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A synecological study of communities with *Santolina corsica* Jordan et Fourr.

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Santolina corsica is endemic to Corsica and Sardinia, with the main distributional area in central-northern Corsica. The distribution and floristic composition of the communities with *S. corsica* were studied in relation to different environmental parameters such as altitude, geology and soil. The data was analysed by numerical methods: two-way indicator species (TWINSPAN) and Canonical Correspondence Analysis (CCA). TWINSPAN classification of 39 relevés revealed seven different community groups which were interpreted as belonging to a new subassociation of *Stachydi-Genistetum* in the alliance *Teucrion mari* (order *Rosmarinetalia*) and to *Helichryso-Santolinetalia.* The floristic composition of the communities studied was significantly correlated with the gradient of soil evolution. Another important factor was interpreted to be substrate coherence/incoherence. The altitude/temperature gradient was not correlated with the floristic composition of the different communities. Several communities were regeneration stages after cultivation or grazing, and others seemed to be relatively unaffected by human activity. The ecological optimum for *S. corsica* was in the former, in codominance with *Helichrysum italicum.*

Key words: *Santolina corsica*, chamaephyte, vegetation, phytosociology, synecology, Corsica, France

Introduction

Santolina corsica Jordan et Fourr., endemic to Corsica and northern Sardinia, grows in arid degraded environments. Its *locus classicus* is near Bastia in Corsica (ARRIGONI 1979, MARCHI et al. 1979, PIGNATTI 1982). This recent polyploid (2n = 36) apoendemism is regarded by some authors as originating from the group of santolinas of the Italian peninsula (GARBARI 1970, VERLAQUE et al. 1995), and by others as originating from those of the Franco-Iberian group (BECHI et al. 1996).

Vegetation types dominated by *S. corsica* have been described from central Corsica and northern Sardinia, and they have been attributed to different phytosociological units. Com-

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munities are reported in garigues on calcareous and schistose substrates, in most cases in codominance with *Helichrysum italicum* (PIGNATTI et al. 1980, GAMISANS 1991).

There have been few synecological studies on species of the genus *Santolina*, despite many descriptions of syntaxa with santolinas as physiognomically characteristic or dominant species (PEINADO and MARTINEZ-PARRAS 1984, ARRIGONI and DI TOMMASO 1991, BIONDI et al. 1996, SCOPPOLA and ANGIOLINI 1997a, 1997b, ANGIOLINI et al. 1998).

In view of the importance of detailed studies on plant endemisms (MAJOR 1988, GARBARI 1990), the main aim of the present study was to examine the ecological and phytosociological range of *S. corsica* in central-northern Corsica and to identify any environmental variables correlated with the distributional pattern and floristic composition of communities with this species.

Study area

The area of investigation is located in central-northern Corsica (42°15' – 42°35' N, 9°0' – 9°25' E Grw), at altitudes between about 200 and 900 m, coinciding with the centre of the distribution of *S. corsica* (Fig. 1). The area is mainly in the schistose and alpine parts of Corsica, with predominantly hilly morphology. Much of the bedrock is basic rocks such as limestone, schist-limestone-sandstone formations and ophiolites. In the Venaco area, whitish non-calcareous feldspathic sandstone is common (ROSSI and ROUIRE 1980).

Climate is sub-Mediterranean and marginally montane (GAMISANS 1991). Zonal vegetation (GAMISANS 1986, 1991) includes woods and high maquis dominated by evergreen oaks (*Galio scabrii-Quercetum ilicis* Boyer et al. (1983) Gamisans 1988) on shallow loose soil; woods dominated by *Quercus pubescens* always with *Q. ilex*, which is sometimes codominant with *Fraxinus ornus* and *Ostrya carpinifolia* (*Galio scabrii-Quercetum ilicis quercetosum pubescentis* Boyer et al. (1983) Gamisans 1988) on better preserved soils, for example in ravines with organic material; meso-Mediterranean chestnut woods having a floristic affinity with *Digitali-Castanetum* Gamisans (1975) 1977 in cooler moister situations, northern exposures and valleys with deep soil.

Materials and methods

Thirty-nine phytosociological relevés, representing the range of the main geographic and soil parameters of communities with *S. corsica*, were carried out in 1997. The following environmental data was obtained or measured for each relevé: vegetation cover (%), lichen and moss cover (%), stoniness (%), rockiness (%), slope (°), aspect (1 = N, 2 = NE, 3 = NW, 4 = E, 5 = W, 6 = SE, 7 = SW, 8 = S), altitude (m a.s.l.), geology (0 = alluvium, 1 = ophiolites, 2 = limestone, 3 = calcareous-arenaceous schists, 4 = sandstone), substrate coherence/incoherence (1/0). Soil samples were taken from the upper 10 cm, dried at 20 °C and used for soil-chemical analysis (M.R.A.A.F. 1994). The following soil parameters were analysed: pH of the < 2 mm fraction suspended 1:2.5 in distilled water (SOC. ITAL. DELLA SCI. DEL SUOLO 1985); organic C by the modified method in GAUDETTE et al. (1974) on the 0.250 mm fraction; total N by the method of Kjeldahl deduced from M.R.A.A.F. (1994) on the 0.200 mm fraction; extractable K^+, Na^+, Mg^{2+}, Ca^{2+} as µg/g d.w. (ppm) in 3 ml HNO^3 (65%) according to standard methods described in M.R.A.A.F. (1994).

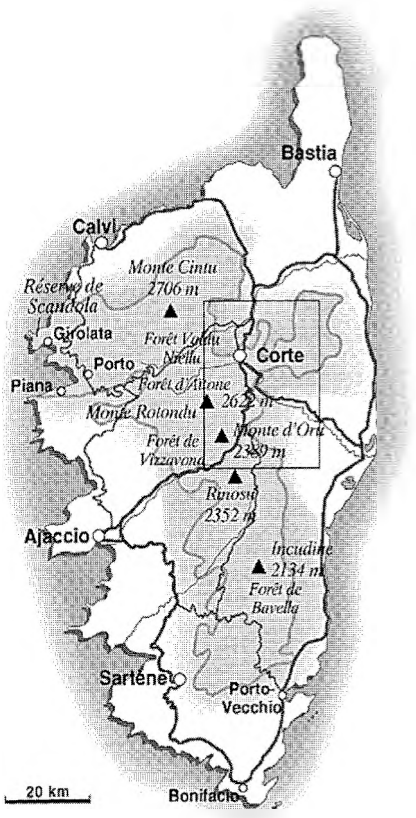

Fig. 1. Study area (rectangle) in Corsica.

The relevés were classified by a divisive polythetic method (Two-Way INdicator SPecies ANalysis – TWINSPAN) (HILL 1979). Five pseudospecies cut-levels were selected corresponding to 0, 2, 3, 5 and 7.

Ordering of the vegetation and environmental data was performed by Direct Gradient Analysis (DGA) to explore the relationships between vegetation and habitat. Since the data was acquired along an environmental gradient, expecting the presence of a major coenocline, a unimodal model was regarded as appropriate (PIELOU 1984, TER BRAAK 1987) and Canonical Correspondence Analysis (CCA, TER BRAAK 1990) was applied. To determine the relative importance of the environmental variables for vegetation, and the relative variation in species data explained by the environmental variables, forward selection of explanatory variables (TER BRAAK 1990) was used. To assess the statistical significance of each variable on inclusion in the regression model and of the first ordination axis, the Monte Carlo permutation test (TER BRAAK 1990) was used with 99 unrestricted permutations of the constraining variable. Throughout the analysis, relations between species and environmental variables were taken to be significant at $P < 0.05$. CCA was carried out using the CANOCO version 3.12 programme (TER BRAAK 1987; 1991). Infrequent species were down-weighted; otherwise default settings were used.

Species cover values in the matrix were transformed according to VAN DER MAAREL (1979) and NOEST et al. (1989). All quantitative skewed variables with a log-normal distribution were transformed by taking their natural logarithm to give them a normal distribution (JONGMAN et al. 1995).

Taxonomic nomenclature is according to TUTIN et al. (1968–1980; 1993).

Results

Vegetation classification by two-way species indicator analysis (TWINSPAN)

The first divisions of the TWINSPAN hierarchical classification and the main indicator species are shown in figure 2. At the third division, the relevés fall into seven main groups (community types). An abbreviated TWINSPAN table with the plant communities recognised and their characteristic and differential species is shown in table 1. The first division of the dendrogram (Fig. 2) is of particular interest as it represents two broad groups of relevés: the relevés of the left hand division (group 0) were almost entirely on coarse, rarely disturbed substrate (indicator species *Teucrium polium* ssp. *capitatum* and *Brachypodium retusum*), whereas plots of the right hand division (group 1) were predominantly on incoherent frequently disturbed substrate (indicator species *Achillea ligustica*).

Stachys glutinosa type (SG)

Relevé groups 000 and 001

This type contains communities rich in endemic chamaephytes and nanophanerophytes, such as *Stachys glutinosa, Teucrium marum* and *Genista corsica,* that colonize rocky soils subject to erosion. *Cistus monspeliensis* and sometimes *Rosmarinus officinalis*

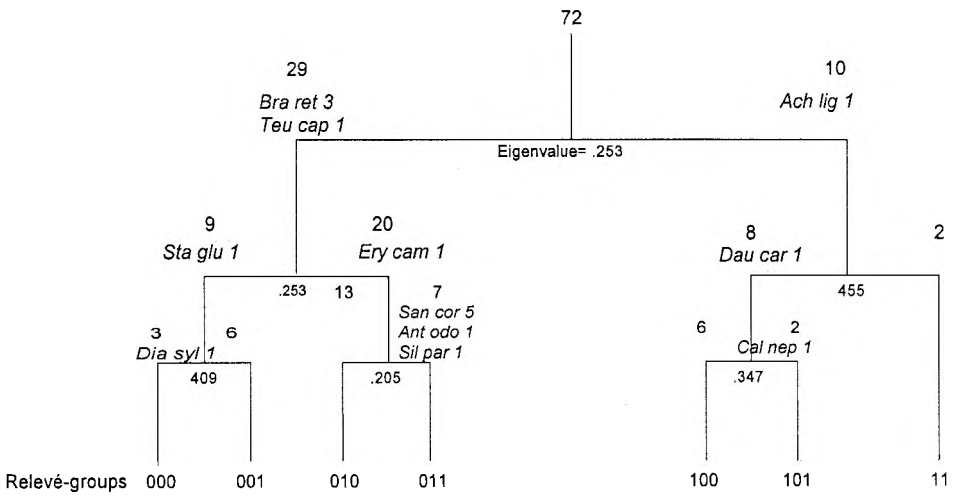

Fig. 2. The first divisions of the TWINSPAN classification. The numbers above the abbreviations of the species refer to the number of relevés in each group. Numbers after three-letter abbreviations are cover cut-levels for indicator species/pseudospecies.

Tab. 1. Simplified TWINSPAN-table of the 7 different *S. corsica* relevé groups. Roman numerals indicate percentage frequency (F) of species (V>80%; IV=61–80%; III=41–60%; II=20–40%; I<20%); arabic numbers indicate mean percentage cover (C) in cluster groups.

Type	SG		SG		EC		EC		DC		DC		DV	
TWINSPAN groups	000		001		010		011		100		101		11	
No of. relevés	3	3	6	6	13	13	7	7	6	6	2	2	2	2
	F	C	F	C	F	C	F	C	F	C	F	C	F	C
Anthoxanthum odoratum	-	-	-	-	I	0.01	V	0.43	I	0.02	-	-	-	-
Pallenis spinosa	-	-	-	-	III	0.05	V	0.77	-	-	III	0.05	-	-
Acer monspessulanum	-	-	-	-	-	-	I	0.01	-	-	-	-	-	-
Agrostis castellana	-	-	-	-	-	-	II	0.03	-	-	-	-	-	-
Anthyllis vulneraria ssp. *praepropera*	-	-	-	-	II	0.21	III	1.09	-	-	-	-	-	-
Campanula rapunculus	-	-	-	-	-	-	II	0.03	-	-	-	-	-	-
Cynosurus echinatus	-	-	-	-	-	-	I	0.01	-	-	-	-	-	-
Origanum vulgare	-	-	-	-	II	0.41	IV	3.23	-	-	-	-	-	-
Prunella laciniata	-	-	-	-	I	0.01	III	0.40	-	-	-	-	-	-
Pulicaria odora	-	-	-	-	I	0.01	II	0.03	-	-	-	-	-	-
Salvia verbenaca	-	-	-	-	I	0.02	II	0.71	-	-	-	-	-	-
Teucrium chamaedrys	II	0.03	-	-	III	0.23	III	0.74	-	-	-	-	-	-
Asparagus acutifolius	-	-	-	-	I	0.2	-	-	-	-	-	-	-	-
Bellis sylvestris	-	-	-	-	I	0.01	-	-	-	-	-	-	-	-
Clinopodium vulgare	-	-	-	-	I	0.01	-	-	-	-	-	-	-	-
Convolvulus cantabrica	-	-	II	0.03	V	0.45	II	0.03	-	-	-	-	-	-
Dorycnium penthaphyllum ssp. *herbaceum*	-	-	-	-	II	0.58	-	-	-	-	-	-	-	-
Eryngium campestre	-	-	-	-	V	0.08	IV	0.41	-	-	-	-	-	-
Helianthemum nummularium	-	-	-	-	I	0.2	-	-	-	-	-	-	-	-
Pistacia lentiscus	-	-	-	-	I	0.2	-	-	-	-	-	-	-	-
Clematis flammula	-	-	I	0.02	II	0.41	I	0.01	-	-	-	-	-	-
Galium lucidum	V	0.1	I	0.42	V	0.83	III	0.73	-	-	III	0.05	-	-
Hieracium piloselloides	II	0.03	-	-	III	0.23	I	0.01	-	-	-	-	-	-
Hyoseris radiata	-	-	III	0.45	II	0.03	V	0.09	-	-	-	-	-	-
Potentilla hirta	IV	0.07	-		II	0.02	III	0.39	-	-	-	-	-	-
Lotus corniculatus	-	-	-		III	0.05	IV	0.07	-	-	-	-	V	0.10
Daphne gnidium	-	-	I	0.42	I	0.01	I	0.01	-	-	-	-	-	-
Teucrium polium ssp. *capitatum*	V	0.9	V	10.4	V	9.45	V	1.11	-	-	-	-	-	-
Trisetum flavescens	-	-	I	0.02	I	0.01	I	0.36	-	-	-	-	-	-
Bupleurum fruticosum	-	-	I	0.42	I	1.15	-	-	-	-	-	-	-	-
Olea europea var. *sylvestris*	-	-	I	0.02	I	0.2	-	-	-	-	-	-	-	-
Ruta graveolens	-	-	I	0.42	II	0.21	-	-	-	-	-	-	-	-
Juniperus oxycedrus ssp. *macrocarpa*	II	0.03	I	0.02	I	0.01	-	-	-	-	-	-	-	-
Allium sphaerocephalon	-	-	-		I	0.01	-	-	I	0.02	-	-	-	-
Euphorbia spinosa	V	6.67	II	0.03	-	-	-	-	-	-	-	-	-	-
Melica minuta	-	-	II	0.03	-	-	-	-	-	-	-	-	-	-
Lolium sp.	-	-	I	0.02	-	-	-	-	-	-	-	-	-	-
Isatis tinctoria	-	-	I	0.02	-	-	-	-	-	-	-	-	-	-
Marrubium vulgare	-	-	I	0.02	-	-	-	-	-	-	-	-	-	-
Rosmarinus officinalis	-	-	II	10.8	I	0.19	-	-	-	-	-	-	-	-
Teucrium flavum	IV	0.87	-		-	-	-	-	-	-	-	-	-	-
Carex flacca	IV	0.07	-		II	0.22	II	0.03	I	0.02	-	-	-	-
Dorycnium hirsutum	-	-	III	0.45	III	0.61	-	-	I	0.02	-	-	-	-
Brachypodium retusum	V	0.9	V	4.18	V	11.9	V	7.86	III	0.85	V	1.30	III	0.05

Tab. 1. – continued

Type	SG		SG		EC		EC		DC		DC		DV	
TWINSPAN groups	000		001		010		011		100		101		11	
No of. relevés	3	3	6	6	13	13	7	7	6	6	2	2	2	2
	F	C	F	C	F	C	F	C	F	C	F	C	F	C
Odontites lutea	-	-	II	0.03	IV	0.63	IV	0.41	III	0.05	-	-	-	-
Ononis spinosa	-	-	I	0.02	IV	0.8	V	9.64	I	0.42	-	-	V	20.00
Scabiosa atropurpurea	-	-	-		II	0.78	II	0.03	II	0.03	III	0.05	-	-
Asphodelus aestivus	-	-	III	0.05	III	0.6	I	0.01	II	0.03	III	0.05	-	-
Carlina corymbosa	-	-	V	0.08	V	1.78	V	1.80	IV	0.07	III	0.05	V	0.10
Dactylis hispanica	-	-	IV	0.07	IV	0.08	III	0.06	IV	0.07	V	1.30	-	-
Hypericum perforatum	II	0.03	V	0.08	V	0.09	V	0.10	IV	0.07	V	1.30	-	-
Plantago lanceolata	-	-	III	0.05	IV	0.07	V	0.09	V	0.08	III	0.05	-	-
Santolina corsica	V	18.3	V	17.9	V	15.6	V	41.07	V	18.33	V	37.50	V	20.00
Reichardia picroides	IV	0.07	III	0.05	III	0.05	V	0.44	II	0.03	V	1.30	-	-
Sanguisorba minor	IV	0.07	V	0.08	IV	0.26	IV	0.07	V	0.48	III	0.05	V	0.10
Cistus monspeliensis	V	10	IV	5.83	V	18.9	II	0.03	V	0.48	III	0.05	III	7.50
Dianthus sylvestris	V	0.1	-	-	-	-	II	0.03	I	0.02	-	-	-	-
Stachys glutinosa	IV	0.87	V	6.27	II	1.55	-	-	III	0.05	-	-	-	-
Teucrium marum	V	18.3	V	3.77	V	5.04	II	0.03	III	2.93	III	0.05	III	0.05
Cynodon dactylon	-	-	I	0.02	I	0.01	-	-	-	-	III	0.05	-	-
Daucus carota	-	-	I	0.02	IV	0.25	III	0.06	V	0.10	V	0.10	-	-
Erica arborea	-	-	-	-	I	0.01	III	0.04	II	0.03	-	-	-	-
Foeniculum vulgare	II	0.03	-	-	II	0.03	II	0.37	I	0.02	V	0.10	III	0.05
Helichrysum italicum	IV	0.87	V	0.9	V	2.89	V	7.51	V	22.08	III	7.50	V	2.50
Quercus ilex	-	-	II	0.03	II	0.03	I	0.01	III	0.05	-	0.00	-	-
Urospermum dalechampii	V	0.1	I	0.02	II	0.02	III	0.06	V	0.08	-	0.00	-	-
Calamintha nepeta	-	-	IV	0.87	-	-	I	0.01	-	-	V	1.30	-	-
Petrorhagia saxifraga	V	0.1	IV	0.07	I	0.01	I	0.01	II	0.43	-	-	III	0.05
Anthyllis hermanniae	II	0.03	-	-	-	-	-	-	-	-	-	-	III	0.05
Genista corsica	II	0.03	IV	0.47	-	-	-	-	I	0.02	-	-	III	1.25
Sedum dasyphyllum	II	0.03	II	0.03	-	-	I	0.01	IV	0.07	-	-	-	-
Allium sp.	-	-	I	0.02	-	-	-	-	-	-	-	-	-	-
Euphorbia characias	IV	0.07	-	-	I	0.01	-	-	I	0.42	III	0.05	V	1.30
Lathyrus latifolius	-	-	-	-	I	0.01	I	0.01	II	0.03	-	-	-	-
Silene paradoxa	V	1.7	I	0.02	-	-	IV	0.41	V	1.28	III	0.05	-	-
Jasione montana	IV	0.07	-	-	-	-	-	-	III	0.05	-	-	III	0.05
Taraxacum gr. *officinale*	-	-	-	-	I	0.02	I	0.01	III	0.45	III	0.05	-	-
Achillea ligustica	-	-	-	-	-	-	II	0.03	V	2.08	V	0.10	-	-
Andryala integrifolia	-	-	-	-	-	-	-	-	II	0.03	III	0.05	-	-
Briza maxima	-	-	-	-	-	-	I	0.01	II	0.03	-	-	-	-
Chondrilla juncea	-	-	-	-	-	-	-	-	IV	0.87	III	1.25	-	-
Clematis vitalba	-	-	-	-	-	-	-	-	II	0.43	III	0.05	III	0.05
Crupina crupinastrum	-	-	-	-	-	-	-	-	I	0.02	III	0.05	III	0.05
Echium italicum	-	-	-	-	-	-	-	-	I	0.02	III	0.05	-	-
Holcus lanatus	-	-	-	-	-	-	-	-	I	0.02	-	-	-	-
Lactuca saligna	-	-	-	-	-	-	-	-	I	0.02	-	-	-	-
Lactuca serriola	-	-	-	-	-	-	-	-	-	-	III	0.05	-	-
Lagurus ovatus	-	-	-	-	-	-	-	-	I	0.02	-	-	-	-
Lavandula stoechas	-	-	I	0.02	-	-	-	-	IV	3.35	-	-	-	-
Malva neglecta	-	-	-	-	-	-	-	-	-	-	III	0.05	-	-

Tab. 1. – continued

Type	SG		SG		EC		EC		DC		DC		DV	
TWINSPAN groups	000		001		010		011		100		101		11	
No of. relevés	3	3	6	6	13	13	7	7	6	6	2	2	2	2
	F	C	F	C	F	C	F	C	F	C	F	C	F	C
Misopates orontium	-	-	I	0.02	-	-	-	-	II	0.03	-	-	-	-
Paronychia argentea	-	-	-	-	-	-	-	-	I	0.42	-	-	-	-
Cistus creticus ssp. *eriocephalus*	-	-	-	-	II	0.39	-	-	IV	5.83	III	1.25	-	-
Potentilla recta	-	-	-	-	I	0.01	-	-	I	0.02	-	-	-	-
Melica ciliata ssp. *magnolii*	-	-	I	0.02	-	-	-	-	I	0.02	-	-	III	0.05
Helleborus lividus ssp. *corsicus*	-	-	-	-	-	-	-	-	-	-	-	-	III	0.05
Hypericum tetrapterum	-	-	-	-	-	-	-	-	-	-	-	-	III	0.05
Scrophularia canina	-	-	-	-	-	-	-	-	-	-	III	1.25	V	20.00
Dittrichia viscosa	-	-	I	0.02	-	-	-	-	I	0.02	-	-	V	2.50

are of physiognomic significance. *S. corsica* and *Teucrium polium* ssp. *capitatum* form part of the flora of these community types. Relevé group 000 contains plots on ophiolitic substrates and is differentiated by *Dianthus sylvestris* and *Euphorbia spinosa.*

Eryngium campestre type (EC)

Relevé groups 010 and 011

These relevés, mainly previously cultivated fields and abandoned pastures, were found to be impoverished in the endemic species that characterized the SG type, but they have a significant presence of *Helichrysum italicum,* regarded as an index of loamy soil with low rockiness (GAMISANS and MURACCIOLE 1985).

Group 011 is more clearly differentiated. It contains almost none of the endemics characteristic of the SG type, whereas species typical of nitrogen-rich soils that conserve some degree of moisture in summer, such as *Ononis spinosa, Origanum vulgare* and *Anthoxanthum odoratum*, become frequent and abundant. *S. corsica* is one of the indicator species of this relevé group.

Daucus carota type (DC)

Relevé groups 100 and 101

This type includes chamaephytic communities colonizing environments subject to human disturbance (road edges, quarries, etc.) with *Daucus carota* as indicator species. Physiognomy is determined by *S. corsica, H. italicum* and *Achillea ligustica.* Species such as *Chondrilla juncea* and *Clematis vitalba* indicate soils poor in nitrogen and frequently disturbed (BIONDI et al. 1994, ANGIOLINI et al. 1998). This type also hosts species of acidophilous garigues, such as *Lavandula stoechas.*

Dittrichia viscosa type (DV)

Relevé group 11

This type includes relevés in ophiolitic areas on river terraces of limited thickness, subject to frequent flooding, structurally very similar to the previous type, from which it is distinguished by glareicolous species such as *Scrophularia canina* and *Dittrichia viscosa.*

Canonical Correspondence Analysis (CCA)

The results of CCA are shown in figure 3. The environmental variables explained 32.0% (axis 1 and 2) of the variance in the weighted averages of the species with respect to the environmental variables. The eigenvalues of axes 1 and 2 were 0.188 and 0.143 respectively, with a sum of unconstrained eigenvalues of 2.154. The eigenvalue of axis 1 was statistically significant ($P<0.05$). The first axis was significantly correlated with soil Mg content and negatively with K content and geology. The second axis was negatively correlated with soil Ca content and coherent substrate. Axis 3 was best correlated with soil organic carbon content and total nitrogen. Axis 4 was correlated with rockiness. The correlations between the CCA-axes and the environmental variables are listed in table 2.

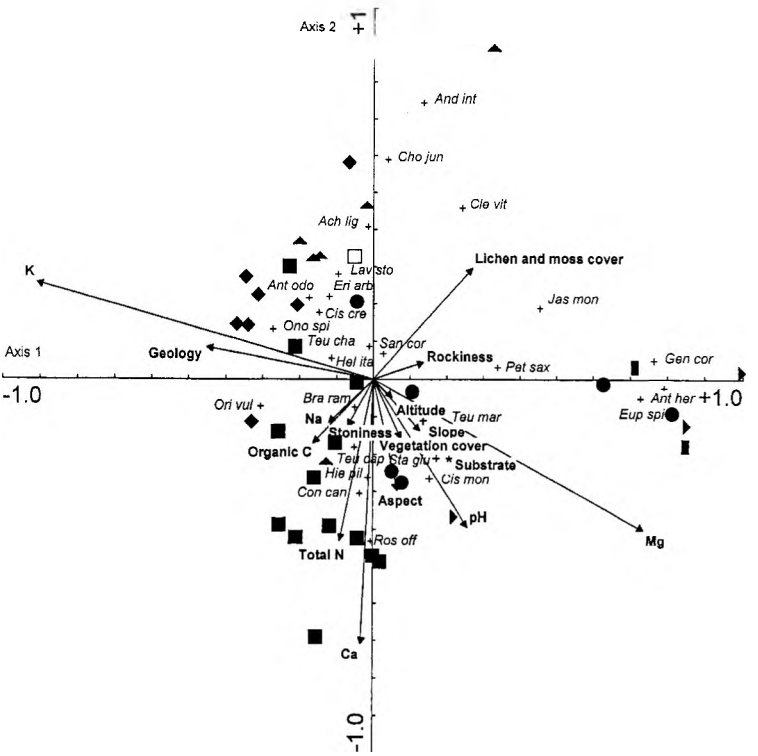

Fig. 3. CCA ordering of the relevés and species on CCA axes 1 and 2 (arrows = quantitative variables, stars = nominal variables). The simbols of the relevé groups are: ▸ 000; ● 001; ■ 010; ◆ 011; ▲ 100; □ 101; ▮ 11.

Ecological interpretation of the CCA-axes

Figure 3 shows the species, relevés and environmental variables in relation to the first CCA-axes. On the first axis, relevé groups 000, 001, 11, the narrow Mediterranean species and Corsican endemics, such as *Cistus monspeliensis, Stachys glutinosa, Teucrium marum, Genista corsica* and *Euphorbia spinosa* are situated in the right part of the diagram; relevé groups 010, 011, 100, 101, the euri–Mediterranean and mesic species, such as *Ononis*

Tab. 2. Canonical correspondence analysis: correlation of environmental variables with CCA axes 1–4. Values in bold are statistically significant (P<0.05).

	Species A×1	Species A×2	Species A×3	Species A×4
Altitude (m a.s.l.)	0.05	–0.04	0.13	0.03
Lichen and moss cover (%)	0.26	0.26	–0.26	–0.02
Vegetation cover (%)	0.07	–0.14	–0.29	–0.17
Aspect	0.06	–0.26	–0.27	–0.27
Slope (°)	0.12	–0.12	0.12	–0.01
Stoniness (%)	–0.07	–0.11	0.38	0.10
Rockiness (%)	0.13	0.04	0.32	**0.48**
pH	0.24	–0.34	–0.31	0.00
Organic C	–0.16	–0.15	**–0.49**	0.05
Total N	–0.09	–0.38	**–0.46**	–0.06
Substrate stability	0.36	**–0.50**	–0.33	–0.06
Geology	**–0.43**	0.07	0.15	–0.02
Na	–0.12	–0.10	–0.11	–0.18
K	**–0.86**	0.23	–0.14	–0.11
Ca	–0.03	**–0.62**	–0.26	0.12
Mg	**0.70**	–0.35	0.13	–0.12

spinosa, *Origanum vulgare*, *Teucrium chamaedrys* and *Hieracium piloselloides* are situated in the left part. Soil Mg content, which is high in serpentine soils, increases in the positive part of the first axis and has an opposite trend to extractable K, a nutrient which is deficient in these soils (BROOKS 1987). The first axis can therefore be interpreted as a soil evolution gradient ranging from xeric, nutrient-poor and infertile (prevalently ophiolitic skeletal and shallow soils) to loamy and nutrient-rich with a humus layer (soils previously used for cultivation and pasture).

According to the ordering of species and relevés, the second CCA axis may be interpreted as an inverse gradient of Ca content and soil coherence. In fact, basophilous and calcicolous species such as *Rosmarinus officinalis, Convolvulus cantabrica* and *Teucrium polium* ssp. *capitatum* were mostly in the lower part of the diagram, the others in the upper part (i.e. *Lavandula stoechas, Erica arborea, Anthoxanthum odoratum*). At the very top we find pioneer species typical of loose soils, such as *Chondrilla juncea, Achillea ligustica, Andryala integrifolia* and relevé groups 100, 101. At the bottom we find species typical of stable coherent substrates, such as *Cistus monspeliensis, Hieracium piloselloides, Convolvulus cantabrica* and relevé groups 010. *S. corsica* is associated with *H. italicum* in the upper, central part of the diagram.

Discussion

Phytosociology

Communities with *S. corsica* can be attributed to two orders: *Rosmarinetalia* Br.-Bl. ex Molinier 1934 of basophilous garigues and *Helichryso-Santolinetalia* Peinado et Martinez-Parras 1984 of subnitrophilous chamaephyte communities.

By its species composition, physiognomy and ecology, the SG type can be attributed to *Stachydi-Genistetum* Gamisans et Muracciole 1984, an association described by GAMISANS

Tab. 3. *Stachydi-Genistetum* Gamisans et Muracciole 1984 *santolinetosum corsicae* subass. nova

Relevé number	1	2	3	4	5	6	7*	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Altitude (m a.s.l.)	740	720	790	460	490	810	810	475	480	780	460	470	475	440	730	510	520	500	510	800	750	430
Slope (°)	0	0	25	10	15	20	25	8	5	25	10	7	5	5	15	5	3	3	5	10	18	3
Aspect	/	/	SSW	S	W	SSW	S	S	S	SE	SE	E	SE	NE	E	SSE	S	SE	S	SW	SE	NE
Cover (%)	70	75	45	65	55	65	55	85	75	40	80	40	60	60	85	45	65	45	70	45	90	35
Plot surface (sq. m)	25	20	20	25	25	30	20	20	25	25	20	20	30	25	30	30	25	15	20	15	35	35
Relevé groups	000	000	000	001	001	001	001	001	001	010	010	010	010	010	010	010	010	010	010	010	010	010
Caracter and differential species of association and alliance																						
Teucrium marum	1	2	3	2		1	1	+	1	+	1	+	2	2	+	2	2	+	1	+	+	+
Stachys glutinosa	+	1	+	+	2	2	1	1	1	1			2	+				+	+		1	+
Genista corsica		+				1	+	+	+													
Rosmarinus officinalis								3	1			+	1									
Differential species of subassociation																						
Santolina corsica	3	2	1	2	3	1	3	+	2	2	3	2	2	1	2	2	3	1	2	2	2	1
Teucrium polium ssp. *capitatum* *	+	1	+	3	2	1	1	1	1	+	2	2	2	3	+	1	1	2	1	2	+	1
Species of *Helichrysum italicum* variant																						
Helichrysum italicum		+	1	+	+	+	+	+	+	1	1	1	2	1	1	1	1	+	1	1	1	1
Species of *Rosmarinetalia, Rosmarinetea* *																						
Cistus monspeliensis	3	3	1		+	3	2	2	3	+			1	+	3	+	+	1	3	2	3	3
Convolvulus cantabrica						+		+			+		+	+	+	1	1	+	+	+	+	+
Dorycnium hirsutum						+		1	+	1				+	+		+	+	1			1
Petrorhagia saxifraga	+	+	+	+	+	+	+				+											
Euphorbia spinosa	2	1	1			1	1															
Scabiosa atropurpurea										1				+				1	1	1		
Potentilla hirta	+	+															+				+	+
Cistus creticus ssp. *eriocephalus*																		1	1	+		
Contacts with *Brometalia rubenti-tectori*																						
Carlina corymbosa				+	+	+	+	+		+	2	1	+	+	1	+	1		+	+		+
Reichardia picroides	+		+	+	+		+			+	+	+		+		+				+	+	
Daucus carota								+		+	+		+		1		+		+		+	+
Urospermum dalechampii	+	+	+		+										+	+		+				
Hyoseris radiata				+	1				+	+	+		+	+								
Salvia verbenaca										+										+		
Contacts with *Quercetea ilicis*																						
Clematis flammula					+									+				+	+		1	1
Quercus ilex						+			+						+				+		+	+
Juniperus oxycedrus ssp. *macrocarpa*		+		+									+									
Olea europea var. *sylvestris*									+			+									1	
Daphne gnidium									1								+					
Asparagus acutifolius														+								1
Pistacia lentiscus																			+			1

Tab. 3. – continued

Relevé number	1	2	3	4	5	6	7*	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Altitude (m a.s.l.)	740	720	790	460	490	810	810	475	480	780	460	470	475	440	730	510	520	500	510	800	750	430
Slope (°)	0	0	25	10	15	20	25	8	5	25	10	7	5	5	15	5	3	3	5	10	18	3
Aspect	/	/	SSW	S	W	SSW	S	S	S	SE	SE	E	SE	NE	E	SSE	S	SE	S	SW	SE	NE
Cover (%)	70	75	45	65	55	65	55	85	75	40	80	40	60	60	85	45	65	45	70	45	90	35
Plot surface (sq. m)	25	20	20	25	25	30	20	20	25	25	20	20	30	25	30	30	25	15	20	15	35	35
Relevé groups	000	000	000	001	001	001	001	001	001	010	010	010	010	010	010	010	010	010	010	010	010	010
Other species																						
Brachypodium retusum	+	+	1	+	1	1	1	1	2	1	2	1	1	2	1	2	2	2	2	1	2	3
Hypericum perforatum	+			+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	
Sanguisorba minor	+	+		+	+	+		+	+		+	+	+	+	+	+			+	1	+	+
Galium lucidum	+	+	+		1					+	1	+	+	+	+	1	+		+	+	1	1
Dactylis hispanica				+			+	+	+	+	+	+	+	+	+	+	+	+				+
Plantago lanceolata				+		+	+			+	+	+			+	+	+	+			+	+
Odontites lutea								+	+	1	+	1	+	1		+		+	+	+		+
Eryngium campestre										+	+	+	+		+	+	+	+	+	+		+
Ononis spinosa							+			+		+			+		1	1	1	1	+	
Asphodelus aestivus				+				+	+		1	1	1	+		+	+					
Carex flacca	+	+														+	+	1	+		+	
Teucrium chamaedrys	+									+							+	1	+	+	+	
Hieracium piloselloides	+													+	+	1		+		+		+
Pallenis spinosa										+	+		+					+	+	+	+	
Origanum vulgare														1			+	+	1			+
Silene paradoxa	1	1	+		+																	
Calamintha nepeta				1	+	+	1															
Ruta graveolens									1		+	1							+			
Dorycnium penthaphyllum ssp. *herbaceum*																+	1	1	1			
Dianthus sylvestris	+	+	+																			
Euphorbia characias	+	+										+										
Sedum dasyphyllum			+	+			+															
Lavandula stoechas					+											+		+				
Teucrium flavum	+	1																				
Bupleurum fruticosum						1				2												
Helianthemum nummularium										+										1		
Jasione montana	+	+																				
Taraxacum gr. officinale																				+		+
Erica arborea																					+	+
Sporadic species	1	2	0	1	1	1	1	1	1	1	1	0	0	1	0	1	1	0	0	0	1	0

List, location, date and sporadic species:

Rel. 1 R. Casaluna 16-07-97 – *Nothalaena marantae* (+); Rel. 2 R. Casaluna 16-07-97 – *Anthyllis hermanniae* (+), *Nothalaena marantae* (+); Rel. 3 Sermanu 16-07-97; Rel. 4 Corte 17-07-97 – *Melica minuta* (+); Rel. 5 P.Leccia/Sermanu 22-07-97 – *Isatis tinctoria* (+); Rel. 6 Bustanico 16-07-97 – *Medicago lupulina* (+), Rel. 7 Bustanico 16-07-97 – *Marrubium vulgare* (+); Rel. 8 Corte 17-07-97 – *Clinopodium vulgare* (+); Rel. 9 Corte 17-07-97 – *Pulicaria odora* (+), Rel. 10 - Tralonca 25-07-97 – *Melica ciliata* ssp. *magnolii* (+); Rel. 11 Corte 17-07-97 – *Bellis sylvestris* (+), Rel. 12 Corte 17-07-97; Rel. 13 Corte 17-07-97, Rel. 14 *Ponte Leccia* 21-07-97 – *Dittrichia viscosa* (+), Rel. 15 - Sermanu 16-07-97; Rel. 16 Ponte Leccia 21-07-97 – *Allium sphaerocephalon* (+), Rel. 17 Ponte Leccia 21-07-97 – *Lathyrus latifolius* (+), Rel. 18 Ponte Leccia 21-07-97, Rel. 19 Ponte Leccia 21-07-97; Rel. 20 Tralonca 24-07-97, Rel. 21 Sermanu 16-07-97 – *Clinopodium vulgare* (+); Rel. 22 Ponte Leccia 16-07-97.

and MURACCIOLE (1984) for the dwarf suffruticose communities of the Scandola Nature Reserve in Corsica and allocated to the alliance *Teucrion mari* (Gamisans et Muracciole 1984) Biondi et Mossa 1992, originally attributed to the order *Lavanduletalia stoechidis* Br. Bl. 1940 em. Riv.-Mart. 1968 (GAMISANS and MURACCIOLE 1984) and after more detailed study to the order *Rosmarinetalia* (BIONDI and MOSSA 1992). However, the floristic impoverishment in species of *Rosmarinetalia* shown in table 3 confirms the difficulty of dividing these communities clearly from those of *Lavanduletalia stoechidis* (BRULLO et al. 1997).

The constant presence of *S. corsica* and *T. polium* ssp. *capitatum* enables us to propose them as differential species of a new subassociation, typical of schistose substrates and the meso-Mediterranean belt, which is transitional towards subnitrophilous garigues of *Helichryso-Santolinetalia*. For the new syntaxon we propose the name *santolinetosum corsicae* (Rel. type no. 7, Tab. 3, *hoc loco*). Although poor in the species characteristic of *Stachydi-Genistetum*, relevé group 010 of EC type can be attributed to this syntaxon, being a variant with *Helichrysum italicum*, typical of soils with low rockiness (GAMISANS and MURACCIOLE 1984) (Tab. 3).

The DC and DV types have some floristic, physiognomic and ecological affinity with *Helichryso-Santolinetalia* (*Pegano-Salsoletea* Br.-Bl. et Bolòs 1958), an order with Mediterranean proper and western distribution (PEINADO and MARTINEZ-PARRAS 1984, PEINADO et al. 1988) (Tab. 4). Structural and dynamic characteristics agree also with the attribution to *Scrophulario-Helichrysetalia* Brullo 1984 (*Scrophulario-Helichrysetea* Brullo, Scelsi et Spampinato 1998) that includes perennial associations with a pioneer character, occurring on loose substrata of different types (screes, gravels, sands, metamorphic and volcanic clasts, etc.) from Sicily and S. Italy (BRULLO et al. 1998). Classification at the rank of association and alliance is not possible because the syntaxa described from Spain and southern Italy are characterized by endemics (PEINADO et al. 1988, BIONDI et al. 1994) and new syntaxa can only be proposed after more extensive study.

Tab. 4. *Helichryso-Santolinetalia* community

Relevé number	1	2	3	4	5	6	7	8	9	10
Altitude (m o.s.l.)	270	275	510	500	510	490	510	490	750	730
Slope (°)	/	/	25	20	25	25	20	/	0	0
Aspect	/	/	ESE	ESE	E	NE	E	/	0	0
Cover (%)	45	60	40	60	40	40	55	40	70	35
Plot surface (sq. m)	20	15	30	25	20	15	20	10	20	15
Relevé groups	100	100	100	100	100	100	101	101	11	11
Species of *Helichryso-Santolinetalia*										
Santolina corsica	3	2	2	1	1	3	3	3	2	1
Helichrysum italicum	1	3	2	3	3	1	2		1	1
Chondrilla juncea	+	1		+		1		1		
Clematis vitalba	+				1		+			
Dittrichia viscosa			+						1	1
Scrophularia canina								1	3	1
Species of *Teucrion mari, Rosmarinetalia*										
Cistus monspeliensis		+	1	+	+	+		+	1	
Cistus creticus ssp. *eriocephalus*			1	2	2	1	1			
Teucrium marum	2	1					+		+	
Scabiosa maritima	+			+			+			

Tab. 4. – continued

Relevé number	1	2	3	4	5	6	7	8	9	10
Altitude (m a.s.l.)	270	275	510	500	510	490	510	490	750	730
Slope (°)	/	/	25	20	25	25	20	/	0	0
Aspect	/	/	ESE	ESE	E	NE	E	/	0	0
Cover (%)	**45**	**60**	**40**	**60**	**40**	**40**	**55**	**40**	**70**	**35**
Plot surface (sq. m)	20	15	30	25	20	15	20	10	20	15
Relevé groups	100	100	100	100	100	100	101	101	11	11
Stachys glutinosa		+	+	+						
Species of *Brometalia rubenti-tectori*										
Daucus carota	+	+	+	+	+	+	+	+		
Carlina corymbosa		+	+	+	+		+		+	+
Urospermum dalechampii		+	+	+	+	+				
Reichardia picroides				+		+	1	+		
Andryala integrifolia	+			+				+		
Foeniculum vulgare			+				+	+	+	
Echium italicum	+							+		
Other species										
Achillea ligustica	1		1	1	1	1	+	+		
Sanguisorba minor	+	1	+		+	+	+		+	+
Silene paradoxa	1	1	+		1	+		+		
Hypericum perforatum	+	+		+		+	+	1		
Brachypodium retusum	1			1		+	1	+	+	
Plantago lanceolata		+	+	+	+	+		+		
Dactylis hispanica			+	+	+	+	1	+		
Lavandula stoechas			2	+	1	1				
Sedum dasyphyllum			+	+	+	+				
Taraxacum gr. officinale				1	+	+	+			
Jasione montana	+	+		+					+	
Euphorbia characias				1			+		1	+
Calamintha nepeta							1	+	+	+
Petrorhagia saxifraga	+	1							+	
Quercus ilex	+		+	+						
Asphodelus aestivus		+		+			+			
Ononins spinosa	+								1	2
Odontites lutea			+		+	+				
Crupina crupinastrum				+			+			+
Lathyrus latifolius	+			+						
Briza maxima		+			+					
Erica arborea			+	+						
Misopates orontium				+	+					
Lotus corniculatus										
Sporadic species	2	4	1	2	3	1	2	4	3	4

List, location, data and sporadic species:
Rel. 1 R. Tavignano 24-07-97 – *Saponaria officinalis* (+), *Genista corsica* (+); Rel. 2 R. Tavignano 24-07-97 – *Lagurus ovatus* (+), *Paronychia argentea* (1), *Anthoxanthum odoratum* (+), *Convolvulus cantabrica* (1); Rel. 3 – Between Corte and Ajaccio 22-07-97 – *Dorycnium hirsutum* (+); Rel. 4 – Between Corte and Ajaccio 22-07-97 – *Potentilla recta* (+), *Prunella laciniata* (+); Rel. 5 Between Corte and Ajaccio 22-07-97 – *Holcus lanatus* (+), *Lactuca saligna* (+), *Potentilla recta* (+); Rel. 6 Between Corte and Ajaccio 22-07-97 – *Dianthus sylvestris* ssp. *longicaulis* (+); Rel. 7 Between Corte and Ajaccio 22-07-97 – *Cynodon dactylon* (+), *Pallenis spinosa* (+); Rel. 8 Between P. Leccia and Sermanu 24-07-1997 – *Lactuca serriola* (+), *Malva neglecta* (+), *Plantago coronopus* (+), *Galium lucidum* (+); Rel. 9 R. Casaluna 16-07-97 – *Helleborus lividus* ssp. *corsicus* (+), *Philostemon casabonae* (+), *Trifolium arvense* (+); Rel. 10 R. Casaluna 16-07-97 – *Anthyllis hermanniae* (+), *Hypericum corsicum* (+), *Melica ciliata* (+), *Populus nigra* (+).

The classification of relevé group 011 of EC type is more problematical. It has good ecological and physiognomic affinity with *Helichryso-Santolinetalia*, but little floristic resemblance (Tab. 5). It is also very close to communities described from northern Sardinia, dominated by *S. corsica* and *H. italicum* and devoid of species typical of *Stachydi-Genistetum*, which PIGNATTI et al. (1980) regard as related to *Thero-Brachypodietalia* Br.-Bl. (1931) 1936. Moreover, it has a large contingent of species of *Brometalia rubenti-tectori* (Rivas-God. et Rivas-Mart. 1963) Rivas-Mart. et Izco 1977, such as *Reichardia picroides, Carlina corymbosa, Hyoseris radiata* and *Daucus carota*.

Tab. 5. Communities with *Ononis spinosa*.

Relevé number	1	2	3	4	5	6	7
Altitude (m a.s.l.)	500	700	810	820	810	750	750
Slope (°)	20	25	5	10	8	10	5
Aspect	S	W	SW	S	SSW	E	ESE
Cover (%)	70	65	60	65	80	70	55
Plot surface (sq. m)	20	15	25	20	30	15	25
Relevé groups	011	011	011	011	011	011	011
Ononis spinosa	2	2	1	2	1	2	1
Species of *Helichryso-Santolinetalia*							
Santolina corsica	3	3	3	3	4	3	3
Helichrysum italicum	2	2	1	1	2	1	+
Species of *Brometalia rubenti-tectori*							
Reichardia picroides	+	1	+	+	+	+	+
Carlina corymbosa	1	+	1		1	1	1
Hyoseris radiata		+	+	+	+	+	+
Daucus carota	+	+			+	+	
Urospermum dalechampii		+	+			+	+
Salvia verbenaca					1		1
Foeniculum vulgare	1					+	
Species of *Teucrion mari, Rosmarinetalia*							
Teucrium polium ssp. *capitatum*	+	1	+	1	+	1	
Potentilla hirta			+	1			+
Convolvulus cantabrica	+			+			
Scabiosa maritima	+		+				
Cistus monspeliensis	+	+					
Teucrium marum				+	+		
Other species							
Brachypodium retusum	1	1	1	2	1	2	2
Hypericum perforatum	+	+	+	+	+	+	+
Pallenis spinosa	+		1	1	+	+	+
Anthoxanthum odoratum		+	+	+	1	+	+
Plantago lanceolata		+	+	+	+	+	+
Eryngium campestre	+		1	+	+		+
Lotus corniculatus			+	+	+	+	+
Origanum vulgare			2	1	1	1	+
Sanguisorba minor	+			+	+	+	+
Silene paradoxa	1		+	+	+	+	
Odontites lutea	1		+	+	+	+	

Tab. 5. – continued

Relevé number	1	2	3	4	5	6	7
Altitude (m a.s.l.)	500	700	810	820	810	750	750
Slope (°)	20	25	5	10	8	10	5
Aspect	S	W	SW	S	SSW	E	ESE
Cover (%)	70	65	60	65	80	70	55
Plot surface (sq. m)	20	15	25	20	30	15	25
Relevé groups	011	011	011	011	011	011	011
Teucrium chamaedrys		1	1		+	+	
Dactylis hispanica		+	+			+	+
Prunella laciniata			1	+	+	+	
Anthyllis vulneraria ssp. praepropera			1	1	1	+	
Erica arborea		+			+	+	
Galium lucidum		1		1	+		
Agrostis castellana			+	+			
Pulicaria odora			+	+			
Dianthus sylvestris ssp. longicaulis				+	+		
Carex flacca ssp. erytrostachys						+	+
Achillea ligustica	+	+					
Campanula rapunculus		+			+		
Sporadic species	3	2	1	3	1	2	5

List, location, data and sporadic species:
Rel. 1 Between P. Leccia and Sermanu 24-07-97 – Daphne gnidium (+), Calamintha nepeta (+), Taraxacum gr. officinale (+); Rel. 2 Tralonca 24-07-97 – Silene vulgaris (+), Quercus ilex (1); Rel. 3 Between Tralonca and Sermanu 25-07-97 – Hieracium piloselloides (+); Rel. 4 Between Tralonca and Sermanu 25-07-97 – Acer monspessulanum (+), Vicia pseudocracca (+), Petrorhagia saxifraga (+); Rel. 4 Between Tralonca and Sermanu 25-07-97 – Sedum dasyphyllum (+); Rel. 6 S. Lucie de Mercurio 25-07-97 – Clematis flammula (+), Lathyrus latifolius (+); Rel. 7 S. Lucie de Mercurio 25-07-97 – Isatis tinctoria (+), Misopates orontium (+), Briza maxima (+), Trisetum flavescens (+), Asphodelus aestivus (+).

Synecology

The communities with *S. corsica* are essentially heliophilous and xerophilous in character. The most frequent species are *Helichrysum italicum* and *Brachypodium retusum* (Tab. 1). Floristic composition includes: i) many endemic chamaephytes in degraded stages of vegetation on relatively unevolved soil. In fact, a degraded environment is determinant for the conservation of endemics and of species with fragmented distributions (PIGNATTI and PIGNATTI 1969, MAJOR 1988), ii) a good contingent of ruderal hemicryptophytes, mainly in communities subject to disturbance by grazing or human activity.

Communities with *S. corsica* are found mainly between altitudes of 400 and 800 m and do not show substantial variations along the altitudinal gradient. They are dominated by steno and euri-Mediterranean species; the number and cover of European and Eurasiatic species is low, except in type EC, which includes coenoses of loamy soils that retain moisture. The pH varies little within and between groups.

Santolina corsica grows mainly on sub-alkaline, only rarely on neutral or alkaline soils. It is therefore an indicator of neutral to alkaline soils in keeping with its geological pattern in central-northern Corsica. In fact it is not found in the granite and volcanic areas of the island where soils have a pH in the range 4.5–5.5. On the other hand, it grows on soils with a wide range of Mg, Ca, K, total N and organic C concentrations. It is not calcicolous because it also grows on ophiolitic soils with a Ca/Mg ratio < 1. It adapts to nutrient-poor soils but

has greatest cover on loamy substrates with residual humus from previous cultivation or grazing, when it takes the role of indicator species. It has quite a wide ecological range with respect to substrate coherence/incoherence and disturbance. Because these factors have a significant effect on the floristic component of a community, they determine its attribution to different syntaxa.

Conclusions

Santolina corsica is quite a common species in central-northern Corsica where it is often dominant and forms large communities in degraded and disturbed environments with sub-alkaline soils. Its distribution largely coincides with the meso-Mediterranean belt, decreasing towards the thermo-Mediterranean and montane belts.

The community types with *S. corsica* described above belong to three main groups: i) garigues of the meso-Mediterranean belt on limestone and sandstone substrates, dominated by chamaephytes and nanophanerophytes such as *Teucrium marum, Cistus monspeliensis* and *Genista corsica* attributed to *Teucrion mari* (*Rosmarinetalia*) (representing the driest situations of the species); ii) *S. corsica* and *H. italicum* dominated communities of abandoned pastures and previously cultivated fields on loamy substrates, belonging to *Helichryso-Santolinetalia* (representing the ecological optimum of the species) (Tab. 1); iii) chamaephytic communities of sub-nitrophilous character belonging to *Helichryso-Santolinetalia* (representing situations with neutral soil). More extensive study about *S. corsica* and *S. insularis*, endemic to Sardinia, could allow the description of a new alliance geographically vicariant to *Artemisio glutinosae-Santolinion rosmarinifoliae* Costa 1975 present in the Iberian peninsula and of *Artemision variabilis* Biondi et al. 1994 of southern Italy.

The floristic composition of the *S. corsica* communities is closely correlated with the gradient of soil evolution. Substrate coherence/incoherence emerged as the second most important gradient. Floristic composition was not correlated with altitude/temperature gradient.

The ecological optimum of *S. corsica* was in communities subject to disturbance. It can therefore be regarded as a good pioneer, like *S. etrusca* (ANGIOLINI and DE DOMINICIS 1998), colonizing environments in which competition is low. Its synecological behaviour is similar to that of other species of the genus, which, although their preferred habitat is in sub-nitrophilous communities subject to disturbance, are also an important component of more stable basophilous garigues (FONT CASTELL 1993, LÓPEZ UDIOS et al. 1997, MUCINA 1997, ANGIOLINI and DE DOMINICIS 1999).

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