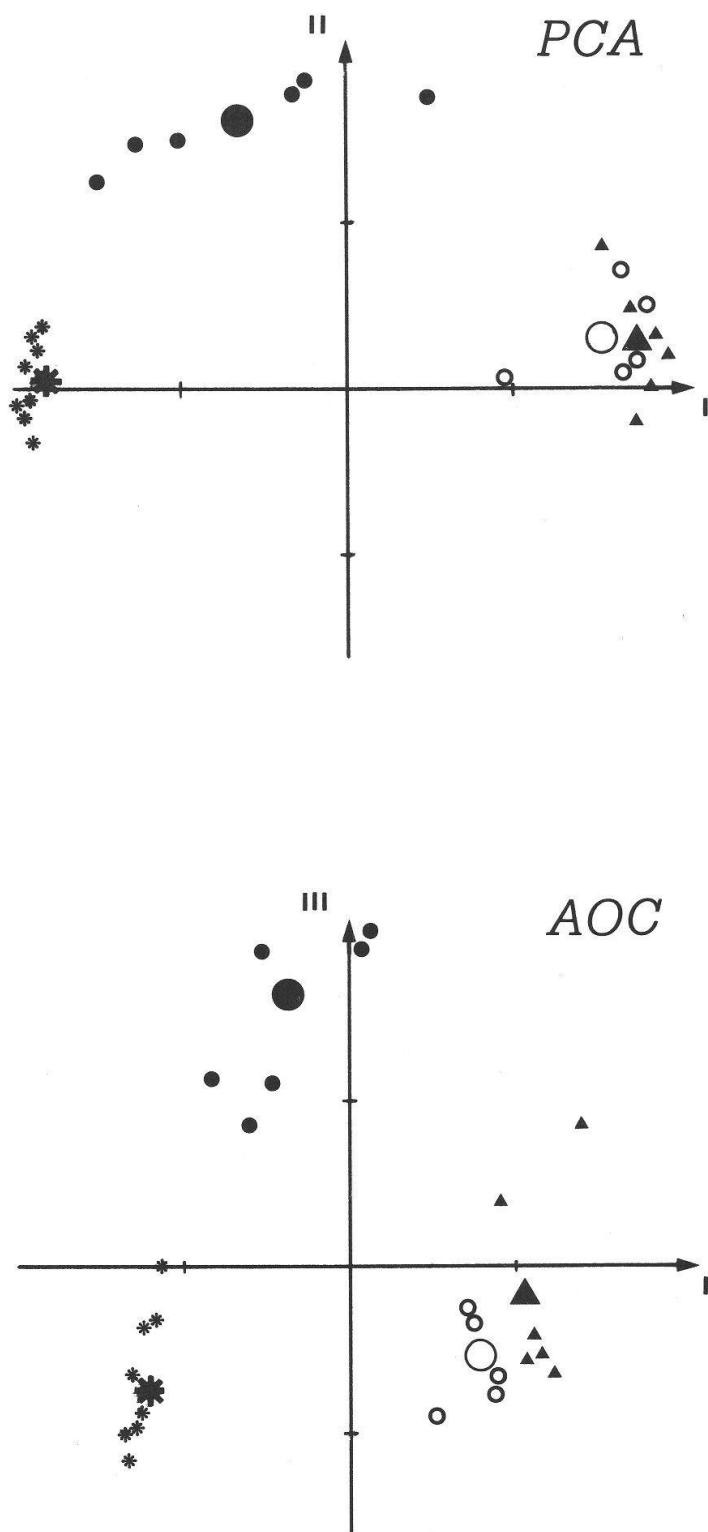


Fig. 2. Ordinations of the relevés by PCA and AOC. The positions of the species in the latter diagram are not indicated. The large symbols indicate the centroids.

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

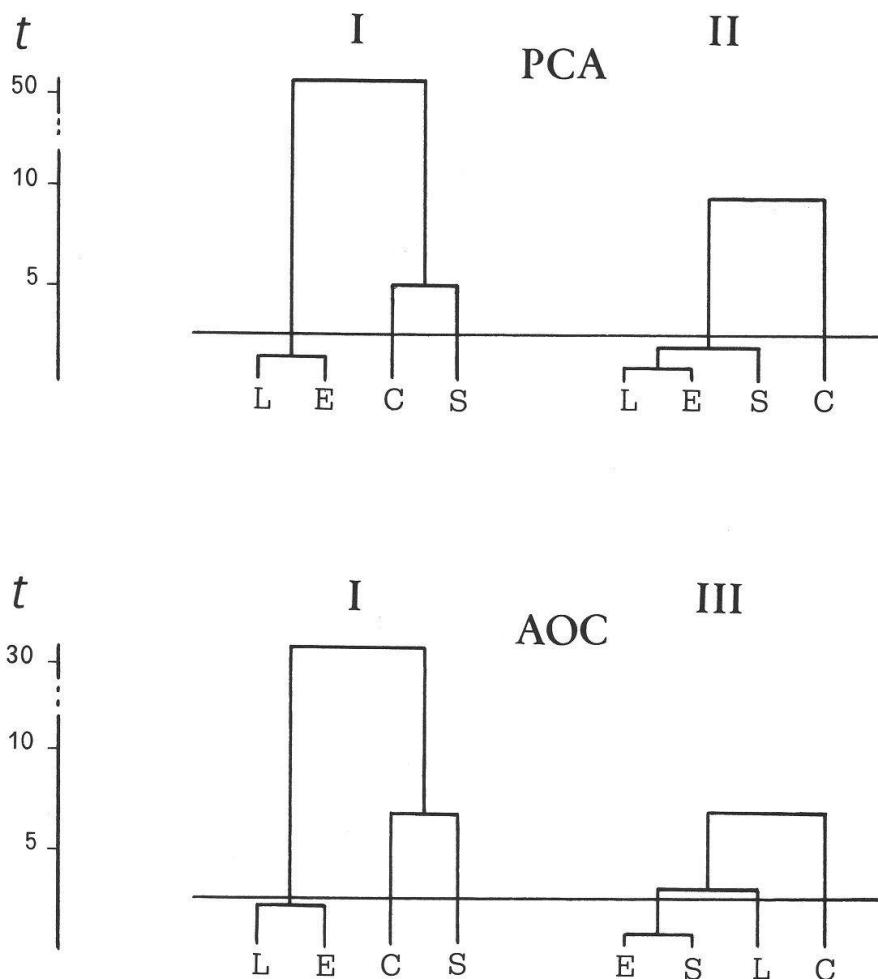


Fig. 3. Classifications of the vegetation types based on the Student's t values (see Table 2). Symbols as in Table 1.

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		LLLLLEEEELECCCCCSSLSSSSSS
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 2
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 2 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 2 2
-0.74 Primula glutinosa		2 3233332222 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 22
-1.11 Soldanella pusilla		2 223335532
-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 22
-1.24 Gnaphalium supinum		2235222 2
-1.30 Polytrichum sexangulare		3 53578857
-1.33 Veronica alpina		2223 2 32
-1.43 Arenaria biflora		3323 55
-1.44 Sedum alpestre		2 22 2
-1.45 Cardamine bellidif. alpina		2 2 32
-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	11	1122	11	1	21122	7648940251936141372528530
Vegetation type	CCCCCCLLSSEESLLSESLESESSS							
3.98 Saponaria pumila	53							
3.78 Pedicularis kernerii	2 2							
3.13 Oreochloa disticha	235	2						
2.54 Senecio incanus carniol.	3322222	2						
1.96 Phyteuma globulariifolium	222							
1.65 Carex curvula	5555553	2	23	2		2	3	
1.58 Juncus jacquinii	2 2							
1.54 Loiseleuria procumbens	22	52	3					
1.15 Primula glutinosa	3233332	32	2		2	2	2	
0.75 Cetraria islandica	32	75	3	332				
0.74 Agrostis rupestris	23	3332	23222	2	3			
0.73 Euphrasia minima	2	2	2			2		
0.71 Avenula versicolor	2	2	22	22		2		
0.69 Solorina crocea	2	2						
0.68 Huperzia selago	22	22		223	2			
0.42 Anthelia juratzkana	252	25	3	2				
0.41 Leucanthemopsis alpina	22222	52	3	3		22		
0.37 Pleurozium schreberi	22			2				
0.34 Phyteuma hemisphaericum	2	222	2	22	22			
0.25 Cladonia arbuscula	35		3	2				
0.22 Vaccinium gaultherioides	23	55	33	33	3	33	2	
0.05 Salix herbacea	23532	75	5	7	3	252		
0.03 Juniperus nana	25		3	3				
0 Homogyne alpina	2	35	32233	3333	3	32		
-0.25 Pohlia drummondii	22	2	5	2	2	253		
-0.26 Gnaphalium supinum	22	2	35	2	2	2	2	
-0.26 Rhododendron ferrugineum	2	53	2	5772	72			
-0.29 Sibbaldia procumbens	2	22		2	2			
-0.30 Pinus cembra	33		333	31				
-0.35 Kiaeria starkei	33	23	2	2	3	23		
-0.36 Selaginella selaginoides	2	2		2	2			
-0.36 Larix decidua	22		333	2				
-0.41 Soldanella pusilla	22	2	33	3	5	25	23	
-0.48 Luzula alpino-pilosa	222	2223	5	2	3	7	375	
-0.50 Vaccinium vitis-idaea	2		3	2				
-0.56 Veronica alpina	2	22	3	2		23		
-0.60 Sphagnum russowii	2	5	3	33				
-0.61 Polytrichum strictum	2	2						
-0.76 Sphagnum nemoreum			35					
-0.76 Vaccinium myrtillus	2	2	737	72				
-0.77 Calliergon sarmentosum	22				2			
-0.80 Sphagnum girgensohnii	2	333	2					
-0.86 Picea excelsa	233		2					
-0.87 Eriophorum vaginatum	23			2	2			
-0.87 Calamagrostis villosa			335	3				
-0.91 Trichophorum caespitosum	85	2	7	8	5			
-0.92 Sphagnum compactum	75	2	8	7	5			
-0.94 Gymnocolea inflata	5				5			
-0.95 Viola palustris	2				2			
-0.95 Polytrichum formosum			222	33				
-1.02 Mylia anomala		2		2				
-1.09 Carex stellulata			2	2				
-1.16 Polytrichum sexangulare	53	5	8		73758			
-1.17 Arenaria biflora	3	3	3	2	55			
-1.22 Cardamine bellidif. alpina	2		2		23			
-1.24 Sedum alpestre	2		2		2	2		
-1.28 Cerastium cerastiooides			3	3	33			

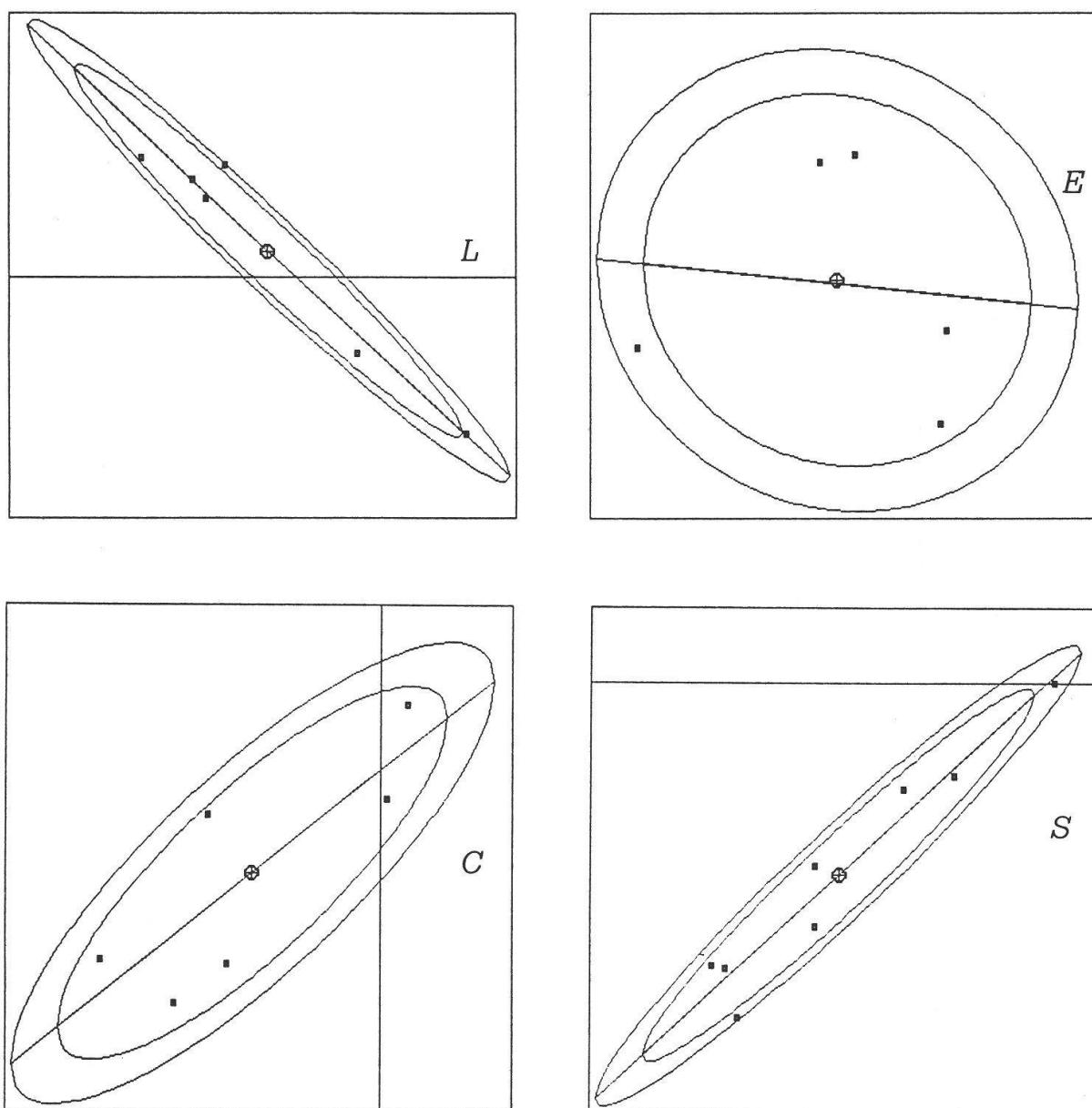


Fig. 4. Ellipses of equal concentration drawn around the barycentres of altitude in the space defined by the I and III canonical variates of AOC. Symbols as in Table 1.

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

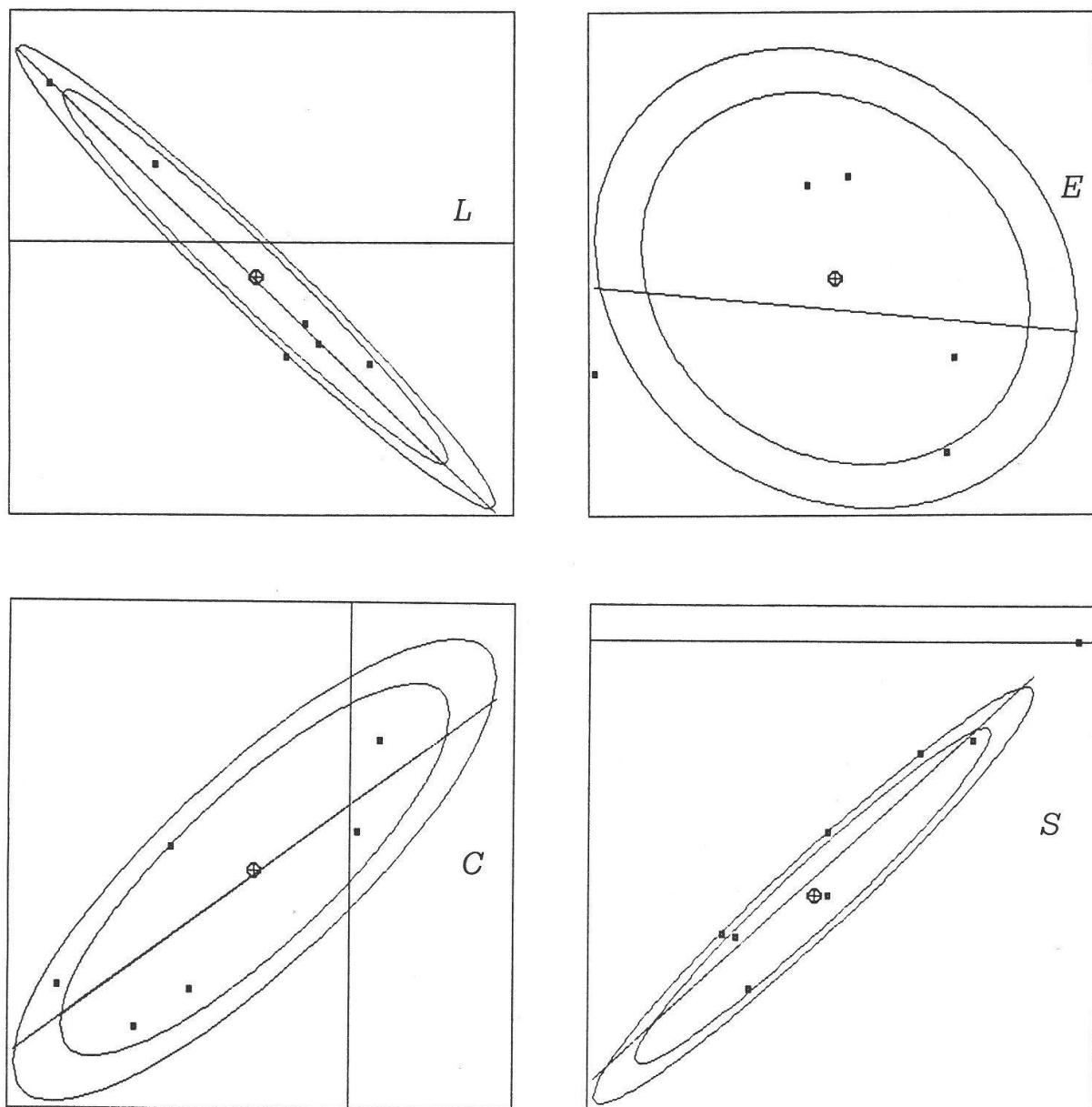


Fig. 5. Ellipses of equal concentration drawn around the barycentres of inclination in the space defined by the I and III canonical variates of AOC. Symbols as in Table 1.

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 ($^{\circ}$)
Larici-Cembretum	2085 \pm 92	10.5 \pm 2.3
Eriophoro-Trichophoretum	2154 \pm 102	2.4 \pm 1.8
Caricetum curvulae	2383 \pm 72	9.0 \pm 3.9
Salicetum herbaceae	2395 \pm 76	3.1 \pm 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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