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A special habitat for bryophytes and lichens in the arid zones of Spain

J. J. Martínez-Sánchez, M. Casares-Porcel, J. Guerra, L. Gutiérrez-Carretero, R. M. Ros, J. Hernández-Bastida and M. J. Cano

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The bryophytic and lichen vegetation on gypsiferous soils in the arid/semiarid climates of South-east Spain shelters beneath bunches of large perennial grasses (mainly *Stipa tenacissima* and *Lygeum spartum*). Three bryo-lichenic vegetation zones were identified which show close correspondence to the degree of protection afforded by the grasses.These zones are clearly differentiated both pedologically and floristically.

J.J.M.-S., J.G., R.M.R. and M.J.C., Depto de Biología Vegetal, Facultad de Biología, Univ. de Murcia, E-30071 Murcia, Spain. – M.C.-P., Depto de Biología Vegetal, Facultad de Farmacia, Univ. de Granada, E-18071 Granada, Spain. – L.G.-C., Estación Experimental de Zonas Aridas, CSIC, E-04001 Almería, Spain. – Depto de Química Agrícola, Geología y Edafología, Facultad de Químicas, Univ. de Murcia, E-30071 Murcia, Spain.

Растительность бриофитов и лишайников на гипсоносных почвах в аридных/полуаридных климатах южно-восточной Испании укрывается под пучками больших многолтних трав (особенно Stipa tenacissima и Lygeum spartum). Растительность зон бриофитов и лишай ников была идентифицирована, это обнаруживает близкое соотношение со степенью защиты, оказанной травами. Эти зоны ясно дифференцированы что касается почвоведения и флористики.

The most arid zone of the European continent, the south-eastern region of the Iberian peninsula (Fig. 1) is, in theory, climatically unfavourable for bryophytes and lichens. Nevertheless, the bryo-lichenic flora of this area is very rich and diverse (cf. Ros and Guerra 1987a,b, Egea and Llimona 1987, Casares-Porcel and Gutiérrez-Carretero 1993) as is the higher vegetation (cf. Alcaraz et al. 1989, Peinado et al. 1992). Under the harsh conditions caused by high temperatures and lack of rain, bryophytes and lichens colonize unexpected habitats in order to take advantage of the shade and greater soil humidity (lower evapotranspiration) offered by some of the larger grasses (generally *Stipa tenacissima* L. and *Lygeum spartum* L.). These microsites favour the development of bryo-lichenic communities, in contrast to generally unfavourable macroenvironmental conditions in this zone.

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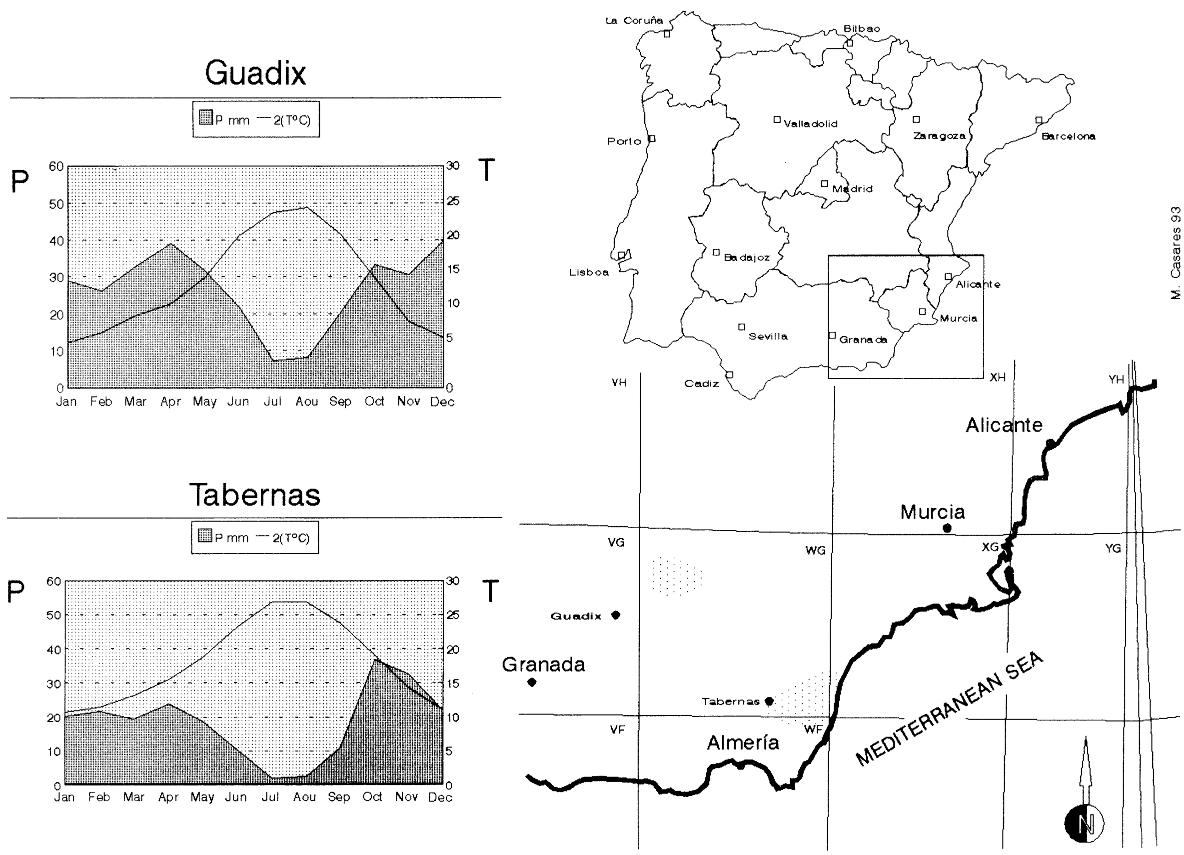

Fig. 1. Representative ombrothermic diagrams and situation of study areas (shaded zones).

Vascular vegetation

The plant communities dominated by hardy, perennial, deeply-rooted grasses (*Stipa tenacissima*, *Lygeum spartum* and *Dactylis glomerata* L. subsp. *hispanica* (Roth) Nyman), found on deep, well-structured, porous soils in the thermo- and mesomediterranean belt of the semi-arid regions of the Iberian South-East are part of the alliance Stipion tenacissimae Rivas-Martínez (Thero-Brachypodietalia retusi (Br.-Bl.) Molinier, Lygeo sparti-Stipetea tenacissimae Rivas-Martínez). Most of these community types are included in the Lapiedro martinezii-Stipetum tenacissimae Rivas-Martínez & Alcaraz, representing the first phase of degradation of sclerophyllous scrub (Chamaeropo humilis-Rhamnetum lycioidis Bolós, Mayteno europaei-Periplocetum angustifoliae Rivas Goday & Esteve, Bupleuro gibraltarici-Pistacietum lentisci Martínez-Parras, Peinado & Alcaraz, Zizipho loti-Maytenetum europaei Fernández-Casas). They are usually found on clay-marl, gypsum-marl and gypsum soils, which accentuate the aridity of the zone.

Methods

Generally the sigmatist method (Braun-Blanquet 1979) was used for the survey. However, in the case of bryophytes, the sociability index was not employed, since it was deemed to be untrustworthy because of the protonematic growth. The "prélèvement partiel" method proposed by Roux (1990) was followed for lichen sampling since it permitted a notable increase in the number of taxa listed in each inventory. The nomenclature followed is that of Corley et al. (1981) and Corley and Crundwell (1991) for mosses, Grolle (1983) for liverworts and Clauzade and Roux (1985, 1987), Breuss (1990) and Timdal (1991) for lichens.

In the area under study, bunches of grass are very frequent. Consequently the microsites could easily be chosen at random for carrying out the relevés. After completing the relevés which were used in order to delimit, in situ, homogeneous floristic zones, a sample of soil was taken from each for chemical analysis.

The following methods were used to determine the chemical properties of the soils. *Organic carbon:* Anne's method modified by Duchaufour (1984); the results are expressed in % organic carbon in soil samples dried at

Table 1. Releves of the cryptogam vegetation in three zones (see Fig. 2) around bunch grasses in the vegetation of the arid S.E. Iberian region. Symbols indicate cover and, in the case of lichens, cover and sociability (according to Braun-Blanquet 1979).

	A						B						C							
Relatives Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
Surface (dm²)	12	20	16	6	15	40	9	16	32	9	20	100	16	30	20	16	12	24	30	
High (m)	300	300	475	300	475	100	400	400	300	300	475	450	400	400	600	200	900	850	290	
Slope (°)	10	30	–	10	5	30	–	–	5	5	5	–	5	–	30	30	30	30	30	
Orientation	NE	NE	–	W	NW	NE	–	–	NE	N	W	–	E	–	N	NW	N	NW	N	
Bryophyte cover (%)	65	65	20	30	35	40	30	60	45	45	50	85	55	55	50	30	60	20	0	
Lichen cover (%)	10	20	60	1	20	1	0	30	15	1	5	0	20	15	25	20	40	50	40	
Species number of Bryophytes	11	12	17	8	10	8	9	9	13	11	6	18	8	10	13	13	7	4	0	
Species number of Lichens	5	4	7	2	5	2	0	2	3	2	1	1	7	3	6	4	7	12	4	
Characteristics of *Trichostomo-Aloinetum aloidis*:																				
Alona aloides	+	+	+	·	·	+	+	+	+	1	·	+	·	·	·	·	·	·	·	III
Trichostomum crispulum	·	·	·	·	·	2	2	4	2	1	·	+	3	1	·	·	·	·	·	III
Characteristics of *Barbuletalia* and *Phascion mitraeformis*:																				
Trichostomum brachydontium	3	2	+	1	3	2	1	+	2	+	·	+	·	1	3	1	1	·	·	IV
Didymodon vinealis	·	1	2	·	+	·	+	+	+	·	+	+	·	+	+	+	1	1	·	IV
Didymodon luridus	+	·	+	+	·	+	+	+	·	1	·	+	+	+	+	+	·	·	·	IV
Gymnostomum luisieri	+	·	+	·	+	·	·	·	+	+	·	+	+	·	+	1	+	·	·	III
Didymodon acutus	·	·	1	+	·	·	·	+	1	+	·	+	+	+	·	+	·	·	·	III
Bryum bicolor	·	·	·	·	·	+	+	·	·	·	+	·	+	1	+	+	+	·	·	III
Weissia triumphans	·	2	·	2	+	·	+	·	+	+	·	·	+	·	·	2	·	·	·	III
Fossombronia caespitiformis	+	2	·	·	+	·	1	·	1	·	·	1	1	·	·	+	·	·	·	III
Phascum corbicolle	+	·	·	·	+	·	·	·	+	+	·	+	·	+	·	+	·	·	·	II
Pleurochaete squarrosa	·	·	·	·	·	·	·	·	·	·	3	5	·	2	1	·	3	·	·	II
Pseudocrossidium hornschuchianum	·	·	+	·	·	·	·	·	·	1	·	·	·	·	+	·	·	1	·	I
Didymodon rigidulus	1	·	·	·	·	+	·	·	·	·	·	·	·	·	1	·	·	·	·	I
Didymodon insulanus	·	·	+	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	I
Dicranella howei	·	+	·	·	·	·	·	·	·	·	·	+	·	·	·	1	·	·	·	I
Barbula unguiculata	+	·	+	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	I
Pottia starcheana	·	·	+	1	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	I
Didymodon fallax	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	I
Species of *Tortulo-Aloinetalia bifrontis*:																				
Crossidium crasinerve	+	+	+	+	1	+	+	1	+	2	+	+	·	1	·	1	·	+	·	IV
Tortula revolvens v. *obtusata*	1	·	+	·	+	·	·	·	·	·	·	+	+	·	·	1	+	+	·	III
Crossidium aberrans	·	·	+	·	·	·	·	·	·	·	·	+	·	·	+	·	·	·	·	I
Didymodon aaronis	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	I
Other Bryophytes:																				
Bryum radiculosum	+	+	+	1	+	·	·	+	·	1	·	·	·	·	+	·	·	·	·	III
Cephaloziella baumgartneri	·	·	·	·	·	·	·	·	+	·	+	+	·	·	·	·	·	·	·	I
Southbya nigrella	·	1	·	·	·	·	·	·	2	·	·	+	·	·	·	·	·	·	·	I
Grimmia pitardii	·	1	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	I
Bryum torquescens	·	·	·	·	·	·	·	·	·	·	1	·	·	·	·	·	+	·	·	I
Phascum cuynetii	·	·	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	I
Pottia caespitosa	·	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	I
Tortella humilis	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	I
Crossidium squamiferum	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	I
Bryum ruderale	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	I
Phascum longipes	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	I
Gymnostomum lanceolatum	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	I
Riccia atromarginata	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	I
Didymodon australasiae	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	I
Weissia sp.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	I
Encalypta vulgaris	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	I
Characteristics of *Psoretea decipientis, Fulgensietalia desertori* and *Psorion saviczii*:																				
Toninia sedifolia	+	+	1.2	+	+	+	·	·	+	+	·	·	·	·	+	+	+	+	·	IV
Squamarina lentigera	2.1	1.1	+	·	+	·	·	3.3	·	·	·	·	+	+	1.1	+	·	+	2.3	III
Fulgensia subbtacteata	+	+	·	·	+	·	·	·	1.1	+	·	·	·	·	1.1	+	·	·	1.2	III
Collema tenax	+	·	3.3	+	·	·	·	+	·	·	·	·	·	+	·	·	+	·	·	II
Squamarina cartilaginea	·	2.1	·	·	·	·	·	·	2.3	·	·	·	+	·	·	·	1.2	1.2	·	II
Diploschistes diacapsis	·	·	+	·	+	·	·	·	·	·	·	·	1.2	·	·	·	·	1.2	·	II
Fulgensia fulgida	·	·	+	·	·	·	·	·	·	·	·	·	+	·	·	·	·	1.1	·	I
Psora crenata	·	·	1.2	·	·	·	·	·	·	·	·	·	·	·	1.1	·	·	+	·	I
Psora decipiens	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	1.1	·	I
Endocarpon pusillum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	I
Psora saviczii	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	I
Fulgensia desertorum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	I
Buellia zoharyi	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	I
Diploschistes ocellatus var. *almeriensis*	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	I

cont.

Table 1.
Continued.

	A						B						C							
Characteristics species of taluses:																				
Lepraria crassissima v. *isidiata*	·	·	·	·	·	·	·	·	·	·	·	+	2.3	+	1.1	2.3	3.3	3.3	2.3	III
Cladonia pyxidata v. *pocillum*	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1.1	·	I
Other Lichens:																				
Cladonia foliacea ssp. *convoluta*	1.2	·	3.3	·	2.3	·	·	·	·	·	·	·	·	·	·	·	·	·	·	I
Cladonia furcata ssp. *subrangiformis*	·	·	·	·	·	·	·	·	·	·	1.1	·	·	·	·	·	·	·	·	I
Parmelia pokornyi	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1.1	·	·	·	·	I
Psora albilabra	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1.1	I
Catapyrenium rufescens	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	+	·	·	I
Placynthium nigrum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	I
Cyanophyta																				
Nostoc sp.	·	·	·	·	·	·	·	·	·	·	·	·	·	1	·	·	·	·	·	I

Relevés origin. – 1: Collado del Manco, Loma de los Yesares (Almería: Sorbas), UTM 30SWF9198. 2, 4, 9, 10, 19: Cerro de las Cuevas (Almería: Lucainena de las Torres), UTM 30SWF8498. 3: Rio de Aguas-Huelí road (Almería: Sorbas), UTM 30SWG7903. 5 y 11: Barranco del Huelí, Near Cortijo de la Guente (Almería: Sorbas), UTM 30SWG7903. 6: Mojacar (Almería), UTM 30SXG0111. 7, 8 y 14: Cerrón to Rio de Aguas track (Almería: Sorbas), UTM 30SWG8105. 12: Near to Peñón de Díaz (Almería: Sorbas), UTM 30SWG8104. 13: Near to Marchalico Viñicas (Almería: Sorbas), UTM 30SWG8508. 15: Yesoncillo de Enmedio (Almería: Gergal), UTM 30SWG4300. 16: Barranco Hondo, Lomilla de las Colmenas (Almería: Sorbas), UTM 30 SWF8697. 17: Near to Benamaurel (Granada), UTM 30SWG2456. 18: Cañada del Caballo (Granada: Benamaurel), UTM 30SWG2861.

ambient temperature for two weeks. *Total nitrogen:* Kjeldahl's method as described by Duchaufour (1984); the results are expressed in mg nitrogen per 100 gr of soil dried as described above. *C/N:* to give an idea of the development of the organic material, data from the previous analyses of C and N were used, both expressed as %. *pH*: Peech's method (1965). *Electrical conductivity:* following the method of Bower and Wilcox (1965), a saturation extract was obtained from the soil being studied by producing a vacuum in a Buschner funnel containing a paste of soil and deionized water. The conductivity was calculated using a conductometer and expressed in mmhos/cm at 25°C. These parameters were studied using two soil samples from each of the three floristically differentiated zones (6 soil samples in all, corresponding to the relevés marked with an asterisk in Table 1).

Results

We were able to distinguish three clearly differentiated zones, characterized by their different floristic composition and equally distinct pedological parameters. In a centripetal direction from the outside towards the inside of the bunch, these zones were as follows (Fig. 2).

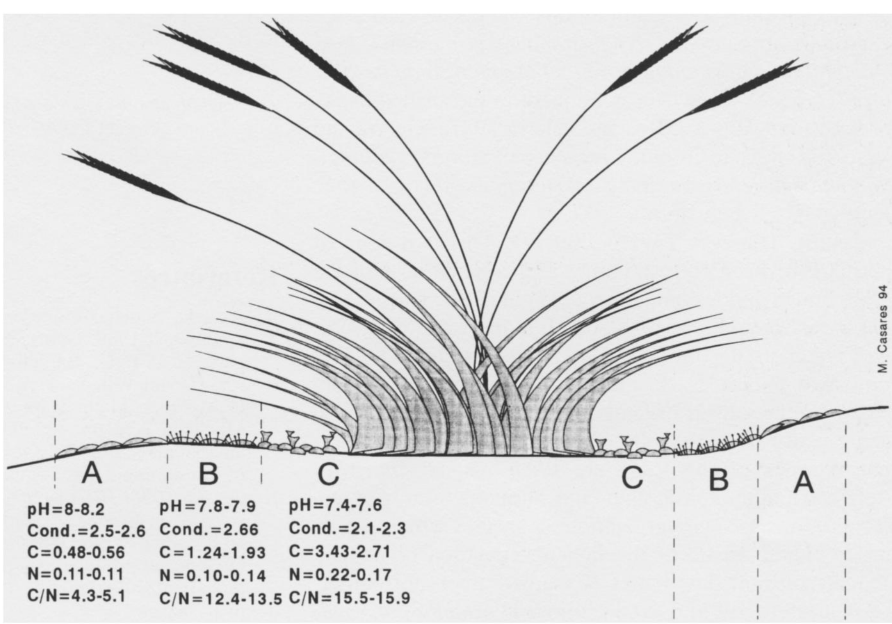

Fig. 2. Schematic representation of the cryptogamic vegetation around a grass bunch.

Zone A (Relevés 1–6, Table 1). This area corresponds to the foot of *Stipa tenacissima* or *Lygeum spartum* plants and is a zone of varying shade both during the day and the year. The bryo-lichenic vegetation found here hardly differs from that found on bare soil not protected by higher plants. Depending on the nature of the substrate, the vegetation of this zone corresponds to undifferentiated communities of Toninion caeruleo-nigricantis Hadac (Psoretea decipientis Matick emend. Barreno & Crespo), when gypsum is absent or scarce, and to communities of the Psorion saviczii Crespo & Barreno when gypsum is abundant. Unlike in the open areas, shade favours the presence of *Cladonia foliacea* subsp. *convoluta*, a foliose lichen species which is much more common in the gypsum soils of Northern Spain (Llimona 1974). In this zone the gypsicolous communities of lichens are found mixed with the bryophytic communities (Crossidio crassinervis-Tortuletum obtusatae Ros & Guerra). Without the influence of the clusters of the different grasses the two communities are usually reasonably well separated since the former, which is less dependent on soil humidity, can colonize shallow soils exposed to the sun, whereas the latter develops better on deeper, lightly shaded soils. In zone A, the gypsum soils were pH 8–8.2 with a conductivity of 2.5–2.6 mmhos/cm. Both organic carbon (around 0.5%) and total nitrogen (around 0.1%) indicate very low levels of organic material in the soil.

Zone B (Relevés 7–12, Table 1). This zone, although not completely covered by the leaves of *Lygeum* or *Stipa*, is in permanent shade. Conductivity was practically the same as in zone A (around 2.6 mmhos/cm) but slightly lower pH values were observed (pH 7.8–7.9). Organic carbon levels were higher with a C/N ratio between 1.24–1.93, indicating the presence of mineralized and developed organic material.

The floristic composition of this zone is roughly that of the Trichostomo-Aloinetum aloidis Guerra & Varo association (*Aloina aloides*, *Trichostomum crispulum*, *T. brachydontium*, *Didymodon luridus*, *Fossombronia caespitiformis*), which elsewhere is frequent in the shaded banks of limestone soils (cf. Ros and Guerra 1987a, Guerra and Varo 1981). Apart from the presence of *Toninia sedifolia*, *Squamarina lentigera* and *S. cartilaginea*, this is a zone with sparse lichen flora.

Zone C (Relevés 13–19, Table 1). This is a zone of permanent shade corresponding to the actual base of the grass bunch and is completely covered by the leaves. Soil pH was slightly lower than zone B at pH 7.4–7.6 (7.7) as was conductivity (around 2.1–2.3 mmhos/cm). The C/N ratio was about 15–16, indicating the presence of only slightly mineralized organic material. This phenomenon can usually be easily observed visually. The characteristic species of this zone are *Pleurochaete squarrosa* (terri-saxicolous, basicolous and humicolous moss) and *Lepraria crassisima* var. *isidiata*, a species which is normally characteristic of the lichen vegetation of heavily shaded gypsum dust banks (Casares-Porcel and Gutiérrez-Carretero 1993). Certain foliose (*Parmelia pokornyi*) and large squamulose species (*Psora albilabra*), rarely found in arid zones, were also encountered sheltering in zone C, the innermost zone of the three.

Discussion

A change in the floristic composition of the terricolous bryo-lichenic communities can generally be observed in the proximities and on the inside of *Stipa tenacissima* and *Lygeum spartum* clump, depending on the distance from the centre of the clump. It is interesting to note that *Aloina aloides*, a xerophilous species usually found on exposed sunny soils, does not penetrate zone C. The same is true of *Grimmia pitardii* and *Phascum cuynetii*. *Cephaloziella baumgartneri* is restricted to zone B since it cannot withstand the exposed conditions of zone A, nor the high levels of organic matter found in zone C. Alongside *Southbya nigrella* in zone B *Gymnostomum viridulum* and *Dicranella howei* appear. These species constitute the association Gymnostomo viriduli-Southbyetum nigrellae (cf. Moya et al. 1994) and always appear on protosoils of very shaded banks. The presence of this association under *Stipa* or *Lygeum* is unusual and can only be explained by the microclimate formed by the grass clump. Something similar occurs with *Lepraria crassisima* var. *isidiata*, *Parmelia pokornyi*, *Cladonia pyxidata* var. *pocillum* and *Psora albilabra*. The microclimatic conditions below these large grasses, together with an appreciable change in some pedological factors, allow the presence of communities rarely observed on sunny and exposed soils of South-east Spain. Although this phenomenon, which we have named "the nest effect", can be observed on any type of soil, it is most important and clearly visible on gypsiferous soils owing to their greater water holding capacity.

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