Impact of reafforestation with *Eucalyptus globulus* Labill. on the edaphic collembolan fauna of Serra de Monchique (Algarve, Portugal)

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Impact of reafforestation with Eucalyptus globulus *Labill. on the edaphic collembolan fauna of Serra de Monchique (Algarve, Portugal).*– Native forests in Portugal have been gradually replaced by *Eucalyptus globulus* plantations. This exotic tree has been referred as a major factor of ecosystem disturbance (Gama et al. 1989, 1991, 1994, 1995; Sousa & Gama, 1994; Vasconcelos et al., 1994). The authors compared edaphic Collembola populations occurring in coppices of *Quercus suber* L. and *Q. canariensis* Willd. with those from stands of *Eucalyptus globulus* Labill. from Serra de Monchique, to evaluate the effects of reafforestation with this exotic tree. The total analysis of data shows a rupture in the collembola communities associated with eucalyptus. Oak biotopes usually present higher values of diversity and species richness, with a greater total number of species and also more exclusive and/or preferential species than eucalyptus biotopes. No significant differences were detected among the different biotopes in terms of mean number of individuals. However, the abundance of individuals in eucalyptus biotopes results mainly from the presence of a few species which are represented by a great number of specimens, making up more than 85% of the individuals on eucalyptus sites.

Key words: Collembola, *Quercus suber, Q. canariensis, Eucalyptus globulus*, Reafforestation, Algarve.

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Introduction

The preservation and re-establishment of global biodiversity has been of increasing concern in the last few decades.

High Endemism Areas (HEA) play an important role in the organization of diversity, at local and regional levels, since they embrace a high biological richness at structural and genetic levels. Endemic species thus deserve special attention, not only because they are of high biological value but also because they are more vulnerable to ecosystem disturbance (DEHARVENG, 1996). Therefore, HEA must be considered as priority areas in biodiversity conservation.

Serra de Monchique at the Algarve Province (Portugal) (fig. 1) is an unique area with a peculiar diversity as compared to the rest of the Algarve. These distinct features are the result of the coexistence of very distinct climatic conditions and a characteristic vegetation cover showing signs of an Atlantic influence, on a strong Mediterranean expression. Some good examples of plant endemicities or species with restricted occurrence in the national territory have been reported for this region. *Quercus canariensis* Willd. presents a very restricted occurrence both in Portugal and Spain, with Serra de Monchique being its exclusive area in Portugal. *Rhododendron ponticum* L. spp. *baeticum* (Boiss. & Reuter) Hand.-Mazz., *Adenocarpus complicatus* (L.) Gay spp. *anisochilus* (Boiss.) Franco and *Senecio lopezii* Boiss. are endemic from the Iberian peninsula, and in Portugal they appear only in Algarve (with the exception of the first species that also exists in Serra do Caramulo). *Euphorbia monchiquensis* Franco & P. Silva is even more restricted, being endemic from Serra de Monchique (MALATO BELIZ, 1982). There are also some endemic species of animals from Thysanura (MENDES, 1985, 1992) Coleoptera Cicindelidae (HORN, 1937; SERRANO, 1988, 1995) and Homoptera Cicadoidea Tibicinidae (BOULARD, 1982; QUARTAU, 1995).

Given the relevance of these findings, and within the framework of a broader European project, entitled "High Endemism Areas, Endemic Biota and the Conservation of Biodiversity in Western Europe", our major aim was to develop a balanced approach to biodiversity evaluation at a regional level, re-evaluating the position of endemic biota for conservation purposes. The data collected provided the background for interpreting and predicting the impact of ecosystems disturbance on endemic biota.

At Serra de Monchique, a major ecosystem disturbance is the reafforestation of large areas with the exotic *Eucalyptus globulus* Labill., which is partially occupying the place of Monchique's original vegetation. Eucalyptus has been extensively planted and exploited because it is a fast growing evergreen species and is therefore very profitable in short periods of time. Because of the speed at which it grows it can induce changes in soil processes and in the structure of soil biota, causing a disruption in their communities.

Several studies (GAMA et al., 1989, 1991, 1994, 1995; SOUSA & GAMA, 1994; SOUSA et al., 1997; VASCONCELOS et al., 1994) comparing collembolan fauna from eucalyptus with those from Portuguese natural forests have shown a rupture in these soil communities, following reafforestation with this exotic tree. In general, eucalyptus plantations seem to support a lower diversity and richness of species than autochthonous forests.

Previous studies did not consider the endemic component and the study areas were concentrated in the centre of Portugal. Our study concerns different oak trees from an area of high endemism in the south of the country.

Our main goal was to evaluate the impact of reafforestation with eucalyptus on the biodiversity and structure of collembolan populations from the ecosystems of Serra de Monchique. Collembola were selected as biological material for our purpose due to their representation in soil arthropod fauna and to their important role in soil processes (PONGE & PRATT, 1982; ARBEA & JORDANA, 1985). As stated before, particular attention was given to the possible effects on endemic or rare species.

Material and methods

Study sites, sampling and soil analysis

Geologically, the upper half of Serra de Monchique is predominantly syenitic whereas the lower zone has a schistose nature. The climate of the area is mesothermic and humid, with high water deficiency during summer.

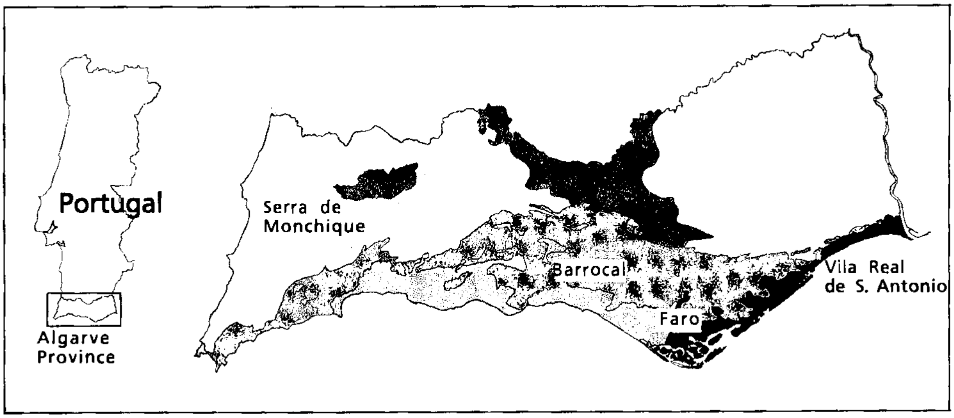

Fig. 1. Study area.
Área de estudio.

Taking into account the original plant species on this mountain most affected by the reafforestation with *E. globulus*, sampling was done in coppices of *Quercus canariensis* Willd. and *Quercus suber* L. and in *E. globulus* Labill. plantations, in November 1994.

With respect to vegetation cover, relatively dense shrub and herbaceous layers, composed of *Pteridium aquilinum* (L.) Kuhn, *Viburnum tinus* L., *Cytisus scoparius* (L.) Link, *Cistus salvifolius* L. and *Erica arborea* L., were associated with *Q. canariensis* site (CAN).

In *Q. suber* biotope, sampling was done at two different sites: at the first site (SUBI), the herbaceous and shrub layers were composed of *Viburnum tinus L.*, *Cistus salvifolius L.* and *Erica arborea L.*; the second sampling site (SUBII) presented a very poor vegetation cover, with only a scarce herbaceous layer composed mainly of Gramineae.

In the eucalyptus biotope, where trees were in second rotation, samples were taken at three different sites: the first site (EUCI) presented an abundant vegetation cover composed of Gramineae, *Erica lusitanica* Rudolphi, *Cistus salvifolius* L., *C. ladanifer* L., *Calluna vulgaris* (L.) Hull, *Lavandula stoechas* L., *Arbutus unedo* L. and *Daphne gnidium* L.; at the second site (EUCII) there was only a dense herbaceous layer composed mainly of *P. aquilinum* (L.) Kuhn (the area was kept relatively untouched, which resulted in a great accumulation of eucalyptus leaves and bark on the soil, thus leading to an increase in standing stock biomass); the third site (EUCIII) had abundant shrub and herbaceous layers composed of *Pteridium aquilinum* (L.) Kuhn, *Erica arborea* L., *Cytisus scoparius* (L.) Link, *Cistus salvifolius* L., *Viburnum tinus*, L., *Arbutus unedo* L., *Rubus* sp. and some young trees of *Castanea sativa* Miller trees.

At each sampling site, several points were randomly selected and sampled. At each sampling point, and after careful removal of the non-decomposed leaf layer, a sample of 250 cm^3 was taken in the organic horizon (OH) and another in the mineral horizon (MH). Simultaneously soil temperature (at the depth of 10 cm) and organic horizon thickness were measured.

Fauna was extracted by means of Berlese-Tullgren funnels, sorted under binocular microscope and identified to species level, under light microscope.

After extraction, air-dried samples were gently crushed and passed through a 2 mm sieve, and four aliquots were separated for analysis. Water content was measured according to Dewis & Freitas (1984), by drying the sample at 105°C, over 18 hours. Organic matter content was expressed as Ash Free Dry Weight, and Carbon and Nitrogen contents were measured by Anne's and Kjeldahl's methods, respectively (Dewis & Freitas, 1984). pH was measured in water (1:6 v/v) at 20°C.

Data analysis

For the different strata of each site, species Diversity (H'), Richness (D) and Evenness (E) were calculated following Shannon-Weaver, Margalef and Pielou indices respectively (Magurran, 1991).

Physical and chemical data, mean abundance of individuals and mean number of taxa were compared by an ANOVA (Zar, 1996). Normal distribution of data was evaluated by the Kolmogorov-Smirnov test and homocedasticity was evaluated by the Bartlett test (Zar, 1996). Almost all data groups presented a normal distribution and homogeneity of variances. The only exceptions were the water and organic matter contents and the C/N ratio of the mineral horizon, which were not homocedastic. However, the ANOVA test is sufficiently robust to overcome the shortcoming problem (Zar, 1996).

Data matrix (species *vs.* sites) was subjected to multivariate analysis. Taxa considered irrelevant (having less than five individuals and appearing only once), were first eliminated. An hierarchical clustering analysis was then performed, using the Bray-Curtis coefficient (Boesch, 1977). Prior to this analysis, data were transformed to $Y_{ij} = \text{Log}(X_{ij}+1)$ to minimize abundance discrepancies.

Results

According to the physical and chemical data (table 1) the various sites differed only slightly from each other, except for *Q. canariensis* site. In this biotope, the organic horizon had significantly lower values of water, organic matter, carbon and nitrogen contents than the other two biotopes, and the mineral horizon had significantly lower values of organic matter and carbon contents than EUCI and EUCII. Nevertheless, eucalyptus sites had significantly lower litter layer thickness than oak biotopes. It is interesting to denote the existence of some similarity between the EUCIII and oaks, which will likely affect collembolan communities.

A total of 9,412 specimens, distributed in 65 taxa, were identified in all sampling stations (table 2). Among these taxa, *Folsomia sexoculata* was the best represented species, being the most abundant in all sites except for CAN and EUCIII. However, this species was also well represented in these two sites.

Five taxa occurred exclusively in eucalyptus sites (table 2), but two of them, *Willemia intermedia* and *Proisotoma coeca*, were represented only by one and two individuals, respectively. *Xenylla brevisimilis mediterranea*, *Tetracanthella hygropetrica* and *Mesaphorura* sp. 2 were more abundant in eucalyptus than in the other sites.

In oak biotopes, 29 species presented character of exclusivity (table 2) and seven were better represented here than in eucalyptus sites. From these 29 exclusive species, 11 were only represented by three or fewer individuals (table 2). The overall analysis shows that, from the 65 taxa collected, more than 50% are exclusive or at least more abundant in oak biotopes.

Serra de Monchique did not appear to be very rich in terms of endemic or rare species. Only a few species were considered Portuguese or Iberian endemisms and others that were recorded for the first time to Portuguese fauna (table 3). On the other hand, no decrease in the richness of endemic Collembola nor in the abundance of their species was observed under eucalyptus plantations, except for *Lepidocyrtus lusitanicus*, an Iberian endemic which, contrary to the oak biotopes, was represented in the eucalyptus site only by one specimen (table 3).

Considering the mean abundance of individuals, no statistically significant differences were observed among the studied biotopes (OH-F = 2.32, MH-F = 2.15; $P >> 0.05$). This is probably due to the high variability within each site (shown by the standard deviations in fig. 2). With respect to the mean number of taxa (fig. 2), oak biotopes (SUB and CAN) have both significantly higher values than the eucalyptus sites, mainly in the organic horizon (OH-F = 13.96, MH-F = 6.78; $P < 0.01$).

This separation between autochthonous and introduced tree species is confirmed by data in table 4, where we can see that oak biotopes, specially CAN, have higher diversity and species richness values than eucalyptus. EUCIII is an exception, presenting high values of diversity. This can be explained by the high values of evenness, both in the

Table 1. Physical and chemical characterization of study sites (mean±SD). Samples were cumulated and means compared by ANOVA ($P < 0.05$). (N. Sampling points.) (For abbreviations of study sites see Material and methods.)

Caracterización física y química de las áreas de estudio (media±SD). Se juntaron las muestras y las medias se compararon mediante una ANOVA (P < 0,05). (N. Puntos de muestreo.) (Para las abreviaturas de las áreas de estudio ver Material y métodos.)

	Study sites					
	EUCI N = 4	EUCII N = 4	EUCIII N = 4	SUBI N = 5	SUBII N = 4	CAN N = 8
* Litter layer thickness (cm)	2.3±0.6	2.4±1.1	3.6±0.5	4.1±0.7	5.5±2.4	4.8±1.3
Soil pH	6.1±0.3	6.2±0.2	6.3±0.3	6.0±0.2	6.2±0.4	6.2±0.2
Soil temperature (°C)	13.6±0.2	14.6±0.3	14.9±0.5	13.9±0.2	14.3±0.4	14.3±0.9
* % water content (litter)	13.2±0.4	15.7±0.9	14.8±2.6	15.0±1.9	11.98±2.4	10.7±2.4
% water content (soil)	8.1±1.6	11.2±3.3	5.6±0.8	8.3±1.3	6.4±1.8	6.0±0.7
* % organic matter (litter)	74.4±5.0	75.5±2.3	60.1±9.2	66.0±9.3	53.2±10.3	42.9±12.4
*% organic matter (soil)	38.4±9.9	50.6±14.5	21.8±4.2	27.8±5.3	24.9±7.9	17.0±2.8
* % carbon (litter)	46.1±4.7	49.9±1.6	39.2±7.2	43.4±6.6	34.2±6.0	26.0±7.9
* % carbon (soil)	20.2±4.9	29.7±11.1	13.8±4.8	15.3±3.8	13.8±5.8	9.0±1.5
* % nitrogen (litter)	1.2±0.2	1.3±0.1	1.3±0.2	1.1±0.3	1.2±0.4	0.9±0.3
* % nitrogen (soil)	0.6±0.3	0.8±0.3	0.5±0.2	0.6±0.2	0.6±0.2	0.4±0.1
C/N (litter)	39.6±9.5	39.1±3.6	29.9±2.8	42.6±18.2	30.4±3.8	30.3±9.6
* C/N (soil)	44.2±23.8	44.1±26.5	28.4±5.2	27.3±4.3	20.6±3.2	24.5±5.8

organic and in the mineral horizons, causing a high diversity, despite its relatively low species richness, mainly in the mineral horizon. This reflects the high sensitivity of the index (H') to the distribution of individuals among the different taxa. The lower values of evenness of the other biotopes result from a great abundance of some particular species (*Folsomia candida*, *Parisotoma notabilis* and *Pseudachorudina bougisi* in CAN, *Folsomia sexoculata* in SUB, EUCI and II and *Xenylla brevisimilis mediterranea* in EUCI and II).

The multivariate analysis also reflects the separation between oak and eucalyptus sites. In the phenogram on the Q mode analysis (fig. 3) we can define four different groups of sites, two of them related with oak biotopes (A and D) and the other two related to eucalyptus sites (B and C).

The strong separation of groups A and D (in opposite positions in the diagram) may be explained by the presence of a small group of species (*Folsomia candida*, *Parisotoma notabilis* and *Proisotoma minuta*) which are much more abundant in CAN3 and CAN4 than in all the others, and to another species (*Onychiurus pseudostachianus*) that is exclusive in CAN3 (table 2).

In group A we can denote a separation into two sub-groups related to *Q. suber* sites (A1) and *Q. canariensis* sites (A2). However, this separation should be considered carefully due to the "stair" shape of the diagram inside group A.

Group B, the first eucalyptus group, encompasses the EUCI and EUCII sites and is completely separated from the remaining samples. This may be the result of the almost

Table 2. Total number of individuals of collembolan species in coppices of oak (*Q. suber* and *Q. canariensis*) and eucalyptus (*E. globulus*): * Taxa occurred exclusively in eucaliptus sites; ♦ Taxa occurred exclusively in oak biotopes. (For abbreviations of study sites see Material and methods.)

*Número total de individuos de las especies de colémbolos en bosquecillos de robles (*Q. suber *y* Q. canariensis*) y eucaliptus (*E. globulus*): * Taxones exclusivos de áreas de eucaliptus; ♦ Taxones exclusivos de biotopos de robles. (Para las abreviaturas de las áreas de estudio ver Material y métodos.)*

	Study sites											
	SUBI		SUBII		CAN		EUCI		EUCII		EUCIII	
	HO	HM	HO	HM	HO	HM	HO	HM	HO	HM	HO	HM
Ceratophysella gibbosa	49	13	34	23	86	4	2		2		60	10
Microgastrura sensiliata		6		1							5	
* *Willemia intermedia*											1	
Xenylla brevisimilis mediterranea	57	1	1				207	42	450	46		
♦ *Xenylla schillei*					2							
Bilobella aurantica	6	2	3		1	1	2	1	4	1	3	1
Deutonura atlantica	9	2	5	2	4		4	4	6	3	4	
Friesea pseudodecipiens			41	18	5	1	1					
Micranurida sp. (2+2 eyes)	8	4	13						2	1	8	1
♦ *Neanura* sp.		3										
Pseudachorudina bougisi	18	38	40	23	281	9	1		3	42	51	34
Pseudachorutes palmiensis					1				1		2	
* *P. parvulus*											11	
♦ *P. subcrassus*		5			1							
♦ *Fissuraphorura gisini*						1						
Mesaphorura arbeai		6	1	5	1				4	8		
M. critica				1					1		1	7
M. sp. 1			1					1		1	1	
M. sp. 2		1	1			1		1	1		19	4
M. sp. 3	1	3	1	3	1		1	1	4	4	10	1
M. macrochaeta	2	4	3	8	8	5		1			13	3
M. yosii	1	1			1	1	1	6			2	9
♦ *Onychiurus circulans*				1								
♦ *O. insinuans*	3	8	3	5	23	29						
* *O. penetrans*											6	10
♦ *O. pseudostachianus*					1	24						
Paratullbergia callipygos			1	2	2	1					2	
* *Protaphorura armata*								4		5		
Cryptopygus debilis			18	45		1				2		
C. scapelliferus	8	19	131	96	4	22	1				12	4
♦ *C. sphagneticola*						3						

Tabla 2 (cont.)

	Study sites											
	SUBI		SUBII		CAN		EUCI		EUCII		EUCIII	
	HO	HM	HO	HM	HO	HM	HO	HM	HO	HM	HO	HM
C. thermophilus			30	15	2		1		1			
♦ *Folsomia candida*					55	526						
F. sexoculata	770	463	936	195	121	13	394	108	801	335	3	42
♦ *Folsomides* cf. *navacerradensis*	3											
Isotomiella minor	88	64	38	38	92	64	4	8	41	110	5	
♦ *Isotomodes sexsetosus*		3				7						
♦ *Isotomurus* sp.	1	4	9	1	9	1						
Parisotoma notabilis	1		19	14	100	133	1	1	4		1	
* *Proisotoma coeca*								2				
P. minuta	1	7	31	4	83	166	1				67	63
Tetracanthella hygropetrica	1		1				49	8				
T. proxima	12	3				1			2	5		1
♦ *Entomobrya albocincta*					4	1						
E. sp.		1							1			
Heteromurus major	64	3	31	9	10	2				2		
♦ *Lepidocyrtus lanuginosus*					1							
L. lusitanicus	9		8		27	2			1			
Pseudosinella picta	67	29	5	3	7	1		7	2	6	3	3
♦ *P.* sp. (0 eyes)					1							
♦ Entomobryidae juv.	19		1		20	4						
♦ *Oncopodura crassicornis*					1							
♦ *Tomocerus vulgaris*					2	1						
Megalothorax minimus	46	1	6	1	9	2					2	1
♦ *Neelus murinus*	3				3							
♦ *Allacma fusca*	1											
♦ *Arrhopalites elegans*			2									
♦ *A.* sp.	9	4			2	5						
♦ *Caprainea bremondi*	2				3							
♦ *Lipothrix lubbocki*		2	14		3							
♦ *Sminthurides parvulus*	3	4										
♦ *Sminthurinus bimaculatus*	2	8	1									
♦ *Sphaeridia pumilis*	111	16	34	5	32	2						
♦ *Stenognathellus denisi*	1		5		4							
♦ *Symphypleona* juv.	2		6	5	9							
Total abundance	1.378	728	1.474	523	1.022	1.034	670	195	1.331	571	292	194
Total taxa	33	31	34	25	40	31	15	15	19	15	24	16

Table 3. Total abundance of Portuguese or Iberian endemic species and species referred to Portugal for the first time.

Abundancia total de las especies portuguesas o ibéricas endémicas y especies citadas para Portugal por primera vez.

Species	Sites: *Q. suber*	*Q. canariensis*	*Eucalyptus*
Iberian endemic			
Microgastrura sensiliata Jordana, 1981	7		5
Friesea pseudodecipiens Arbea & Jordana, 1997	59	6	1
Mesaphorura arbeai Simón & Luciáñez, 1994	12	1	12
Mesaphorura sp. 1	1		3
Lepidocyrtus lusitanicus Gama, 1994	17	29	1
Portuguese endemic			
Deutonura atlantica Deharveng, 1982	18	4	21
Mesaphorura sp. 2	2	1	25
Mesaphorura sp. 3	8	1	21
Proisotoma coeca Gama, 1961			2
First time in Portugal			
Friesea pseudodecipiens Arbea & Jordana, 1997	59	6	1
Fissuraphorura gisini (Selga, 1963)		1	
Mesaphorura critica Ellis, 1976	1		9
Onychiurus penetrans Gisin, 1952			16
Folsomides navacerradensis Selga, 1952	3		
Cryptopygus debilis (Cassagnau, 1959)	63	1	2
Stenognathellus denisi (Cassagnau, 1953)	6	4	

complete absence of species from the Symphypleona and Entomobryidae groups, which are present in the oak biotopes. Furthermore, several species from the Isotomidae group are well represented in the oak biotopes, which are absent or poorly represented in EUCI and EUCII (table 2). *Isotomiella minor* and *Xenylla brevisimilis mediterranea* are taxa clearly associated with EUCI and EUCII (table 2).

The second eucalyptus group (group C) contains only samples from the EUCIII site. This group is completely separate from the other eucalyptus sites, which form group B. EUCIII can be considered in an intermediate position between oak and eucalyptus biotopes. This may be due to the presence of some species that are common to oak biotopes and EUCIII but do not occur or are very rare in the other eucalyptus sites (*Ceratophysella gibbosa, Cryptopygus scapelliferus, Proisotoma minuta, Megalothorax minimus, Microgastrura sensiliata*). Moreover, *Onychiurus penetrans, Pseudachorutes parvulus* (both exclusive from EUCIII) and *Mesaphorura* sp. 2 (more abundant in this site) are associated with EUCIII.

In the phenogram of R mode analysis (fig. 4), eight groups can be distinguished:

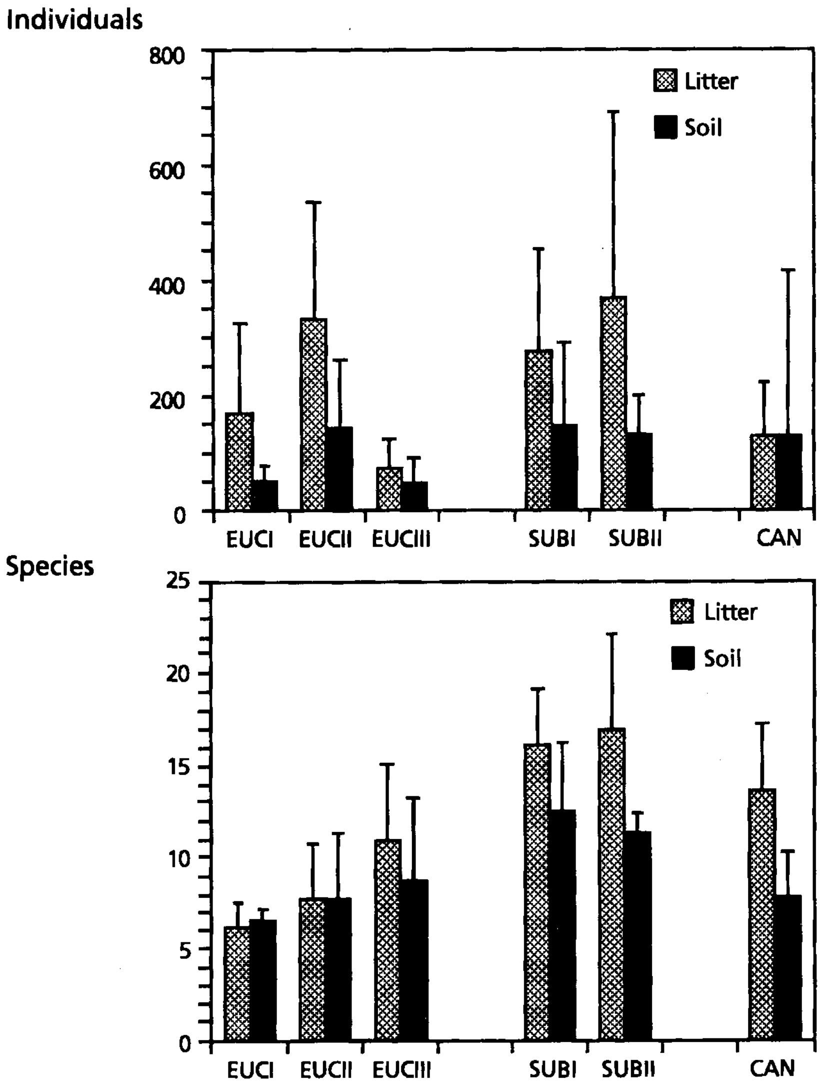

Fig. 2. Mean number (±SD) of individuals and taxa of Collembola in oak and eucalyptus biotopes. (For abbreviations of study sites see Material and methods.)

Número medio (±DS) de individuos y taxones de Colembola en los biotopos de robles y eucaliptus. (Para las abreviaturas de las áreas de estudio ver Material y métodos.)

- Group A contains 13 species with preference for oak sites; nevertheless, *Ceratophysella gibbosa* and *Isotomiella minor* are represented with a relative great abundance in EUCIII and II respectively.

- Group B contains species occurring preferentially in *Eucalyptus* although some of these are also well represented in *Q. suber* (e.g. *Bilobella aurantiaca, Deutonura atlantica* and *Micranurida* "2+2 eyes").

Table 4. Diversity (H'), Evenness (E) and Species Richness (D) for the different strata in the several biotopes.

Diversidad (H'), Uniformidad (E) y Riqueza Específica (D) en los distintos estratos de varios biotopos.

	H'		E		D	
	HO	HM	HO	HM	HO	HM
Q. suber (I)	2.64	2.37	0.52	0.48	4.43	4.55
Q. suber (II)	2.40	3.15	0.47	0.68	4.52	3.83
Q. canariensis	3.64	2.47	0.68	0.50	5.63	4.32
E. globulus (I)	1.50	2.19	0.38	0.56	2.15	2.66
E. globulus (II)	1.38	1.95	0.33	0.50	2.50	2.21
E. globulus (III)	3.44	2.88	0.75	0.72	4.05	2.85

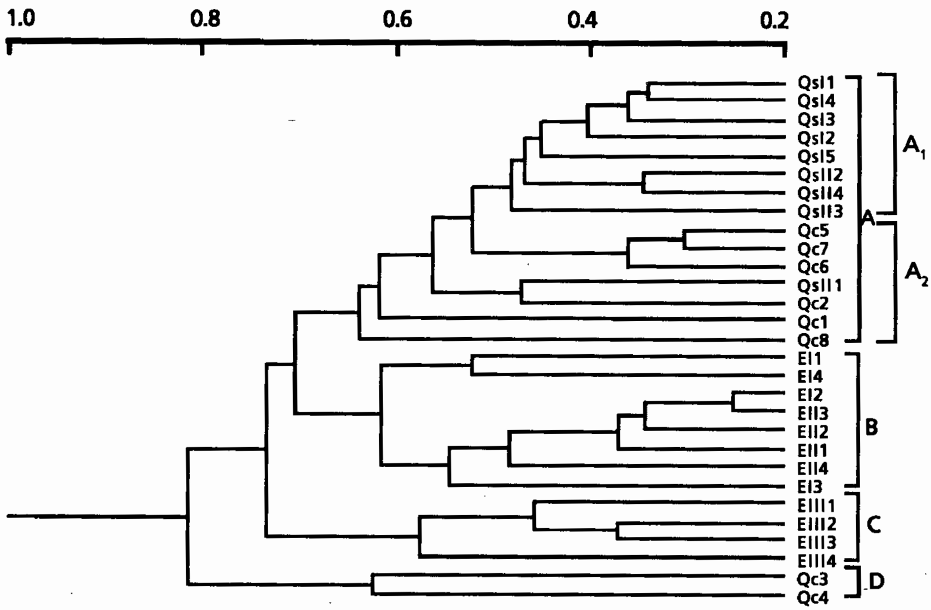

Fig. 3. Phenogram corresponding to the Q mode analysis based on Bray-Curtis distances.

Fenograma correspondiente al análisis modal Q basado en las distancias de Bray-Curtis.

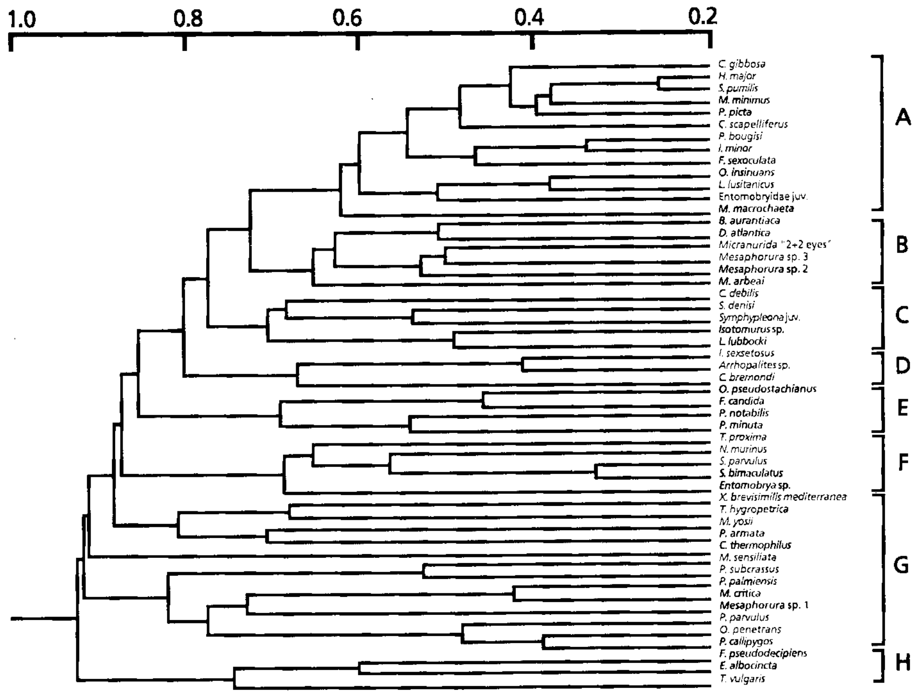

Fig. 4. Phenogram corresponding to the R mode analysis based on Bray-Curtis distances.
Fenograma correspondiente al análisis modal R basado en las distancias de Bray-Curtis.

- Group C contains five species found mostly in SUBII, and *Isotomodes sexsetosus*, *Caprainea bremondi* and *Arrhopalites* sp. are exclusive of SUBI and *Q. canariensis*, constituting group D.
- Group E is constituted by species that are exclusive (*Onychiurus pseudostachianus* and *Folsomia candida*) or occur preferentially (*Parisotoma notabilis* and *Proisotoma minuta*) in *Q. canariensis*.
- Group F contains species that appeared in SUBI, some occurring preferentially (*Tetracanthella proxima*, *Sminthurinus bimaculatus*) or being exclusive (*Sminthurides parvulus*) of this biotope.
- Group G contains several species, most occurring preferentially in eucalyptus. *Protaphorura armata*, *Pseudachorutes parvulus* and *Onychiurus penetrans* are exclusive of this group.
- Group H, a very small group made up of three species, two of them found only in *Q. canariensis* (*Entomobrya albocincta* and *Tomocerus vulgaris*) and one (*Friesea pseudodecipiens*) with a marked preference for SUBII.

Although no distinct separation of the species exists among the different biotopes (not so clear biotope differentiation as in fig. 3), the diagram shows groups of species associated preferentially to either oak or eucalyptus sites, thus reinforcing the distinction of the respective faunas.

Discussion

In this study, contrary to DEHARVENG (1996), the endemic component does not seem to have been influenced by the reafforestation with eucalyptus. Although endemic, these species do not seem to be very demanding in terms of microhabitat characteristics and were not affected by the change in the tree cover. An eucalyptus plantation usually causes a perturbation on species with more specific requisites, independently of their character of endemicity. This was also found by Sousa et al. (1994, 1997) where some endemic species were not affected by the substitution of oak species by eucalyptus. On the other hand, the lowest representation of endemic species under *Q. canariensis* (the rarest tree) in our study is explained by the great degradation and fragmentation of this biotope. There are not any real oak forests, only small spots of this oak.

The overall data analysis suggests that the reafforestation with *Eucalyptus globulus* caused some disruption on the structure of edaphic collembolan populations. Fauna associated with oaks has a different composition, being richer and generally more diverse than that associated with *Eucalyptus globulus*.

The impoverishment of soil fauna in eucalyptus plantations, in comparison with that from other autochthonous forests, has already been reported by several authors (Gama et al., 1989, 1991, 1994, 1995; Sousa & Gama, 1994; Vasconcelos et al., 1994; Sousa et al., 1997). However, in the present study the separation observed between eucalyptus plantations and coppices of oak is not so clear as in the above mentioned studies. In terms of abundance of individuals, we did not find any significant difference between eucalyptus and oak sites. Nevertheless, the values of abundance in eucalyptus result mainly from the presence of a few species which are represented by a great number of specimens in EUCI and EUCII. *Xenylla brevisimilis mediterranea* and *Folsomia sexoculata* make up more than 85% of the individuals in EUCI as well as in EUCII. This is an evidence of an opportunistic type behaviour, generally associated with a disruption at community level. When a perturbation occurs, most species usually decrease or even disappear and a small group, more resistant and with a higher reproduction rate, takes advantage of the new edaphic conditions and increases in abundance (Bonnet et al., 1976,1977, 1979; Arbea & Jordana, 1985).

Despite the absence of significant differences in abundance, the results in terms of number of taxa and diversity indicators showed a different picture. All eucalyptus sites had a lower total number of species and a lower number of preferential and/or exclusive species than oak sites. Regarding diversity descriptors, and with the exception of EUCIII, values for Shannon, evenness and Margalef indexes were higher in oak sites.

Previous studies, also comparing fauna from eucalyptus with that from several autochthonous species (oaks and pines), report an impoverishment in abundance and/or diversity in eucalyptus stands. This is generally attributed to changes in chemical parameters, such as the contents of water, organic matter, carbon and nitrogen (Gama et al., 1994a, 1994b, 1995; Vasconcelos et al., 1994; Sousa & Gama, 1994 ; Sousa et al., 1997).

Some researchers, also dealing with the impact of eucalyptus plantations, have stressed the importance of forestry practice connected with the establishment and management of the plantation. The usual procedures cause a decrease or even disappearance of the vegetation cover and of the standing stock biomass, leading to a decrease in nutrient content and moisture conditions and, consequently, to an impoverishment of the soil. In the eucalyptus plantations that are not currently exploited, the signs of rupture are not so evident (Sousa et al., 1997).

However, in the present case, a direct relationship between the differences in collembolan communities and physical and chemical parameters is not so evident. Although the eucalyptus biotopes have a higher content of organic matter, water and nutrients, the abundance of individuals does not differ between oaks and eucalyptus sites and diversity is even higher in oaks. Nevertheless, other factors such as litter layer thickness (Vasconcelos et al., 1994; Gama et al., 1995) and C/N ratio, considered as an index of substrate quality (Richards, 1987), have often been considered important. Both factors are favourable to oak sites. However, differences in collembolan communities between EUCIII and the other eucalyptus sites and its relatively proximity to oaks can be partially explained by the observed similarities in terms of chemical parameters. This eucalyptus site present similar organic matter and carbon contents and C/N ratios than those observed in oak sites.

Other not so evident factors must certainly explain our results and be responsible for the lower species richness in eucalyptus biotopes. According to DEHARVENG et al. (1989), high diversity values could be connected to a wider range of narrow trophic niches. This is particularly true in climax forests which tend to be diversified mosaics of plant species, therefore increasing biological diversity of soil fauna.

Furthermore, differences in the community composition can be related with litter quality and feeding preferences. PINTO et al. (1997) suggest that leaf chemistry (namely N content) may be an important factor in controlling the structure of soil collembolan communities. Moreover, oak litter is more "palatable" to soil fauna than eucalyptus litter, supporting a higher fungal biomass, thus arthropod communities feeding on fungal spores/hiphae (personal data, unpublished). Collembola are mainly grazers and do not feed indiscriminately, displaying preference for particular fungal species and fungal development stages (PARKINSON & VISSER, 1979; RUSEK, 1989; KLIRONOMOS et al., 1992; GRAÇA, 1993). Oak litter could thus provide, in qualitative terms, more food resources for collembola, and this would explain higher diversity indexes.

On the other hand, we may wonder if the disappearance of Entomobryidae and Symphypleona groups could not be attributed to changes in the habitat of this litter dwelling species instead of food resources. Testing collembolan response to experimental perturbations of litter supply, PONGE et al. (1993) pointed out the importance of litter as a substrate for reproduction of epigeic species. They observed that changes in collembolan communities were attributed to shifts in the habitat of these species, rather than in food resources. It is thus possible that the litter from the eucalyptus biotope does not provide suitable microhabitat conditions for these groups of collembola. Furthermore, eucalyptus litter thickness is lower.

In conclusion, it is clear that eucalyptus plantations, as compared to oak forests, have a very different faunal spectra, with impoverished communities. These facts and, also, the number of species cited for the first time for our country and the number of rare or endemic species, enhances the need to preserve the Serra de Monchique area, if we are looking for biodiversity conservation.

Reafforestation always disturbs the ecosystem and induces a rupture in the biocenotical balance of soil communities. However, the magnitude of the rupture depends on the changes in soil characteristics, due not only to the new plant species but also to the procedures used in the establishment (complete cutting of vegetation and groove formation) and management (regular clearing and cutting) of the plantation. The more a plantation is managed, the higher the rupture in the soil community will be.

Thus, it is of prime importance to adopt more appropriate methods and instruments in the preparation of soil for planting eucalyptus and in the maintenance of the plantation, in order to cause as little disturbance in habitat configuration as possible. If the frequency of intervention in the system is decreased and less drastic procedures in the establishment of the plantation are performed, the organic horizon and the vegetation cover will have more suitable microhabitat conditions for soil microarthropods (namely in terms of food resources and moisture).

Resumen

Impacto de la reforestación con Eucalyptus globulus *Labill. sobre la fauna de colémbolos edáficos de la Serra de Monchique (Algarve, Portugal)*

Los bosques autóctonos de Portugal han sido gradualmente reemplazados con plantaciones de *Eucalyptus globulus*. Este arbol exótico ha sido citado como el principal factor de perturbación del ecosistema (Gama et al. 1989, 1991, 1994, 1995; Sousa & Gama, 1994; Vasconcelos et al., 1994). En este trabajo se comparan las poblaciones de colémbolos edáficos que se encuentran en bosquecillos de *Quercus suber* L. y *Q. canariensis* Willd. con los de zonas con *Eucalyptus globulus* Labill. de la Serra de Monchique, para evaluar los efectos de la reforestación. El análisis de los datos muestra separación entre las comunidades de colémbolos asociados al eucaliptus. Los biotopos de *Quercus* normalmente presentan valores más altos de diversidad y de riqueza específica, números más

altos de especies y especies más exclusivas o preferenciales que los biotopos de eucaliptus. No se observaron diferencias significativas entre los distintos biotopos en cuanto a la media del número de individuos. La abundancia de individuos en los biotopos de eucaliptus es el resultado principalmente de la presencia de unas pocas especies representadas por un gran número de especímenes y que constituyen más del 85% de los individuos de los biotopos de eucaliptus.

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