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Chorological and ecological information as basis for the syntaxonomy of beech forests in Italy

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Introduction

The beech forests are widespread over most of Europe, from south Spain, Italy and Greece to the Scandinavian region. These forests are characterized by the dominance of *Fagus sylvatica* and the occurrence of a lot of herbaceous character species so that as a first approximation they seem to form a very natural group. Nevertheless up to now the syntaxonomy ob beech forests, at least for vegetation occurring in central and southern Italy, Sicily and Corsica, is still unclear.

For Europe a chorological classification, chiefly developed by SOO (1964), is mainly used, with the following syntaxa:

Scillo-Fagion	Iberian Peninsula
Fagion austro-italicum	Italian Peninsula, Sicily, Corse
Fagion illyricum	Balkans
Fagion dacicum	Carpathians
Fagion orientalis	from Thracia to Caucasus
Fagion medio-europaeum	Central and North Europe
Eu-Fagenion	mesophilous
Luzulo-Fagenion	acidophilous
Galio-Abietenion	montane
Cephalanthero-Fagenion	thermophilous

The general criticism to this classification is that the south European alliances with local character are well identified, whereas the widespread allicance of Central and northern Europe appears from the floristic point of view as an impoverished aspect. In reality this is the optimal growing zone for the beech forest. As a matter of fact the southern endemics occur mostly in pioneer stages and become rarer and rarer in ripe aspects of the forest, even in the southern parts of Europe. This contradiction between floristic optimum in the south and ecological optimum in Central and Northern Europe is a first difficulty. In addition the information we can gain from such a classification is very limited: if a beech forest is e.g. in Spain, then the forest belongs to the Spanish syntaxon, a form of circular (tautologic) sentence.

In Italy (including Corsica) the beech forest reaches its southern boundary and occurs only in montane habitats (mostly between 1500 and 2000 msm). The Italian endemics characterizing the *Fagion austro-italicum* are relatively few and scattered through the southern portion of the peninsula: whether the beech forests occurring further north belong to the same allicance or to the central European one is not clear. Even in southern Italy and islands riper forest types are hardly distinguishable from middle European ones, whereas character species of the endemic alliance are widespread in pioneer aspects.

The present investigation is an attempt to classify, on the basis of the floristic information, the beech forests occurring in Italy and in particular to ascertain the relationships between *Fagion medio-europaeum* and *Fagion austro-italicum* in this region.

Material and methods

A large amount of information on the floristic composition of beech forests is presently available in form of phytosociological relevés. The published vegetation tables include surely some 10–20000 relevés scattered over the entire range of *Fagus sylvatica* in Europe. In many cases the

investigated areas are overlapping. For these reasons this information can be regarded as highly redundant.

In the present investigation 35 phytosociological tables have been selected on the basis of 3 conditions: representativity of all geographical areas where the beech forests occur, representativity of the most important ecological types and availability of geographical and topographical information. From each table a triplet of relevés has been randomly picked; whenever the original table was divided into different subassociations the three relevés represented only the „typical" (i.e. the most mesophilous and widespread) aspect.

The sample of 105 relevés represents the matrix used for data analysis. About 350 species have been recorded but all rare elements (presence under 5 %) not belonging to the character species were excluded. The final matrix consists of 105 columns and 241 rows.

Assuming that the relevés of beech forests may be 10–20000, this sample represents only 0.5–1 % of the gross total. Nevertheless the sample can be regarded as significant: in fact all major types of beech forest and all character species mentioned by the authors are included.

The data analysis was carried on according to the procedures discussed by CAMIZ (1988, 1989), through WILDI and ORLÓCI (1988) MULVA-4 package. Therefore the computations were performed as follows:

1) Withdrawal of species present in only one relevé;
2) Computation of two resemblance matrices based on presence-absence data, more suitable for both literature and forest data: for the species, each entry corresponds to the number of relevés where two species are co–occurrent (non-centered non-standardised sum of squares); for the relevés, each entry corresponds to the number of species present in either relevé (euclidean distance);
3) Hierarchical classification, based on complete linkage (ANDERBERG, 1973) for species and on WARD'S (1963) minimum variance criterion for relevés;
4) Choice of dendrograms cutpoints based on the major length of the branches for the relevés (corresponding to 4, 5, 8 and 11 groups), and on the last fusion at 1. level for the species (corresponding to 36 groups, the following fusions having all zero level).
5) Analysis of concentration (FEOLI and ORLOCI, 1979) of the four possible classifications;
6) Hypothesis of three likely gradients, based on the high value of the first three canonical correlations (.70, .60, .59);
7) Correspondence analysis (BENZÉCRI 1973–82, HILL 1973, ORLÓCI 1978) of the raw data table;
8) Hierarchical classification of both relevés and species, based on euclidean distance in the space of the first three extracted factors;
9) Choice of dendrogram cutpoints, as above, corresponding to 4, 6 and 12 groups of relevés, and 7, 9, and 22 groups of species;
10) Analysis of concentration of 4x7, 6x9 and 12x22 classifications;
11) Rearrangement of data table according to 12x22 classification, as above;
12) Comparison of the 11x36 and 12x22 classifications, through analysis of concentration.

The choice of a high number of groups in the classifications is useful for an accurate structuration: actually, it may be sufficient, for the discussion of the results, to limit the attention to the two major gradients and to few (4–6) groups.

The list of the 35 tables considered is given in appendix.

Results

The results of data analysis concern two classifications of relevés, obtained using the different procedures described above: a) on the basis of the complete set of species (steps 3–4) and b) on the basis of the relevés coordinates on the first 3 factors of correspondence analysis (steps 8–9), and ordination both of relevés and species (step 7).

From each table only three relevés have been processed and it may be expected that each group of 3 relevés with common origin will reveal a high internal affinity. In fact in an large ma-

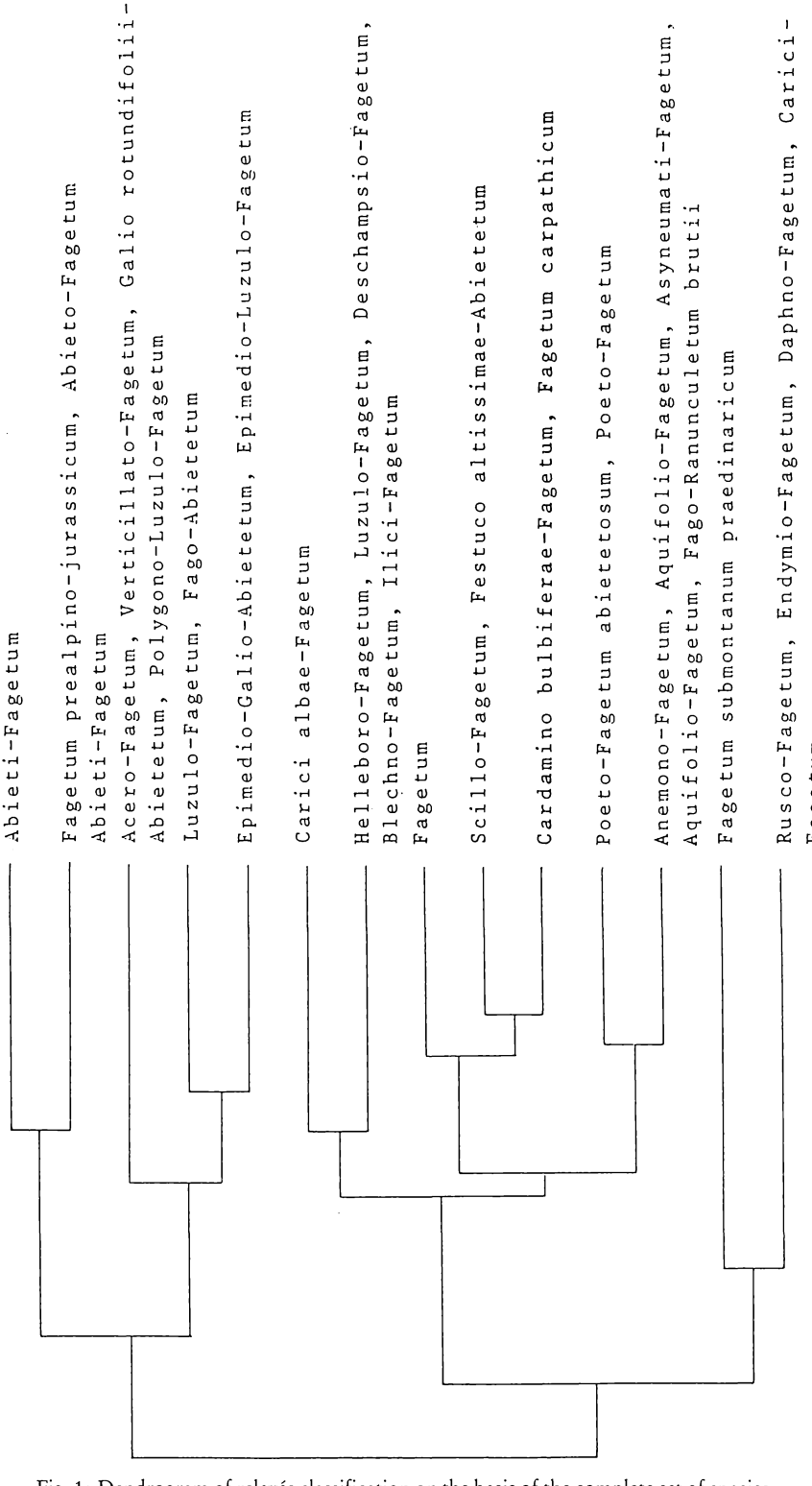

Fig. 1: Dendrogram of relevés classification on the basis of the complete set of species.

jority of cases the 3 relevés derived from a single table have been classified together by the clustering procedures. With minor exceptions, it is consequently possible to simplify the dendrogram indicating only the original tables for each triplet of relevés.

Classification of relevés (a) is summarized in fig. 1. The dendrogram includes 11 clusters, each corresponding to one or more (up to 5) association tables:

1) only relevés of *Abieti-Fagetum* from mountains at the boundary between South Germany and Austria;
2) montane beech-forests from Switzerland and Czecoslovakia;
3) montane beech-forests from Slovakia and Slovenija;
4) acidophilous forests from Bosnia;
5) id. from Slovenija;
6) one type of thermophilous forest from Slovakia;
7) forests from N. Spain, costal districts in France and Norway, all having ± oceanic caracter;
8) very heterogeneous: tables from the Pyrenées, Karawanken, Rheinland and Carpathians;
9) all data from Italy and surrounding islands, divided in two subclusters for Corsica and for Italy with Sicily;
10) a forest type from Slovenija, probably related to the *Carpinion* alliance;
11) a group of thermophilous aspects from Western France and Belgium.

In general the dendrogram shows good resolutions for such types (e.g. Italian forests or *Abieti-Fagetum* type) which are well represented in the matrix, whereas less represented types sometimes appear mixed together.

Classification of relevés (b) is summarized in fig. 2. The simplified dendrogram includes 12 clusters, which can be arranged into 4 major groups:

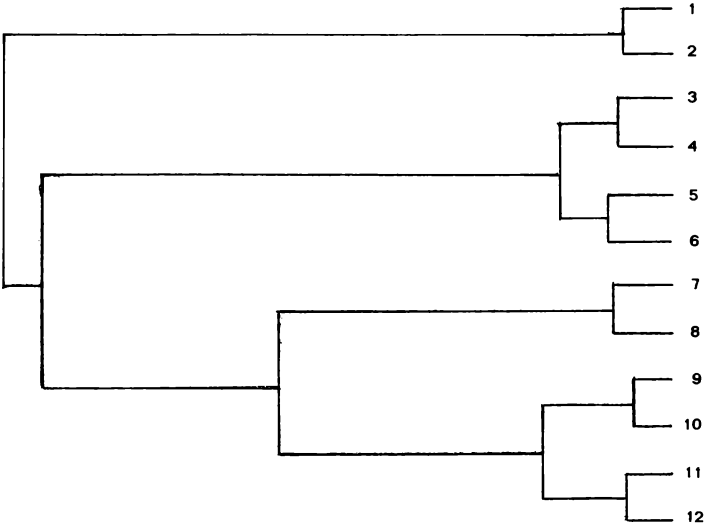

Fig. 2: Dendrogram of relevés classification on the basis of the coordinates on the first 3 factors of correspondence analysis.

1) one type of thermophilous of Slovakia, divided into two groups, whose position is evidently apart from the other on the first correspondence analysis axis;

2) all data from Italy and surronding islands excluded two relevés from Monti della Laga, divided into four subgroups, corresponding to Southern Italy and a relevé from Monti della Laga, Southern Italy and Monte Pollino, Corse, and Sicily, distributed all in the negative side of the second axis and the positive side of the third;

3) a group formed mostly by relevés of acidophilous forests from Bosnia and Slovenija, montane beech-forests from Slovakia and Slovenija (one subgroup), the other subgroup inclu-

ding also forests from Belgium and Norway, having oceanic character: the relevés are distributed on the first quadrant of the plane of the second and third axis;

4) a very heterogeneous group, subdivided, according to their position along the third axis, into four subgroups: the first one consists of relevés from Navarra, French atlantic coast and Belgium; the second one includes six relevés from Belgium, Jura and Slovenija, probably related to the *Carpinion* allicance; the third group is composed of relevés from Karawanken, french atlantic coast, Navarra and two others; the last one is highly diversified grouping all the rest.

The comparison of classifications a) and b) performed through analysis of concentration (step 12) confirms the accordance of both. The data of tables from Italy and Islands are in both cases distinct from all others.

The ordination of relevés on the x and y axes is of reduced interest because of a highly divergent table (the thermophilous *Carici albae-Fagetum* from Slovakia). The scattering is not much better on the x and z axes. On the contrary the ordination on the y and z axes enables to recognize many different groups (fig. 3a). On the negative side of axis y and positive side of axis z all data from Italy, Sicily and Corsica are scattered. On the positive side of y there are the West European tables and others from the Carpathians and Alps of the *Abieti-Fagetum* type. On the negative values of z are the thermophilous forests of the *Cephalanthera* type and finally all tables of mesophilous forests are concentrated around the origin of the axis.

On the species diagram on axes y and z some most significant species have been plotted: *Luzula albida* (fig. 3b) as acidophilous character species, *Lonicera nigra* (fig. 3c) as a montane element and *Hedera helix* (fig. 3d) as indicator of warm and oceanic conditions. Each of these indicators seems to occupy a distinct part of the diagram.

Species ordination (fig. 4) resembles that of relevés, but offering a very complicate picture: in fact 241 species are present and overlapping is frequent so that it is even difficult to distinguish groups. Fig. 4 gives a simplified account showing only the location of a reduced group of character species; also in this case the distribution along the y and z axes was selected. The general patterns resemble those of the relevés ordination: species from the Italian beech forests on the upper side to the left, montane species on the upper right side, thermophilous species on the bottom and the character species of the mesophilous forest near the axes origin.

In conclusion, on the basis of classification and ordination, it is possible to detect a number of different groups of beech forests and to visualize the relationships among them.

Discussion

The ordination of relevés and species gives a similar scattering for both as shown above (cfr. figs. 3a and 4). Some considerations are possible concerning the interpretation of the ecological meaning of axes y and z. The first of the three extremes of the scattering picture includes species from Italy which are thermophilous and acidophilous at the same time. On the second extreme there are indicators of acidity and cool conditions. At the bottom are basiphilous species and finally the mesic ones occupy the centre of the scattering area. It is possible to indicate – at least as a hypothesis – that axis y corresponds to a thermic gradient from a maximum of warmth in the negative side to cooler conditions in the positive and axis z reflects an acidity gradient with maximal values on the positive side.

Soil acidification is caused by conditions of high rainfall and low evaporation and possibly what is identified as an acidity gradient can be also regarded as a humidity gradient, maximal on the positive side of axis z.

The selection of character species is summarized in fig. 4.

The elaboration of polyploidy we presented at the IAVS symposium on the syntaxonomy of beech forests held in 1961 but never published (cfr. TÜXEN 1960), indicated that the southern aspects of this vegetation have the character of pre-glacial relicts whereas the forests of Central and northern Europe are post-glacial i.e. more recent. Apparently the beech forests (or at least some elemens of them) already existed in Europe before the ice time. During the cold phases this type of vegetation remained confined in distinct areas of southern Europe and there some species underwent an independent evolution: this hypothesis explains the occurrence of local

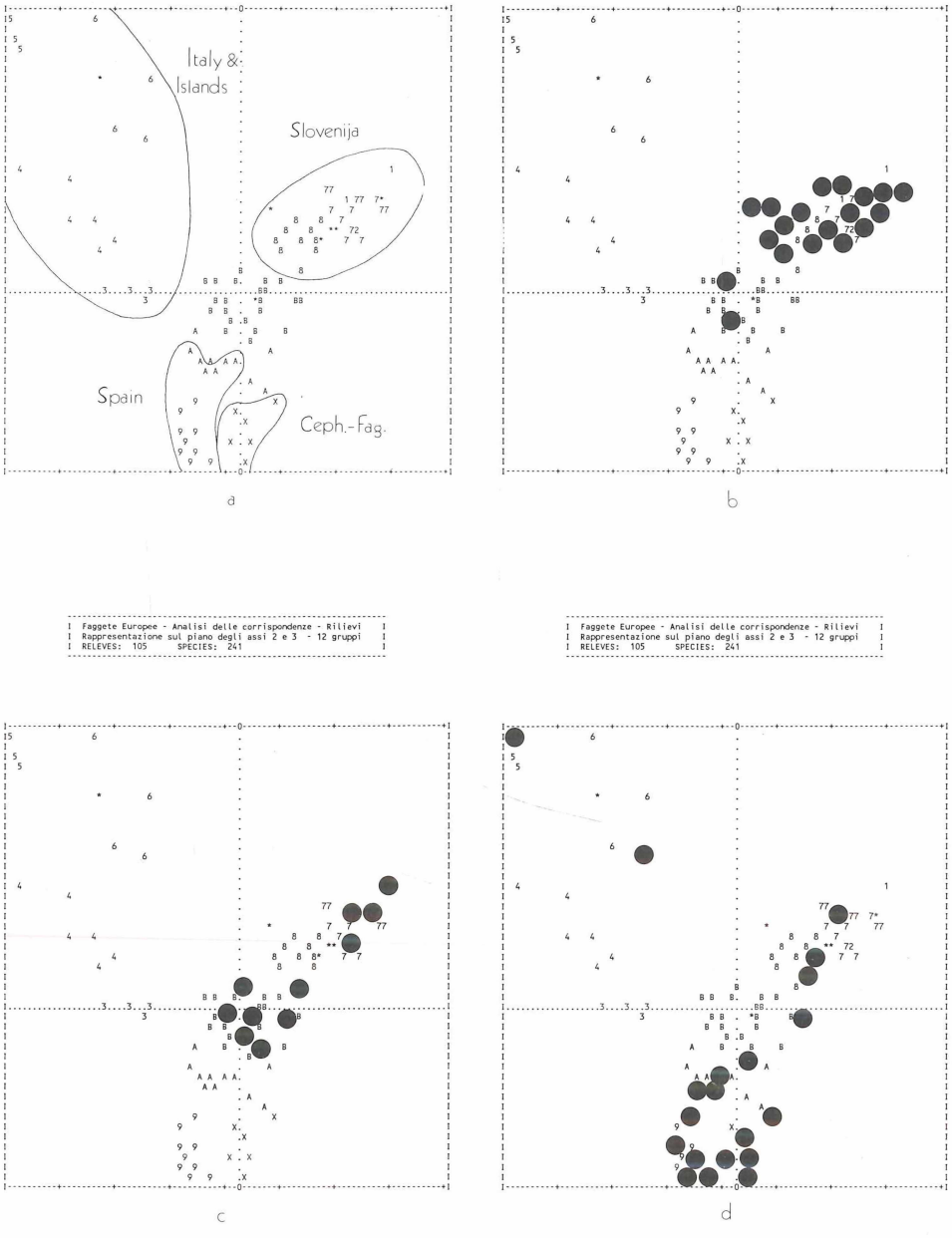

Fig. 3: Scatter diagram of relevés on axes y and z of correspondence analysis. a) groups distribution; b) distribution of relevés with *Luzula albida;* c) id. *Lonicera nigra;* d) id. *Hedera helix.*

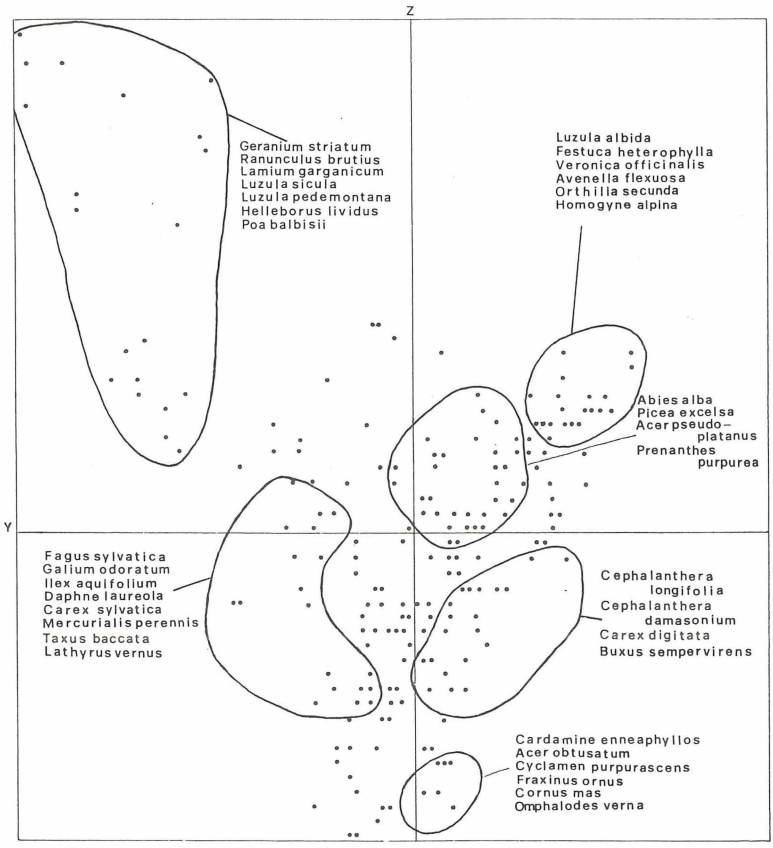

Fig. 4: Scatter diagram of species on axes y and z of correspondence analysis.

endemics in the beech forests of southern Europe. The beech vegetation advanced into Central Europe only very recently (about 10000 years ago) and there was no time for the appearance of endemics in this area.

As a matter of fact,in the beech forest there are some floristic elements which seem to have spread relatively recently and others on the contrary with a relictic character. Species of recent diffusion are in general widespread over areas covered by the quaternary ice sheet, e.g. *Fagus sylvatica* and the most diffused character species of the different types of *Fageta.* On the other side, the evergreen species like *Taxus baccata, Ilex aquifolim, Daphne laureola* appear to be remnants of a late-tertiary community with evergreen and deciduous elements mixed together. In the correspondence analysis on y and z axes such evergreen species appear closely bound with *Fagus* and other character species. It seems that despite of the difference in leaf duration and geographical distribution, *Fagus sylvatica* was not able to occupy a different ecological niche.

The symphenological investigation of the beech forest (LAUSI & PIGNATTI, 1972) prooved that each sub-alliance presents well-characterized phenological patterns while the regional classification appears almost meaningless as to phenology of the beech forests. Consequently, the following sub-alliances can be distinguished in the *Fagion medio-europaeum:*

Eu Fagenion – mesic
Cephalanthero-Fagenion – thermophilous
Luzulo-Fagenion – acidophilous
Galio-Abientenion – montane

The beech forest can be regarded as a system with an optimal space and increasing constraints in the periphery. Consequently the central space has more degrees of freedom and can

diversify in many ecological syntaxa (mostly considered as suballiances). At the same time the periphery has geographical as well as ecological meaning: peripheral are the beech forests of the mediterranean mountains, the thermophilous beech forests on limestone and the strong acidophilous ones. Under such conditions the beech forest is at the margin of survival and cannot have an ecological diversification like in the center of the system.

Conclusions

The data analysis of a table extracted from 35 vegetation tables shows that the relevés deriving from the Italian Peninsula, Sicily and Corsica occupy a distinct space in the ordination diagram. In consequence, the opinion of SOO that all associations from these regions belong to the endemic alliance Fagion austro-italicum seems supported.

In a more general sense it seems that all mediterranean-montane alliances have a floristic identity; the alliance *Fagion medio-europaeum* corresponds to the ecological optimum of beech forest and is poor on character species but presents some suballiances which can be ordered along ecological gradients. The results are not conclusive because the present investigation was chiefly oriented on the vegetation of the Italian area and only few data from central Europe have been treated. Consequently a parallel investigation centered on the diversity of beech forests in central Europe seems very promising.

Summary

Relevés from 35 phytosociological tables of beech forests from many proveniences in Europe (but with prevalence of material from Central and South Italy, Sicily and Corsica) have been submitted to multivariate analysis. For each table only a sample of 3 relevés was considered i.e. a total of 105 relevés with 241 species.

The results indicate that relevés of italian provenience (and from the islands) occupy a distinct space without overlapping with relevés from other proveniences; this supports the opinion of SOO, who included the beech forests of the italian area in an endemic alliance.

Zusammenfassung

Aufnahmen aus 35 pflanzensoziologischen Tabellen von Buchenwäldern aus verschiedenen Teilen Europas (allerdings überwiegend aus Mittel- und Süditalien, Sizilien und Korsika) wurden mit multivariaten Analyse behandelt. Für jede Tabelle wurden nur 3 Aufnahmen bearbeitet, d.h. insgesamt 105 Aufn. mit 241 Arten.

Die Ergebnisse zeigen die Aufnahmen aus Italien (inkl. der Inseln) über eine Fläche verteilt, die sich nicht mit den Aufnahmen aus anderen Gebieten überschneiden; die Auffassung von SOO, der die italienischen Buchenwälder in einem endemischen Verband eingliedert, wird bestätigt.

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