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Use of the Multi-Response Permutation Procedure and Indicator Species Value for the statistical classification of the gypsicolous Iberian scrub communities

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Abstract

MOTA, J. F., J. A. GARRIDO-BECERRA, F. J. PÉREZ-GARCÍA, A. J. SOLA & F. VALLE (2010). Use of the Multi-Response Permutation Procedure and Indicator Species Analysis for the statistical classification of the gypsicolous Iberian scrub communities. *Candollea* 65: 117-134. In English, English and French abstracts.

The Iberian gypsophilous scrub communities, belonging to the phytosociological order *Gypsophiletalia* (Bellot 1952) Bellot & Rivas Goday 1957, are considered as priority ecosystems for conservation because of their richness in endemic and s tenoecious species. Six complete revisions and a number of partial revisions of *Gypsophiletalia* have been published up to now, producing over 100 phytosociological tables and about 800 vegetation relevés. This large amount of information has been analysed here to reevaluate this phytosociological order. The statistical techniques of Multi-Response Permutation Procedure (MRPP) and Indicator Species Value (IV) have been carried out on this data set and the results have been compared with data obtained from cluster analysis. Our results reveal the inconsistency and lack of objectivity of some of the previous syntaxonomical typologies. We conclude that objective classifications must be based on clearly defined criteria easy to replicate in following the same procedures. Both IV and MRPP have proved useful techniques, not only for the clarification of the diagnostic potential value of taxa, but also for the production of objective syntaxonomical typologies.

Key-words

Spain – Phytosociology – Gypsophilous scrub communities – Indicator Species Value (IV) – Multi-Response Permutation Procedure (MRPP) – Cluster analysis – Conservation

Résumé

MOTA, J. F., J. A. GARRIDO-BECERRA, F. J. PÉREZ-GARCÍA, A. J. SOLA & F. VALLE (2010). Utilisation de la Procédure de Permutation de Multi-Réponse et de la Valeur Indicatrice Spécifique pour la classification statistique des communautés gypseuses végétales broussailleuses. *Candollea* 65: 117-134. En anglais, résumés anglais et français.

Les communautés gypseuses végétales appartenant à l'ordre *Gypsophiletalia* (Bellot 1952) Bellot & Rivas Goday 1957 sont considérées comme des écosystèmes prioritaires en matière de conservation en raison de leur grande richesse d'espèces endémiques et sténooeciques. Six révisions complètes et plusieurs révisions partielles de *Gypsophiletalia* ont été publiées jusqu'à aujourd'hui, produisant quelques 100 tables phytosociologiques et 800 relevés de végétation. Cette grande quantité d'informations a été analysée ici pour réévaluer la pertinence de cet ordre phytosociologique. Des tests statistiques tels que la Procédure de Permutation de Multi-Réponse (PPMR) et la Valeur Indicatrice Spécifique (VIS) ont été réalisés sur ces données et les résultats produits ont été comparés à ceux obtenus d'une analyse par regroupements. Nos résultats montrent l'inconsistence et le manque d'objectivité des typologies syntaxonomiques précédentes. Nous en concluons que les classifications objectives doivent être basées sur des critères clairement définis et faciles à reproduire en suivant les mêmes procédures. Les PPMR et VIS sont des techniques utiles à ce titre, non seulement pour diagnostiquer les valeurs des taxa caractéristiques des typologies syntaxonomiques, mais aussi pour fonder objectivement ces dernières.

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Introduction

Andrea Cesalpino was the first person to record the occurrence of endemic species on Italian serpentines back in 1583. In particular, he mentioned *Alyssum bertolonii* Desv., nowadays well known as a nickel accumulating species (Brooks & Radford, 1978). Kruckeberg (2002), currently one of the most eminent authorities on the interaction between plants and particular geological substrates, considers Thurmann and Unger as the pioneers in this field. According to Kruckeberg, it is to Unger (1836) that we must turn for a full-blown conceptualization of the geology-plant connection.

In the early 20th century, the contributions of Schimper (1903) are of interest since, according to McDougall (1949), Schimper's second law states that "the distribution of plants within a restricted area is mostly determined by edaphic factors". For Kruckeberg (1986), the geoedaphic influences (the reciprocal interactions between topography or landforms, lithology and soils with floras and vegetation) is inextricably associated with the contributions of the great plant ecologists of the 20th century, such as Cowles, Clements, Gleason, Warming or Braun-Blanquet.

The European followers of the Clementsian school considered the relationships between plants and unusual geological substrates as very significant. The leading figure of this approach was the phytosociologist Braun-Blanquet, founder of the Zurich-Montpellier school. Since the Braun-Blanquetian method is based on the floristic composition of the communities, not surprisingly the number of associations tends to multiply on rich geological landscapes as a result of the local diversification of plant life which presents extremely restricted endemic species. These endemic species are the epitome of what the phytosociological method, i.e. the Braun-Blanquet approach, calls the characteristic species (Braun-Blanquet, 1932; Braun-Blanquet & al., 1951; Rivas-Martínez & al., 2002), the character species (Müller-Dombois & Ellenberg, 1974) or, in a broader sense, diagnostic species (Westhoff & van der Maarel, 1973; Bruelheide, 2000). They are also necessary for distinguishing one association from another.

In Spain, Huguet del Villar (1925) mentioned, as a prelude to the enormous amount of phytosociological research in the 50's, the "associations" between *Gypsophila struthium* Loeffler and *Lepidium subulatum* L. This geobotanical research gathered momentum with the proposal of the order *Gypsophiletalia* (Bellot, 1952), encompassing the thickets on gypsum outcrops (these outcrops are known as "aljezares" in Spain). New associations were eventually ascribed to the order (Rivas-Goday & al., 1956; Braun-Blanquet & Bolós, 1957; Rivas-Goday & Rigual-Magallon, 1958; Rivas-Goday & Esteve-Chueca, 1968), and finally, in 1970, the first revision of the order was published (Rivas-Martínez & Costa, 1970). From that moment, thickets on gypsum soils have been preferred issues for Spanish phytosociologists (see Appendix 1 for the phytosociological conspectus), who have also dealt with the therophytic vegetation (Izco, 1974, 1976; Izco & al., 1986; Alcaraz & al., 1998; Peñas & al., 1999) and the cryptogamic communities and flora associated with these outcrops (e.g. Llimona, 1974; Crespo & Barreno, 1975; Tarazona & al., 1980).

According to the recently published syntaxonomical checklist for Spain and Portugal (Rivas-Martínez & al., 2001), the *Gypsophiletalia* order includes some twenty associations. These associations result from the recognition of some thirty characteristic species as defined by Rivas-Martínez & al. (2002). However, apart from this checklist, the thickets on gypsum soils have recently been thoroughly revised. Four of these revisions coincide completely in the recognition of 16 associations in all the cases (Diez-Garretas & al., 1996, 1999; Loidi & Costa, 1997; Mota, 2001), but on the other hand they maintain a scheme very different from the one proposed both in the checklist (Rivas-Martínez & al., 2001) and the immediately preceding list (Rivas-Martínez & al., 1998). Some documents related to the development of the EU-Habitats and Species Directive for Spain also show schemes very similar to the checklist, with over 16 associations recorded (Rivas-Martínez & al., 1993; Rivas-Martínez & al., 2003). In most of the above mentioned cases the justification for the structure and composition of the *Gypsophiletalia* order is insufficiently detailed and poorly supported, and it is not always easy to grasp the criteria supporting one or another of the syntaxonomical classifications.

Although some authors have suggested that the number of associations depends very much on the researcher's point of view (cf Müller-Dombois & Ellenberg, 1974), the structure of the *Gypsophiletalia* order and the number of associations are far from being insignificant issues. Indeed, the checklist is not only a basic document for describing and understanding plant communities, but also has a significant importance for the conservation of the Iberian, Balearic and Canary biodiversity. We should not forget that the Iberian "aljezares" and the communities growing on them are EU Priority Habitats (CEC, 1994), whose conservation should be contemplated in the Sites of Community Interest (SCIs). In this respect, the creation of a future network of natural reserves on gypsum soils should take into account the different gypsicolous communities involved and their geographical distribution (Mota, 2001).

In addition, the huge amount of data available on the *Gypsohiletalia* provides a unique opportunity to review the phytosociological method and supplement the current battery of numerical analysis techniques with new, hardly used approaches in syntaxonomy. Some authors have called for the implementation of numerical techniques and very recently, van der Maarel (2005) has also stressed this issue.

Inspired by the classical cluster analysis, a multivariate analysis technique widely used in the last 20 to 30 years (e.g. GOODALL, 1973; KENT & COKER, 1992), our approach applies new multivariate techniques which have been hardly used before in syntaxonomical analyses (HÖLZEL, 2003). Among these, the MRPP is eminently suitable for phytosociological classifications, since it is a nonparametric method for testing group differences (MCCUNE & GRACE, 2002). The Indicator Species Value (IV) is also an extremely appropriate procedure to evaluate the diagnostic potential of the species, now considered individually (DUFRÊNE & LEGENDRE, 1997).

Thus, our objectives were to:

a. to objectively revise the syntaxonomical structure of the *Gypsophiletalia* order, ascertain how many subgroups it contains and which is the most suitable rank for each of them (alliances, suballiances or a combination of both);

b. to establish which taxa must be used to support the resulting scheme and to determine whether or not the selection of these taxa is related to the a priori diagnostic value previously ascribed;

c. to provide the most objective answer to the following question: how many associations are sufficient to reflect the variability of these communities in the Iberian Peninsula?

Material and Methods

Study area and phytosociological background of the Iberian gypsum dwarf scrubs

The *Gypsophiletalia* order is found in the eastern half of the Iberian Peninsula (Fig. 1), in the biogeographical territories labelled by RIVAS-MARTÍNEZ & al. (2002) as the Mediterranean Central Iberian (Castilian and Aragonese subprovinces), Murcian-Almeriensian (Almeriensian and Alicantine-Murcian sectors), Valencian-Catalonian-Provenzal and Betic (Guadician-Bacensean sector) provinces. Most of these territories have a Mediterranean xeric (oceanic and continental steppic variant) and/or a Mediterranean pluviseasonal (oceanic and continental variant) bioclimate, from the thermomediterranean to the lower supramediterranean belt under arid to dry ombrotypes (RIVAS-MARTÍNEZ & al., 2002). These thickets grow on a variety of soils such as gypsic regosols, gypsic yermosols and haplic yermosols, and, in the depositional areas, calcareous fluvisols (PÉREZ-PUJALTE & OYONARTE, 1987; PÉREZ-PUJALTE & al., 1989; DELGADO & al., 1991; OYONARTE & al., 2002). However, it is not unusual to find gypsicolous thickets growing directly on rock, where cryptogamic crusts are particularly abundant (MOTA & al., 2003).

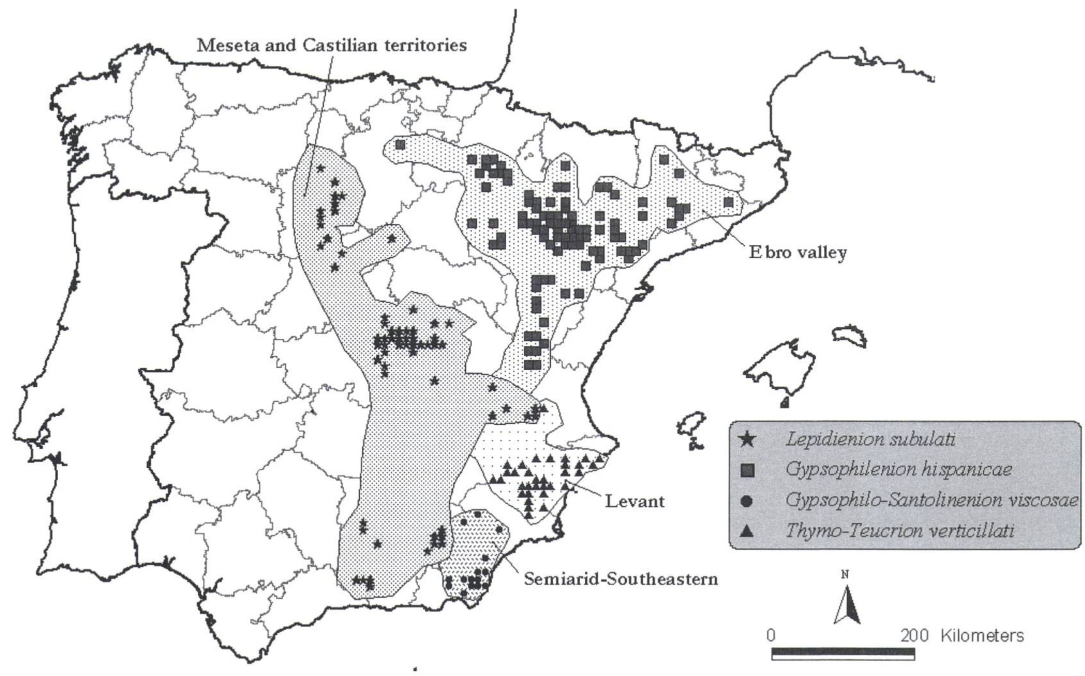

Fig. 1. – Geographical distribution of the relevés published on the *Gypsophiletalia* order in the Iberian Peninsula. The groups or suballiances mentioned in the text can be recognized on the map: Ebro valley *(Gypsophilenion hispanicae)*, Levant *(Thymo-Teucrion verticillati)*, Meseta-Castilian territories *(Lepidienion subulati)* and Semiarid-Southeastern *(Gypsophilo-Santolinenion viscosae)*.

All the available information published in phytosociological tables on the *Gypsophiletalia* order was gathered together. A total of 800 relevés arranged in 85 detailed tables obtained with the Braun-Blanquet phytosociological method have been published. The basics of this method have been accurately described in a large number of manuals (e.g. BRAUN-BLANQUET, 1932; WESTHOFF & VAN DER MAAREL, 1973; MÜLLER-DOMBOIS & ELLENBERG, 1974) and articles (e.g. POORE, 1955). Each one of these detailed tables has been summarized in a column indicating the presence (1) or absence (0) of each species. Here we must mention that when the detailed tables included two or more subassociations (or variants) these tables were broken down into the corresponding number of summary columns. Finally, we obtained a preliminary summary matrix (file TOTAL) with 250 species (rows) and 106 relevé groups (columns). From now on, we will refer to these columns as operational syntaxonomic units (OSUs). With the Braun-Blanquet abundance-dominance index and the average values of the equivalences ascribed both by BOUDERESQUE (1971) and MÜLLER-DOMBOIS & ELLENBERG (1974) to each value of this index, we obtained another matrix, similar to the one mentioned above, but with the plant coverage expressed as a percentage. Out of the TOTAL matrix a number of partial matrices or submatrices were obtained using the diagnostic value or syntaxonomical signification of the different species according to the characteristic species list suggested by RIVAS-MARTÍNEZ & al. (2002). As a result of this analysis, 4 groups of species can be distinguished:

1. taxa of the *Gypsophiletalia* order;
2. taxa of the *Rosmarinetea* class;
3. taxa of any of the orders included in the *Rosmarinetea* class except those belonging to *Gypsophiletalia* order;
4. accompanying species (Table 1).

Table 1. – Diagnostic groups reflecting the classification of the 250 species recorded in the tables so far published for the *Gypsophiletalia* order. Diagnostic taxa have been chosen following RIVAS-MARTÍNEZ & al. (2002).

Diagnostic taxa of the order *Gypsophiletalia* and subordinated units. It includes the taxa considered as characteristic of the following units: order *Gypsophiletalia*, alliance *Lepidion subulati*, all. *Thymo-Teucrion verticillati*, suballiance *Lepidenion subulati*, suball. *Gypsophilo-Santolinenion* or suball. *Gypsophilenion hispanicae*.
Diagnostic taxa of *Rosmarinetea*: species and subspecies considered as characteristic of the class *Rosmarinetea*.
Diagnostic taxa of any order of the class *Rosmarinetea*, except for the order *Gypsophiletalia*. All the characteristic taxa of the orders *Rosmarinetalia officinalis*, *Erinacetalia anthyllidis*, *Anthyllidetalia terniflorae* and *Convolvuletalia boissieri*, just as the characteristic taxa of their subordinated units are included here.
Accompaying species: any taxon not included in the reference work as characteristic of the mentioned units.

By means of the different diagnostic values of each of the 250 species under consideration, 6 files or presence-absence matrices (Table 2) were constructed.

In Tables 1 and 2, each of the 106 OSUs was ascribed to one of the 20 associations mentioned in the check-list (RIVAS-MARTÍNEZ & al., 2001) for the *Gypsophiletalia* order. For this purpose, we took into consideration the nomenclatural synonyms mentioned in that list. Five tables formerly presented

Table 2. – Files used to carry out the analyses described in the text. The name of each file is the name used in the text (abbreviated) and the number of taxa included in the raw matrixes.

File	No. taxa	Characteristic
TOTAL	250	The 250 taxa that happen to be in the 106 OSUs are included. Only the therophyte and lichen species have been removed from the original relevés. These two groups are removed because of their insignificance as diagnostic species in the gypsophilous scrubs and, in addition, and their rareness in the published tables. In fact, only the most remarkable or frequent lichens are included in a few tables and just as anecdotes.
ROSMA	132	It collects the diagnostic species of the cl. *Rosmarinetea* and its subordinated units. In this file, the accompaying species have been removed from the previous one.
ROSCL	22	It collects the presence or absence of the species of the cl. *Rosmarinetea sensu stricto*. The characteristic species of the different orders and subordinated syntaxa (alliances, suballiances...) are not included.
ROSOR	83	It collects exclusively the diagnostic species of the different orders, except for *Gypsophiletalia* (i.e. *Rosmarinetalia officinalis, Erinacetalia anthyllidis, Anthyllidetalia terniflorae* and *Convolvuletalia boissieri*).
GYPSO	27	In this case, it collects only the diagnostic species of the order *Gypsophiletalia* and its subordinated units.
ACCOM	118	It collects exclusively the species considered as accompanying in the table.

as "community of..." and without any explicit ascription to a given association in the original publications are exceptions to this rule. In the figures they appear with the abbreviation "NM" (not mentioned). However, it was not difficult to ascribe each one of these five communities to a biogeographical group, as with the rest of the OSUs. For reasons of brevity, each OSU is given a code name. Thus, the code name for the *Helianthemo alypoidis-Gypsophiletum struthii* ass. is HGS_GS. The last two letters refer to the encompassing *Gypsophilo-Santolinenion viscosae* suballiance (south-eastern gypsum outcrops located in the chorological Murcian-Almeriensian province). Finally, as a total of 8 OSUs belong to this association, the abbreviations HGS_GS1, HGS_GS2, HGS_GS3, ..., HGS_GS8 can be seen in the results. The name of each of the 106 OSUs, with an indication of their respective origin, i.e. Southeast (GS), Meseta or Castilian (LS), Ebro or Aragonese (GH) and Levant or Alicantine-Murcian (TT) are shown abbreviated in Appendix 1 following the check-list's syntaxonomical scheme.

The last 4 files (Table 2) are complementary, i.e. they do not share species and all together they form the file TOTAL. Each of these files has a corresponding version where the coverage of their different taxa is shown. However, since no novelty arose from the analyses carried out on these versions, they are omitted in our results and discussion. It is worth mentioning that all the methods implemented are compatible with quantitative and binary (presence-absence) variables, including the Indicator Value (IV) analysis (McCune & Grace, 2002: 198). As far as the cluster analysis using Ward's method is concerned, the relative Euclidean distance was used for measuring purposes. This strategy reduces the difficulties involved in dealing with matrices indeed not sensitive to double zeros (McCune & Grace, 2002: 93).

The suballiances obtained for the *Gypsophiletalia* order formed the required pre-existing group in all the analyses. The combination of all the above mentioned methods permitted the exploration of the data structure from various angles, as is the leading trend (Mucina, 1997).

Data analysis

1. Cluster analysis

Agglomerative cluster analysis has a long history in ecology and has been extensively used to obtain plant classifications (cf. Orloci, 1967; Goodall, 1973; Whittaker, 1973; Greig-Smith, 1983) As far as the *Gypsophiletalia* order is concerned, the aim was to find out whether the arrangement in alliances and suballiances was also supported by more objective methods of classification. For this purpose, a dendrogram for each of the files (Table 2) was calculated. Despite the large number of similarity coefficients and clustering strategies (Hadju, 1981; Hubbalek, 1982; Everitt, 1993, Legendre & Legendre, 1998), we opted for the relative Euclidean distance and Ward's method (Ward, 1963). Ward's method is not only an effective tool but also one of the few space-conserving strategies (McCune & Grace, 2002). As an agglomeration technique, it is also very effective in displaying relationships among clusters and the problem of chaining is usually limited. Dendrograms were later checked to see how many OSUs had been left out of their corresponding *a priori* group (suballiance). All dendrograms are scaled by means of Wishart's objective function (McCune & Grace, 2002).

2. Multi-response Permutation Procedure (MRPP)

MRPP is very useful for evaluating classifications obtained by means of different criteria. It is a non-parametric procedure for testing the null hypothesis of no difference between two or more groups of entities (Zimmerman & al., 1985). The groups must be established a priori. For example, one could compare the species composition between alliances to test the hypothesis of no differences. Discriminant analysis is a parametric procedure that can be used on the same general type of questions. However, MRPP has the advantage of not requiring assumptions that are seldom met with ecological community data. The statistic A is given as a descriptor of within-group homogeneity, compared to the random expectation. This is known as chance-corrected within-group agreement. When all items are identical within groups, then the observed $delta = 0$ and $A = 1$, the highest possible value for A. If heterogeneity within groups equals expectation by chance, then $A = 0$. On the other hand, if there is less agreement within groups than expected by chance, then $A < 0$. According to McCune & Grace (2002), in community ecology, values for A are commonly below 0.1, even when the observed delta differs significantly from the expected. The MRPP can provide a quantitative, objective criterion for picking the most syntaxonomical meaningful structure for the *Gypsophiletalia* order. By means of this procedure we have tested all possible syntaxonomical schemes with 4 or fewer groups, including those supported by Díez Garretas & al. (1996), Loidi & Costa (1997) and Mota (2001) and Rivas-Martínez & al. (1998, 2001) and Boira & al. (2002). These are shown in Table 3 as combinations 14 and 3. Combination 3 corresponds to Rivas-Martínez & al. (2001). Combination 14 can be found in the revisions of Díez-Garretas & al. (1996), Loidi & Costa (1998) and Mota (2001).

Table 3. – Possible theoretical combinations to describe the syntaxonomical structure of the *Gypsophiletalia* order.

Combination	N. groups				
1	2	GH +	LS - GS - TT		
2	2	LS +	GS - GH - TT		
3	2	TT +	LS - GS - GH		
4	2	GS +	LS - GH - TT		
5	2	GH - LS +	GS - TT		
6	2	GH – TT +	LS - GS		
7	2	GH - GS +	LS - TT		
8	3	GH - LS +	TT +	GS	
9	3	GH - TT +	GS +	LS	
10	3	GS - GH +	TT +	LS	
11	3	LS - TT +	GH +	GS	
12	3	LS - GS +	TT +	GH	
13	3	TT - GS +	GH +	LS	
14	4	LS +	GS +	GH +	TT

We have applied the Sørensen coefficient, one of the most commonly used in this kind of research and particularly suitable for presence-absence data with many double absences. However, use of relative Euclidean distances gave practically identical results. We also rank transformed the matrix distance because this procedure can help to correct the loss of distance measures as community heterogeneity increases, as well as other reasons detailed by McCune & Grace (2002).

3. Indicator Value (IV)

This method (Dufrêne & Legendre, 1997) has been used mostly to detect and describe the value for different species for indicating environmental conditions (McCune & Grace, 2002) and, as McCune & Grace (2002) state, the method requires two or more a priori groups of sample units and data on species abundance or species presence. In our research (the method gives an integrated measure for the relative mean coverage and the relative frequency of the studied taxa in the four suballiances) it has been used to evaluate the IV of each species in relation to the possible groups or suballiances (alliances) within the *Gypsophiletalia* order. IV for each of the taxa was determined following the partitions shown in Table 3. Those partitions backed by species with higher and significant IVs were used to determine which groups can be differentiated within the *Gypsophiletalia* order. The Indicator Species Analysis (ISA) has the advantage that the IV obtained for each species are almost coincidental both by means of coverage data and by means of presence-absence data. Likewise, they are also independent of the number of species in the tables and do not vary whether we calculate them with the 250 species (file TOTAL) or with partial files (i.e., any of the other options contemplated in Table 2). Dufrêne & Legendre (1997) and Legendre & Legendre (1998) also highlighted this fact. Species that are weakly associated with one suballiance because they are either not abundant or not present in all the OSUs belonging to it will score a low IV. To test whether the observed IV of a species in a certain group (suballiance) was significantly higher than could be expected based on random distribution, the observed IV was compared with 10000 randomly generated IVs. The statistical significance of IVs was evaluated by the Monte Carlo method, randomly reassigning OSUs to groups 1000 times (McCune & Grace, 2002). To determine if a species was an indicator, we first examined the significance of the index and arbitrarily retained a threshold of 50% ($P < 0.01$).

The IV analysis can also be very helpful for interpreting the cluster analysis results, since it provides an objective quantitative criterion for the most suitable pruning of a dendrogram (McCune & Grace, 2002). For this purpose we have used the number of species with a significance $P < 0.01$ at each level of the cluster formation plotted against cluster step. The point where the cluster level presents its highest number of indicator species is considered as the most informative of all to determine the number of alliances.

To carry out all our analyses we have implemented the very useful programmes SYNTAX 5.0 (Podani, 1994) and PC-ORD 5.0 (McCune & Mefford, 1997). The data files mentioned in Table 2 are available to researchers on request.

For the names of taxa and syntaxa and the references to syntaxonomical and chorological units we have followed the nomenclature of Rivas-Martínez & al. (2002) (see Appendix 1).

Results

Cluster analysis

All the cluster analyses carried out with the files of Table 2 revealed 4 or 5 groups at around the 25% level of information retained. Most of these groups are readily assimilated into the 4 typical suballiances already recognized. However, depending on the file used in each case, the number of OSUs located outside the *a priori* corresponding group differed tremendously. Considering all the species (file TOTAL) and the cutting point of the 4 groups, the analysis produces 18 misclassified OSUs (Fig. 2), i.e. OSUs included in a group or suballiance different from their a priori corresponding group or suballiance. Working with the file ROSMA we have the same situation with 14 OSUs, and the cases are 13 if we work with the file GYPSO (Fig. 3). The situation becomes even worse with the rest of the files: there are 35 OSUs outside their corresponding group or suballiance if we work with the file ROSCL, 33 with ROSOR and 26 using the file ACCOM (Fig. 4). It is striking that, despite the high number of OSUs out of place in the last three cases, the structure of four large groups encompassing clearly distinguishable phytosociological suballiances is unquestionable. Only in Fig. 4 there is a group not ascribed to any level and only when using the file ACCOM does the *Thymo-Teucrenion* levantine suballiance (or alliance) (Fig. 4) become blurred. The higher correlation observed in the clusters between TT y GS with higher hierarchical levels and the accompanying species is due to the fact that both alliances share a high number of thermophilous elements, whereas the others (GH and LS) occur in a more continental and colder kind of climate.

Almost a third of the wrongly classified OSUs belong to the *Lino-Lepidietum subulati* association (LLS-LS) in all the dendrograms. If we consider 5 higher level branches, this association and most of the wrongly located OSUs in the cluster analysis using strict gypsophytes are clearly included in the same group. This result is almost exactly coincidental with pruning the dendrogram from the cluster analysis at the 25% level of information retained (Fig. 3). This cutting point also coincides with the largest number of taxa with P values < 0.001 for the ISA (Fig. 5).

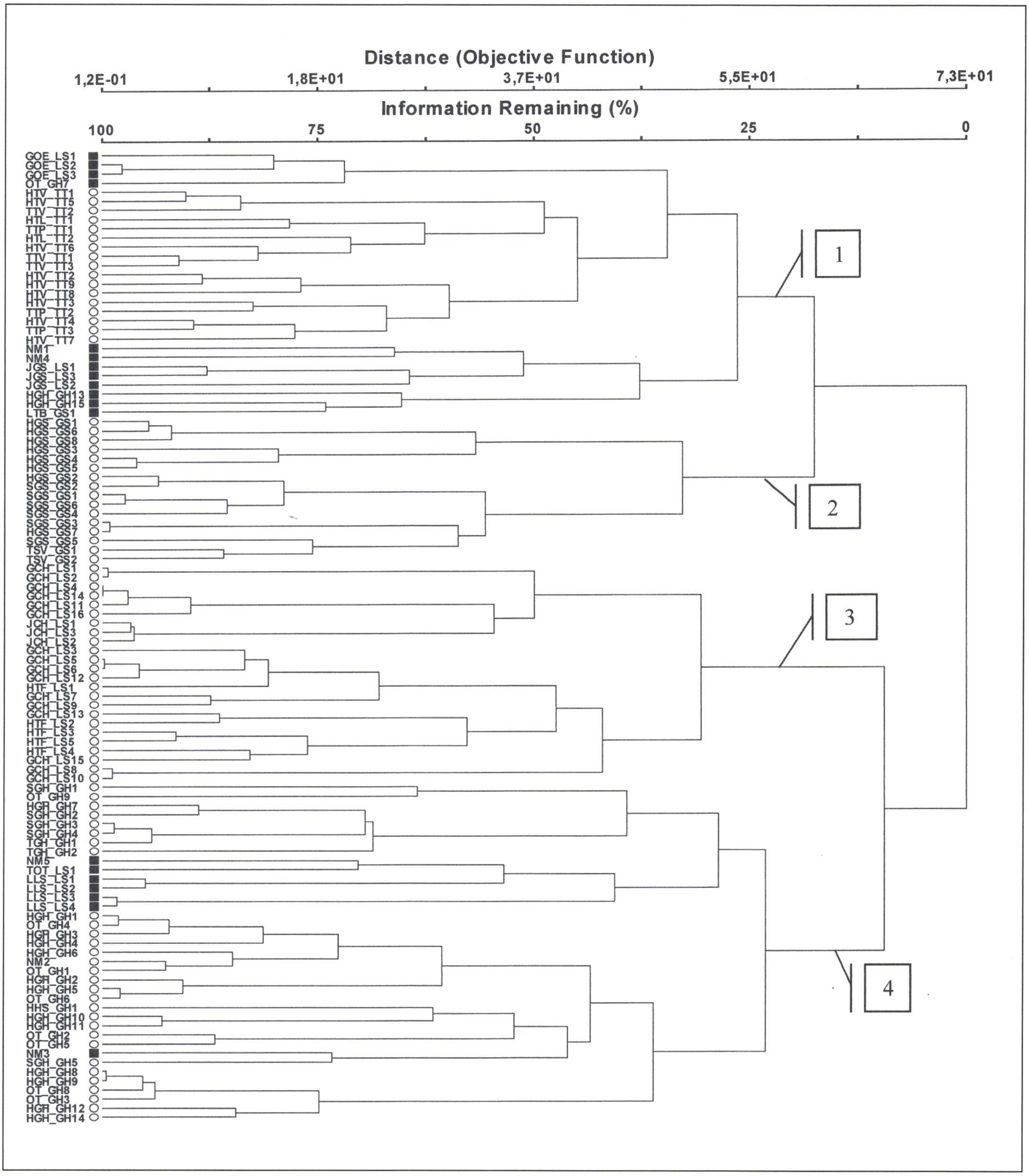

Fig. 2. – Cluster analysis using all the species included in the tables published for the *Gypsophiletalia* order (file TOTAL). The OSUs which are not included in their *a priori* corresponding group are marked with a black circle. The numbers in the insets identify the 4 groups corresponding to the alliances or suballiances: (1) *Thymo-Teucrion verticillati*, (2) *Gypsophilo-Santolinenion viscosae*, (3) *Lepidienion subulati* and (4) *Gypsophilenion hispanicae*.

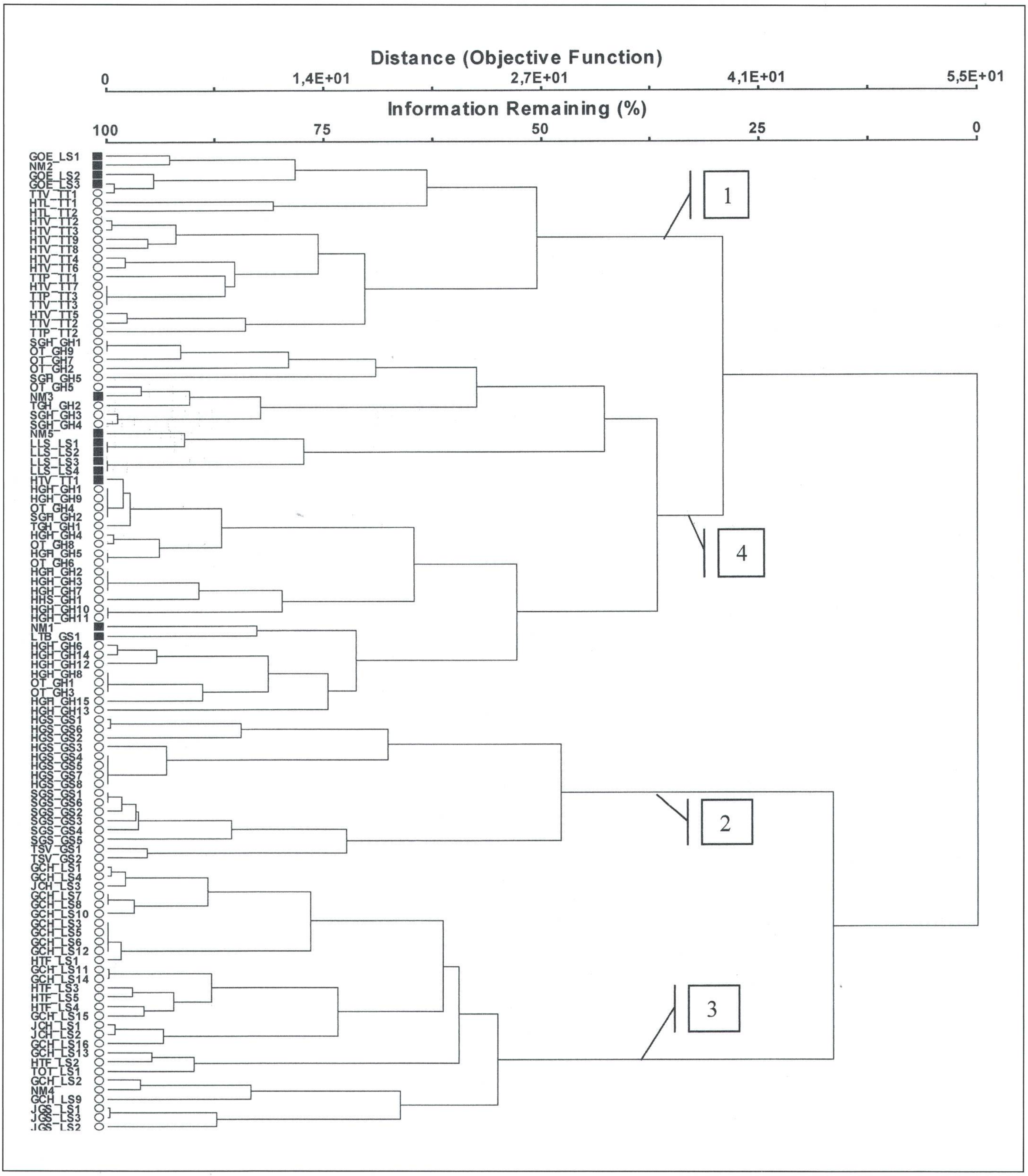

Fig. 3. – Cluster analysis using strict gypsophytes, *i.e.*, the characteristic species of the *Gypsophiletalia* order (file GYPSO). Black circles and numbers have the same meaning as in Figure 2.

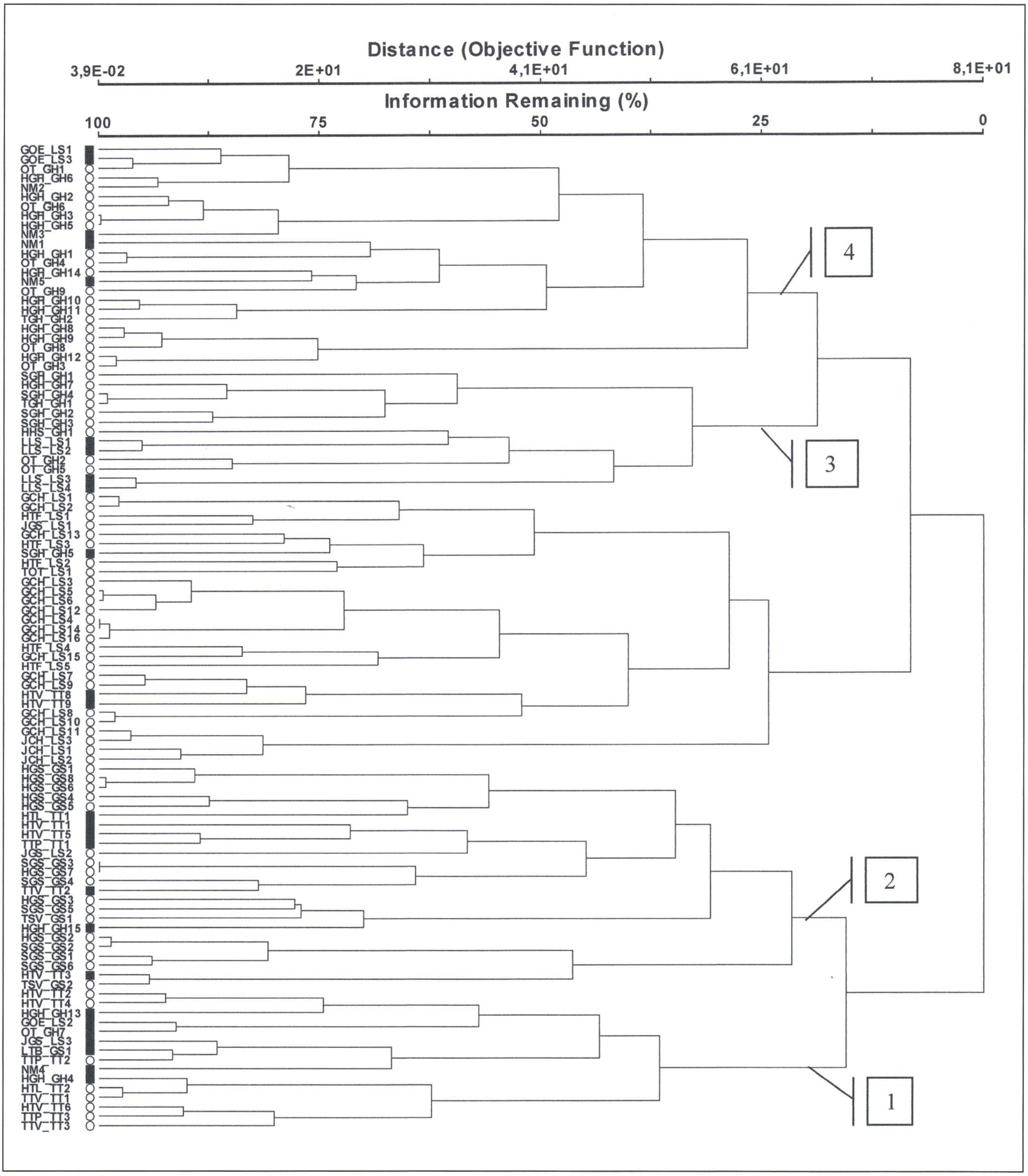

Fig. 4. – Cluster analysis using exclusively companion species (file ACCOM). Legends have the same meaning as in the two preceding figures.

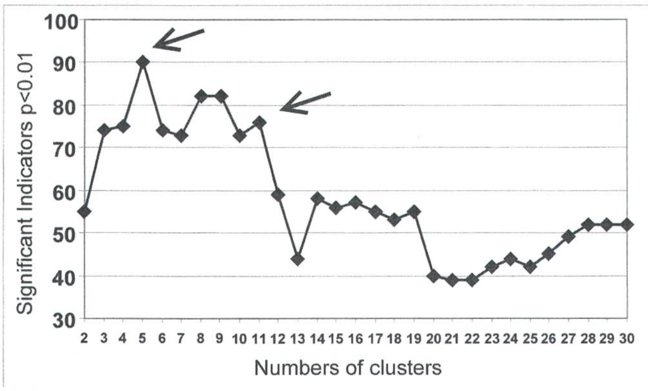

Fig. 5. – Use of IV as an objective criterion to determine the number of divisions of the *Gypsophiletalia* order. The upper arrow indicates a suitable number of alliances and the lower arrow indicates the appropriate number of associations. Ordinates show the number of species with $P < 0.01$ for each step of clusterin.

Separation between groups: the MRPP

Table 4 shows the MRPP results. In this table the first seven alternatives divide the *Gypsophiletalia* order into 2 groups; the following six, into three groups; and the last one, into 4 (cf. Table 3). As already mentioned, this last scenario is supported by most of the previous revisions of the order, with the exception of those led by Rivas-Martínez & al. (1993, 1998, 2001), Boira & al. (2002) and Rivas-Martínez & Penas (2003), who suggests a scheme with 2 alliances, one of them divided into three suballiances.

As can be expected, the results of Table 4 clearly reveal that the A value (chance-corrected within group agreement) tends to increase as the number of groups under consideration increases, since this means that the heterogeneity within the group decreases. It is also noticeable that the worst results are obtained mostly with companion species, however numerous the species of the group are (118 species).

Indicator Species Values

Table 5 shows the species which, with IV > 50, can be used to support the subdivisions of the *Gypsophiletalia* order. As can be seen in Table 5, if we opt for a system with the 4 typical groups (row 14), there is always at least one gypsophyte to support that division: *Centaurea hyssopifolia* Vahl for the Meseta, *Gypsophila hispanica* Willk. for the Ebro valley, *Teucrium libanitis* Schreb. for Levant, and *Coris hispanica* Lange and *Santolina viscosa* Lag. for the southeast. We find gypsophytes supporting all the groups (rows 1, 4 and 14) in only three of the 14 combinations.

The ISV revealed that of the 118 species considered as companions, only 3 (*Launaea lanifera* Pau, *Stipa tenacissima* L. and *Koeleria vallesiana* (Honck.) Gaudin) had an IV > 50 ($P < 0.001$) in some combinations. This means a percentage

Table 4. – Values for the descriptor of within-group homogeneity (A statistic) in the MRPP following the combinations shown in Table 3 ($P < 0.01$ in all cases after Bonferroni-correction).

	GH+	LS+	TT+	GS+	GHLS+	GHTT+	GHLGS+	GHTS++	GHTT++	GHGS++	LSTT++	LSGS++	TTGS++	4AL
TOTAL	0.12	0.14	0.1	0.19	0.23	0.13	0.06	0.32	0.32	0.2	0.28	0.23	0.33	0.42
TOTAL_IV50	0.14	0.15	0.1	0.2	0.22	0.14	0.08	0.33	0.34	0.22	0.31	0.25	0.34	0.45
ROSCL	0.05	0.07	0.05	0.1	0.11	0.08	0.03	0.17	0.18	0.11	0.14	0.12	0.16	0.22
ROSOR	0.1	0.08	0.1	0.17	0.25	0.04	0.04	0.31	0.21	0.15	0.24	0.17	0.29	0.35
GYPSO	0.13	0.12	0.07	0.18	0.11	0.17	0.09	0.25	0.31	0.19	0.28	0.23	0.24	0.38
ACCOM	0.1	0.12	0.06	0.11	0.17	0.1	0.04	0.2	0.22	0.15	0.18	0.17	0.26	0.29

Table 5. – Taxa with IV 50 for the 14 combinations and groups shown in Table 3. Species written in bold are considered characteristic species for the *Gypsophiletalia* order or for any of its alliances and suballiances.

1	GH + *Genista scorpius* (61.3) ***Gypsophila hispanica*** (74.4) *Koeleria vallesiana* (69.2) ***Ononis tridentata*** (50) *Rosmarinus officinalis* (53.6) *Teucrium capitatum* subsp. *capitatum* (50.5) *Thymus vulgaris* (56.4)	LS – GS – TT ***Gypsophila struhium*** (52.1) *Stipa tenacissima* (54.7)	
2	LS + ***Centaurea hyssopifolia*** (59) ***Koeleria castellana*** (52.4) ***Lepidium subulatum*** (53.1) *Teucrium capitatum* subsp. *capitatum* (51.9)	GS – GH – TT *Helianthemum syriacum* (61.2)	
3	TT + *Anthyllis cytisoides* (73.3) *Atractylis humilis* (58) *Fumana ericoides* (52.2) *Fumana thymifolia* (63.8) *Helianthemum syriacum* (61.8) ***Teucrium libanitis*** (88.2)	LS – GS – GH *Teucrium capitaum* subsp. *capitatum* (54.5)	
4	GS + *Anthyllis terniflora* (67.4) ***Coris hispanica*** (94.1) *Diplotaxis lagascana* subsp. *intricata* (61.7) ***Gypsophila struthium*** (55.9) *Helianthemum almeriense* (57.7) *Helianthemum syriacum* (56.4) *Launaea lanifera* (58) ***Santolina viscosa*** (94.1) *Thymelaea hirsuta* (52.8)	LS – GH – TT ***Herniaria fruticosa*** (64.2) *Teucrium capitatum* subsp. *capitatum* (59.6) *Thymus zygis* (50.6)	
5	GH – LS + *Genista scorpius* (52.8) *Koeleria vallesiana* (50.2) *Teucrium capitatum* subsp. *capitatum* (69.5) *Thymus zygis* (50.7)	GS – TT *Diplotaxis lagascana* subsp. *intricata* (61.8) *Helianthemum syriacum* (62.3)	
6	GH – TT + *Helianthemum syriacum* (51.3) ***Herniaria fruticosa*** (53) *Rosmarinus officinalis* (59.1)	LS – GS None	
7	GH – GS + None	LS – TT None	
8	GH – LS + *Genista scorpius* (52.8) *Teucrium capitatum* subsp. *capitatum* (60.3)	TT + *Anthyllis cytisoides* (60.1) ***Teucrium libanitis*** (88.2)	GS *Anthyllis terniflora* (56.5) ***Coris hispanica*** (94.1) *Helianthemum almeriense* (53.5) *Launaea lanifera* (58.8) ***Santolina viscosa*** (94.1) *Thymus hyemalis* (54.8)

Table 5 (cont.). – Taxa with IV 50 for the 14 combinations and groups shown in Table 3. Species written in bold are considered characteristic species for the *Gypsophiletalia* order or for any of its alliances and suballiances.

9	GH – TT + None	GS + *Anthyllis terniflora* (65.1) ***Coris hispanica*** (94.1) *Diplotaxis lagascana* subsp. *intricata* (56.2) *Helianthemum almeriense* (56.9) *Launaea lanifera* (58.8) ***Santolina viscosa*** (94.1) *Thymus hyemalis* (60.9)	LS ***Centaurea hyssopifolia*** (59) ***Koeleria castellana*** (51.9)	
10	GS – GH + None	TT + *Anthyllis cytisoides* (66.1) *Fumana thymifolia* (50.8) ***Teucrium libanitis*** (88.2)	LS ***Centaurea hyssopifolia*** (59)	
11	LS – TT + None	GH + *Genista scorpius* (58.8) ***Gypsophila hispanica*** (74) *Koeleria vallesiana* (63.2) *Thymus vulgaris* (53.3)	GS *Anthyllis terniflora* (65.6) ***Coris hispanica*** (94.1) *Diplotaxis lagascana* subsp. *intricata* (57.5) *Helianthemum almeriense* (57.1) *Launaea lanifera* (58.8) ***Santolina viscosa*** (94.1) *Thymus hyemalis* (61.3)	
12	LS – GS + None	TT + *Anthyllis cytisoides* (68) ***Teucrium libanitis*** (88.2)	GH *Genista scorpius* (58) ***Gypsophila hispanica*** (74) *Koeleria vallesiana* (63.2)	
13	TT – GS + *Diplotaxis lagascana* subsp. *intricata* (61.8)	GH + *Genista scorpius* (52.6) ***Gypsophila hispanica*** (73.3)	LS ***Centaurea hyssopifolia*** (59) *Koeleria castellana* (51.1)	
14	LS + ***Centaurea hyssopifolia*** (59)	GS + *Anthyllis terniflora* (56.5) ***Coris hispanica*** (94.1) *Helianthemum almeriense* (53.5) *Launaea lanifera* (58.8) ***Santolina viscosa*** (94.1) *Thymus hyemalis* (54.8)	GH + *Genista scorpius* (52.6) ***Gypsophila hispanica*** (73.3) *Koeleria vallesiana* (56.5)	TT *Anthyllis cytisoides* (56.9) ***Teucrium libanitis*** (88.2)

value lower than 3%. Of the 24 characteristic taxa of the *Rosmarinetea* class only 7 (29%) comply with the requisites needed to be considered as indicator species. The following taxa are among these: *Atractylis humilis* L., *Anthyllis cytisoides* L., *Fumana ericoides* (Cav.) Gand. subsp. *ericoides*, *F. thymifolia* (L.) Webb, *Helianthemum syriacum* (Jacq.) Dum. Cours., *Thymelaea hirsuta* (L.) Endl. and *Thymus vulgaris* L. Many of these taxa clearly prefer arid gypsum and marl soils. Of the 83 diagnostic taxa included in the non-gypsicolous 4 orders of the *Rosmarinetea* class (or of its subordinate alliances) 6 (7.2%) have an IV > 50 ($P < 0.01$). The species related to the orders *Anthyllidetalia terniflorae* (e. g. *Anthyllis terniflora* (Lag.) Pau, *Diplotaxis lagascana* subsp. *intrincata* (Willk.) Rivas-Mart. & Cantó, *Helianthemum almeriense* Pau) and *Rosmarinetalia* (e.g. *Genista scorpius* (L.) DC. and *Teucrium capitatum* L. subsp. *capitatum*) are the most remarkable within this group. By contrast, there is no species growing on gypsum soils which can be considered as a characteristic species of the orders *Erinacetalia anthyllidis* (orophilous) or *Convolvuletalia boissieri* (dolomiticolous). Nevertheless, we must mention that *Jurinea pinnata* (Lag.) DC., commonly found on Iberian gypsum soils, frequently occurs within communities on dolomites too (Mota & al., 1993; Mota & al., 2008).

Within the *Gypsophiletalia* order, of the 27 taxa which RIVAS-MARTÍNEZ & al. (2002) mention as characteristic taxa 10, i.e. over 37% of them, have an IV higher than 50 ($P < 0.01$) and six are exclusively (or almost exclusively) restricted to one of the 4 suballiances: *Centaurea hyssopifolia* and *Koeleria castellana* Boiss. & Reuter for *Lepidienion subulati), Gypsophila hispanica* for *Gypsophilenion hispanicae, Coris hispanica* and *Santolina viscosa* for *Gypsophilo-Santolinenion viscosae,* and *Teucrium libanitis* for *Thymo-Teucrion verticillati.*

Discussion and conclusions

Perhaps the most striking aspect of the results is that the information derived from the presence or absence of the companion species supports the division of the *Gypsophiletalia* order into four groups. The cluster analyses (Fig. 2-4) strongly support this conclusion. However, according to these analyses, the species which best reflect the syntaxonomical structure in four groups and produce the lowest number of correspondingly discordant ascriptions (Fig. 4) are those genuinely belonging to the *Gypsophiletalia* order. In all the cluster analyses most of the NM cases and the associations GOE_LS and LLS_LS (Fig. 2-4) appear wrongly located with regard to their biogeographical group. LOIDI & COSTA (1997) consider this last association as belonging to the *Rosmarinetalia* order and, consequently, clearly unrelated to the *Gypsophiletalia* order. Most of the OSUs which are related to LLS_LS in the dendrograms and/or wrongly located exhibit a number of gypsophytes (character species of *Gypsophiletalia*) lower than 4 (first quartile) in their accompanying flora when the median is 6. Considering that the ISA supports the division into 5 groups (alliances, in this case) as probably the most suitable option, the message seems undisputable: most of the last OSUs under consideration may be included in one or other of the 4 alliances of the *Gypsophiletalia* order, but a fifth group seems to represent a transition group towards the *Rosmarinetalia* communities.

As we have already said, the MRPP may provide us with the most suitable syntaxonomical structure for the *Gypsophiletalia* order of all the possibilities (Table 4). The most obvious conclusion is that it is hard to maintain the scheme suggested by RIVAS-MARTÍNEZ & al. (1993, 1998, 2001), BOIRA & al. (2002) and RIVAS-MARTÍNEZ & PENAS (2003), with two alliances, one for the thickets of Murcia and Alicante *(Thymo-Teucrion verticillati)* and another for the rest *(Lepidion subulati)*. In fact, this classification exhibits the worst results among all the possible divisions of the *Gypsophiletalia* order into two groups (Table 4). The only group of gypsicolous thickets suitable for a clear separation from the rest would be that found in the southeast *(Gypsophilo-Santolinenion viscosae)*. However, among the scenarios with two groups or alliances the MRPP provides two alternative solutions:

- to separate the thickets found in more continental areas *(Lepidenion subulati – Gypsophilenion hispanicae)* from the thermophilous species *(Gypsophilo-Santolinenion – Thymo-Teucrion verticillati)*;
- to separate the taxa found in the centre and south *(Lepidenion subulati – Gypsophilo-Santolinenion)* from those found in the Ebro valley and Levant *(Gypsophilenion hispanicae – Thymo-Teucrion verticillati).*

Another striking aspect is that in partial files the best results are generally obtained using the characteristic species of the *Gypsophiletalia* order. This same situation is observed when considering three groups or alliances (Table 4). As expected, the classifications with three groups produce *A* values higher than those obtained with 2 groups in almost all the cases. Finally, the division into four groups all at the same syntaxonomical level is the one providing the higher chance-corrected agreement (A) within group.

At this point, we must try to answer the question as to which species can be used to support the different options provided by the MRPP for the *Gypsophiletalia* order. Although the previous analysis has already revealed some indication, the ISA can be of great help in answering this question. The procedure makes it clear that not all the species have the same value for defining subdivisions, since only a small number of the 118 species considered as companions support the division of the *Gypsophiletalia* order into four suballiances. In addition, as far as the phytosociological epistemology is concerned, it seems wise to dispense with the companion species to obtain the syntaxonomical scheme of the *Gypsophiletalia* order, because, among other reasons, the fidelity level thus achieved for gypsicolous thickets could be very low (WESTHOFF & VAN DER MAAREL, 1973). This issue of establishing objectively the fidelity level has usually been overlooked not only in the vast phytosociological bibliography on the Iberian Peninsula but also in the bibliography on Europe (VAN DER MAAREL, 2005). Thus, to consider a taxon as a "character-species" for a particular syntaxonomical unit seems to depend more on the experience of the researcher than on any statistical analysis. Among the taxa considered as "characteristic" by RIVAS-MARTÍNEZ & al. (2002) for the *Rosmarinetea* class and the non-gypsophilous orders, the percentage of "indicator" species used to define the groups is higher than that of the companion species, but considerably lower than the record found among gypsophytes (Table 5). From our point of view, it makes no sense to define a syntaxon within the *Gypsophiletalia* order without including at least one characteristic gypsophyte. If we accept this premise, only some of the possibilities suggested by the MRPP could be supported by these "indicator species". Consequently, the *Thymo-Teucrion verticillati* alliance (TT) cannot be maintained as distinct from the rest (LS-GS-GH), since this last group lacks a gypsophyte which could provide coherence to the group and, at the same time, distinguish it from the levantine thickets. However, the thickets of the southeast (GS) and those of the Ebro (GH) do have this possibility. Apart from the option of defining 4 distinct groups (LS+GS+GH+TT), there is no other possibility of establishing groups characterized by at least one gypsophyte. The options already mentioned in relation to the MRPP of either recognising a continental group as distinct from a thermophilous group (LS-GH + GS-TT) or an eastern group as distinct from all the rest (GH-TT + LS-GS) are supported by the presence of gypsophytes (Table 5). Unfortunately, dendrograms indicated no clear structures on these higher levels.

Now we must ask ourselves which criteria or characteristic species have been used to defend a scheme with two alliances (TT + LS-GS-GH). Although phytosociologists have never been very explicit about their arguments to justify their classifications, there is no doubt that the only criterion to support the separation of the Alicantine-Murcian group (TT) as distinct from the rest is the presence of *Lepidium subulatum* L. in the rest of the territories and its absence in the Iberian Levant. This is a qualitative criterion in line with the phytosociological method. However, it is subject to two serious objections. The first objection is that *L. subulatum* is present in five of the 17 OSUs considered in this study for the Alicantine-Murcian group. This presence is occasional and only takes place in transition areas towards more continental territories would not only be an *ad hoc* explanation but also not entirely true if we consider the original tables. Secondly, if the criterion is the presence or absence of a taxon, *Gypsophila struthium* should be used as opposed to *G. hispanica* (see Table 5, row 1). By doing this, the thickets of the Ebro would be separated from all the rest. This option is also supported by the fact that the *Teucrium* species belonging to the *Pumilum* subsection (*Teucrium pumilum* L., *T. balthazaris* Sennen, *T. libanitis, T. lepicephalum* Pau, *T. turredanum* Losa & Rivas Goday and *T. carolipaui* C. Vicioso & Pau) are absent in the Ebro but occur, almost without exception, throughout the rest of the Iberian gypsum outcrops (Navarro, 1995). This interpretation would also provide the proposal with a phytogeographical value, a fundamental criterion in modern phytosociology (Gehú & Rivas-Martínez, 1980). By contrast, the proposal of separating into one single group the Alicantine-Murcian gypsicolous thickets "fractures" the territorial unit of the Murcian-Almeriensian province (Rivas-Martínez & al., 2002), since the thickets belonging to the *Gypsophilo-Santolinenion* suballiance, peculiar to the same biogeographical province, are left on the other side. The option of maintaining in one group separated from the rest the syntaxa occurring on the south-eastern gypsum outcrops (GS + LS-GH-TT) is subject to similar objections. In this case, *Coris hispanica* and *Santolina viscosa* (and, to a lesser extent, *Gypsophila struthium*) would characterise the SE group. On the other hand, *Herniaria fruticosa* L. would agglutinate the rest of the groups (Table 5, row 4). However, if we consider the biogeographical map provided by Rivas-Martínez & al. (2002), it makes more sense to keep the thickets on Almeriensian and Alicantine-Murcian gypsum outcrops (thermophilous group or GS-TT) together in one single alliance as distinct from two other alliances: that of the Meseta and that of the Ebro. However, as already mentioned, this option is not supported by the presence of characteristic gypsophytes in both groups (Table 5, row 5).

Taking all this into consideration, the best solution is to maintain four groups of gypsicolous thickets for two reasons. The first reason is strictly objective: as the previous analyses have revealed, there are no other options supported by the gypsicolous flora. The other reason has to do with the fact that in the end all the classifications agree on considering the occurrence of at least four groups as a minimum. Our analysis also leads us to the same conclusion if we disregard the transition OSUs towards Rosmarinetalia, which would form a fifth group of associations without cohesion from a biogeographical point of view. There is now another question to be answered. Which rank should be ascribed to these four groups? Are they alliances or suballiances? We can only use our common sense, even though it contradicts most of the suggestions made to date. The rank of suballiance is an auxiliary rank which, from our point of view, should only be used when necessary or, in other words, when it provides a solution. However, for the classification of the *Gypsophiletalia* order, what is the advantage of accepting one single alliance with four suballiances as compared to the alternative option of directly accepting four alliances? Consequently, we defend the existence of four alliances.

Finally, how many associations are included in the *Gypsophiletalia* order? If we look again at Figure 5 we will observe that the number of indicator species ($P < 0.01$) considerably diminishes with more than 11-12 groups. Twelve associations is a number which is even lower than the record provided by the above mentioned syntaxonomical revisions. For 20 associations, the number suggested by Rivas-Martínez & al. (2001) the number of indicator species is the lowest. Nevertheless, it is evident that in some alliances the number of associations is too high however we look at it. The most extreme example is the gypsum outcrops in the Ebro, where there is only one widely distributed gypsophyte with a high IV *(Gypsophila hispanica)* but, nevertheless, Rivas-Martínez & al. (2001) accept up to 5 associations. By contrast, other researchers support the existence of two associations for this territory (Loidi & Fernández-González, 1994; Loidi & Costa, 1997).

With all the data available a "conservative" proposal would be to accept eleven or twelve associations. One association for the Ebro (with three subassociations), two associations for the

Levant (to which two subassociations could be added), up to four associations for the Meseta and the same for the Southeast. Despite the strong influence of elements belonging to *Rosmarinetalia,* the gypsum outcrops of the Duero valley may also claim another association. If we opted for a more fragmentary approach ascribing a higher rank to the subassociations, we would find 15 or 16 associations. This last scheme would be very similar to the one already suggested by most researchers (RIVAS-MARTÍNEZ & al., 1993; DÍEZ-GARRETAS & al., 1996, 1999; LOIDI & COSTA, 1997; MOTA, 2001; BOIRA & al., 2004).

Since, as we have already mentioned, the Iberian gypsum outcrops are priority habitats for the EU, their huge diversity of associations presents a challenge for conservation policies. From our point of view it is essential to protect at least one extensive area of these gypsum outcrops in each one of the chorological units (Ebro, Meseta, Levant or Southeast). However even this measure would not cover all the variability of these thickets. In fact, the dendrograms clearly reveal that OSUs belonging to the same association show little relation with one another. Despite the highly valuable data provided by the phytosociological criteria, this fact questions the idea that they should be the only criteria for any policy aiming at identifying the areas to be preserved. Probably the best answer to the challenge of conservation biology of preserving these "island habitats" endangered both by deficient planning of mining development and today's inappropriate restoration legislation would be a network of natural reserves with several areas under special protection in each one of these chorological territories (MOTA & al., 2004, 2005).

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Appendix 1. – Phytosociological conspectus with the plants communities described.

Class

Rosmarinetea officinalis Rivas Mart., T. E. Díaz, Fern. Prieto, Loidi & Penas 2001

Orders

Rosmarinetalia Molin. 1934

Anthyllidetalia terniflorae Rivas Goday, Rigual, Esteve, Borja & Rivas Mart. 1961

Erinaceetalia anthyllidis Quézel 1953

Convolvuletalia boissieri B. Díez & A. Asensi 1994

Gypsophiletalia (Bellot 1952) Bellot & Rivas Goday 1957

Alliances & Suballiances

Lepidion subulati Bellot & Rivas Goday 1957

Thymo-Teucrion verticillati Rivas Goday 1957

Lepidienion subulati Alcaraz, Sánchez-Gómez, De la Torre, S. Ríos & J. Álvarez 1991

Gypsophilo-Santolinenion viscosae (Rivas Goday & Esteve 1968) Díaz-Garretas, Fern.-Gonz. & A. Asensi 1998

Gypsophilenion hispanicae (Braun-Blanq. & O. Bolòs 1958) A. Molina, Loidi & Fern.-Gonz. 1993

Associations

Gypsophilo struthium-Centaureetum hyssopifoliae Rivas Goday, Borja, Monasterio, Galiano, Rigual & Rivas Mart. 1957

Gypsophilo struthium-Ononidetum edentulae M. J. Costa, Peris & Figuerola 1985

Herniario fruticosae-Teucrietum floccosi Rivas Mart. & M. J. Costa 1970

Jurineo pinnatae-Centaureetum hyssopifoliae Rivas Goday 1957

Jurineo pinnatae-Gypsophiletum struthium (Rivas Goday & Esteve 1968) Peinado, Alcaraz & Mart. Parras 1992

Lino diferentis-Lepidietum subulati Rivas Goday 1957

Thymo gypsicolae-Ononidetum tridentatae Rivas Mart. & G. López 1976

Helianthemo alypoidis-Gypsophiletum struthium (Rivas Goday & Esteve 1968) Alcaraz, T. E. Díaz, Rivas Mart. & Sánchez-Gómez 1989

Lepidio subulati-Teucrietum balthazaris Alcaraz, Sánchez-Gómez, De la Torre, S. Ríos & J. Álvarez 1991

Santolino viscosae-Gypsophiletum struthium Rivas Goday & Esteve 1968

Teucrio balthazaris-Santolinetum viscosae Peinado, Alcaraz & Mart. Parras 1992

Helianthemo thibaudii-Gypsophiletum hispanicae Rivas Goday 1957 corr. Rivas Mart., Báscones, T. E. Díaz, Fern. Gonz. & Loidi 1991

Herniario fruticosae-Helianthemetum squamati O. Bolòs 1996

Ononidetum tridentatae Braun-Blanq. & O. Bolòs 1958

Salvio lavandulifoliae-Gypsophiletum hispanicae Rivas Goday 1957

Teucrio expansi-Gypsophiletum hispanicae Rivas Mart., T. E. Díaz, Fern.Gonz., Izco, Loidi, Lousâ & Penas 2002

Helianthemo thibaudii-Teucrietum verticillati Rivas Goday & Rigual 1996

Helianthemo thibaudii-Teucrietum lepicephali Rivas Goday & Rigual 1958 corr. Alcaraz, T. E. Díaz, Rivas Mart. & Sánchez-Gómez 1989

Teucrio verticillati-Thymetum pallentis Bellot, Esteve & Rivas Goday 1968

Thymo moroderi-Teucrietum verticillati Alcaraz, Sánchez-Gómez, De la Torre, S. Ríos & J. Álvarez 1991