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The occurrence and distribution of *Xiphinema* species (Nematoda : Dorylaimida) in Spanish fir woodlands

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Summary – A comparative study was made to investigate the influence of some edaphic factors on the occurrence and relative abundance of four *Xiphinema* species found in the soils of five selected fir forests (*Abies pinsapo* Boiss.) in southern Spain. The samples were taken seasonally for one year. Univariate (one-way analysis of the variance) and multivariate (cluster and correspondence analyses) methods were applied in order to relate species to habitat characteristics and to reveal their distribution patterns throughout the studied areas. Three of the species seem to be distributed in accordance with the textural gradient of the soils. *X. sphaerocephalum* Lamberti, Castillo, Gómez-Barcina & Agostinelli, 1992 showed the largest frequency of occurrence and relative abundance in soils on calcareous rocks, but was not found on peridotites, i.e. more sandy soils. It prefered the most silty textures. *X. pachtaicum* (Tulaganov, 1938) Kirjanova, 1951 was found in clayey textured soil more clearly subjected to Mediterranean climatic conditions. *X. diversicaudatum* (Micoletzky, 1927) Thorne, 1939 gave evidence of a strong relationship with more sandy textured, acid soils with high silt content. Finally, *X. turcicum* Luc & Dalmasso, 1964 was rarely found and at such very low numbers that its distribution becomes obscure in these soils.

Résumé – ***Présence et répartition d'espèces de* Xiphinema *(Nematoda : Dorylaimida) dans des forêts de sapin, en Espagne*** – Une étude comparative a été réalisée en vue de définir l'influence des facteurs édaphiques sur la présence et l'abondance relative de quatre espèces de *Xiphinema* observées dans le sol de cinq forêts de sapin (*Abies pinsapo* Boiss) du sud de l'Espagne. Les prélèvements ont été effectués de façon saisonnière pendant une année. Afin de relier la présence des espèces avec les caractéristiques de l'habitat et mettre en évidence leur mode de répartition dans les aires étudiées, les méthodes d'analyses univariées (analyse linéaire de la variance) et multivariées (analyses en grappe et de correspondance) ont été utilisées. La répartition de trois des espèces s'est révélée correspondre aux gradients de texture du sol. *X. sphaerocephalum* montre ses plus grandes fréquence et abondance relative dans les sols à roche-mère calcaire, mais n'a pas été trouvé sur les péridotites, c'est-à-dire dans des sols plus sableux, préférant les textures plutôt limoneuses. *X. pachtaicum* est rencontré dans les sols à texture argileuse plus nettement soumis aux conditions climatiques méditerranéennes. La répartition de *X. diversicaudatum* est très nettement liée aux sols acides de texture plus sableuse avec un taux élevé d'argile fine. *X. turcicum*, enfin, n'est rencontré que très rarement et en faible nombre, aussi sa répartition dans ces sols demeure-t-elle obscure.

Key-words : ecology, distribution, edaphic factors, *Xiphinema*, Spanish fir forests.

Spanish fir forests are relict zones with *Abies pinsapo* Boiss. as the characteristic or prevalent tree species, located in restricted mountainous parts of the southern area of the Iberian Peninsula, the Betic and Subbetic Mountains, with altitudes often over 1000 m. These woodlands are related with other *Abies* woods from northern Africa. During autumn-summer of 1992-93 soil samples were collected around fir trees from isolated areas. The study of the nematofauna showed the presence of the following four species of *Xiphinema* Cobb, 1913 : *X. sphaerocephalum* Lamberti, Castillo, Gómez-Barcina & Agostinelli, 1992; *X. pachtaicum* (Tulaganov, 1938) Kirjanova, 1951; *X. diversicaudatum* (Micoletzky, 1927) Thorne, 1939 and *X. turcicum* Luc & Dalmasso, 1964.

X. sphaerocephalum tends to show the largest frequency of occurrence and population size and its distribution pattern in the area can be more clearly defined; this provides initial information on the ecology of this species. No previous ecological and/or distribution data are known from the literature and it has been recorded only twice, both on the Iberian Peninsula, by Lamberti *et al.* (1992) and by Roca and Bravo (1993). However, some data has been reported for the other species studied. Cohn (1969) relates *X. pachtaicum* (cited as *X. mediterraneum* Martelli & Lamberti, 1967) to loamy and clayey heavy soils and *X. diversicaudatum* to sandy lighter soils in Israel. Dalmasso (1970), from a study of the family Longidoridae in France, concludes that *X. pachtaicum* is a species present in alluvial and other non-sandy soils,

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Table 1. *Seasonal values of pH, organic matter % (O.M.), nitrogen % (N), C : N ratio, sand % (SA), silt % (SI) and clay % (CL), and*

Zone/Site	pH				O.M.				N			
	a	w	s	u	a	w	s	u	a	w	s	u
Ronda												
1	7.68	7.23	7.14	7.38	28.00	9.35	11.98	8.48	0.63	0.26	0.30	0.23
2	7.38	7.12	7.28	7.22	24.83	12.02	17.66	13.56	0.72	0.37	0.51	0.38
3	7.72	7.38	7.20	7.44	44.09	20.19	23.74	30.14	0.57	0.69	0.70	0.73
4	7.80	7.21	7.24	7.35	14.88	9.48	5.88	8.45	0.43	0.37	0.26	0.29
$\bar{x} \pm s$		7.36 ± 0.20				17.67 ± 9.96				0.47 ± 0.18		
Parauta												
5	6.86	6.54	6.28	6.41	53.39	17.35	3.74	10.17	1.43	0.62	0.09	0.30
6	7.40	7.11	6.55	6.99	9.30	3.66	16.54	15.47	0.29	0.10	0.36	0.51
7	7.32	6.98	6.78	7.05	18.51	8.75	16.26	10.18	0.48	0.23	0.46	0.28
8	7.54	7.05	6.96	7.18	5.45	4.98	5.54	7.49	0.17	0.18	0.15	0.26
$\bar{x} \pm s$		6.94 ± 0.34				12.92 ± 11.56				0.37 ± 0.31		
Yunquera												
9	6.90	6.86	7.10	7.02	18.32	2.62	12.04	8.56	0.47	0.12	0.36	0.30
10	7.14	6.92	7.12	7.02	9.02	7.38	5.00	6.15	0.20	0.24	0.19	0.19
11	7.31	6.88	7.04	7.17	4.15	6.67	7.64	7.60	0.12	0.27	0.19	0.24
$\bar{x} \pm s$		7.04 ± 0.13				7.93 ± 3.90				0.24 ± 0.10		
Genalguacil-Estepona												
12	6.65	6.49	6.37	6.28	10.60	6.59	7.74	8.34	0.22	0.17	0.18	0.23
13	6.44	6.23	6.30	6.45	10.90	7.78	8.86	8.98	0.33	0.29	0.29	0.37
14	6.39	6.17	5.86	6.22	8.37	5.49	7.84	6.46	0.24	0.16	0.26	0.19
$\bar{x} \pm s$		6.32 ± 0.19				8.16 ± 1.52				0.24 ± 0.06		
Grazalema												
15	7.52	7.40	6.91	7.08	21.81	9.78	7.56	18.33	0.56	0.36	0.23	0.49
16	7.79	7.48	7.53	7.56	14.55	12.15	16.18	9.47	0.32	0.27	0.23	0.19
17	7.70	7.21	7.34	7.45	17.39	15.56	14.30	12.14	0.55	0.69	0.53	0.48
18	7.48	7.35	7.01	7.26	18.18	12.38	9.40	10.74	0.42	0.30	0.24	0.28
$\bar{x} \pm s$		7.38 ± 0.23				13.75 ± 3.84				0.38 ± 0.15		

with relatively high silt content, and well adapted to Mediterranean climatic conditions, while *X. diversicaudatum* is found mainly in wetter soils in an Atlantic climate. According to Arias *et al.* (1985), *X. pachtaicum* is a species frequent in Spain; it is associated with arable lands (soils deficient in organic matter) and tolerates dry conditions (see Arias *et al.*, 1986 for Central Region). Navas *et al.* (1988) did more extensive studies, which documented the potential distribution of this species in Mediterranean areas of the Iberian Peninsula with calcareous or siliceous soils, as well as broad zones in the northern and southern Plateau with calcareous and clayey soils. A similar analysis was carried out by these authors for *X. diversicaudatum,* which appears to be associated with natural or uncultivated soils with a high sand and organic matter content; Navas *et al.* (1988) concluded that this species may occur in practically all mountainous peninsular zones with siliceous soils as well as in some Atlantic areas. Its ecological behaviour is the opposite of that in *X. pachtaicum.* Finally, information on *X. turcicum* is scarce. It was recorded by Arias *et al.* (1985) in different localities, by Peña Santiago and Jiménez Millán (1986) in eastern Andalusia (mainly associated with sclerophyllous forests) and included by Bello *et al.* (1986) in the southwest central group in a general biogeographical classification of some plant-parasitic species in Spain.

Univariate and multivariate statistical analyses provide a more objective tool for exploring patterns relating species to their habitats and may be used to reveal trends *textural classification of the soils in the sampling sites studied.* (a = *autumn,* w = *winter,* s = *spring,* u = *summer).*

Variable/Season																
C:N				SA				SI				CL				Soil texture
a	w	s	u	a	w	s	u	a	w	s	u	a	w	s	u	
22.22	17.48	19.96	18.32	4.98	6.17	5.43	5.79	25.14	31.04	28.19	30.66	69.88	62.79	66.38	63.55	clay
17.24	16.24	17.31	17.49	34.80	33.56	36.44	40.51	39.57	36.81	38.04	39.04	25.63	29.63	25.52	20.45	clay loam
38.67	14.57	16.95	20.51	36.18	39.25	37.87	38.67	51.70	40.19	44.68	43.26	12.12	20.56	17.45	18.07	loam
17.30	12.79	11.30	14.17	21.79	28.32	24.12	25.16	28.91	36.05	32.29	31.91	49.30	35.63	43.59	42.93	clay
	18.28 ± 5.91				26.19 ± 13.06				36.09 ± 6.76				37.72 ± 18.97			
18.66	13.84	20.77	16.46	9.19	8.62	8.06	6.38	63.03	64.10	61.92	59.48	27.78	27.28	30.02	34.14	silty clay loam
16.03	18.30	22.97	15.06	10.70	9.47	9.41	9.01	58.80	52.78	59.62	62.79	30.50	37.75	30.97	28.20	silty clay loam
19.28	18.46	17.67	18.18	15.06	12.83	14.10	13.97	53.17	47.15	50.88	52.68	31.77	40.02	35.02	33.35	silty clay loam
16.02	13.35	18.46	14.44	32.50	18.17	22.27	16.77	55.71	58.90	60.91	66.32	11.79	22.93	16.82	16.91	silt loam
	17.37 ± 2.49				13.53 ± 6.41				58.02 ± 5.23				28.45 ± 7.59			
19.48	10.91	16.72	13.97	29.41	30.67	27.55	24.36	36.19	38.81	38.51	39.72	34.40	30.52	33.94	35.92	clay loam
22.55	15.22	13.15	15.78	19.30	16.50	18.00	17.81	51.42	39.16	43.53	41.01	29.18	44.34	38.47	41.18	silty clay loam
17.29	12.01	20.10	15.41	35.90	21.93	28.62	25.08	40.40	36.06	32.00	34.19	23.70	42.01	39.38	40.73	clay loam
	16.05 ± 3.28				24.59 ± 5.80				39.25 ± 4.74				36.15 ± 5.82			
24.09	18.97	21.50	17.99	53.58	45.16	50.47	55.03	34.12	25.15	28.96	26.01	12.30	29.69	20.57	18.96	loam
16.51	13.41	15.27	12.07	42.71	31.01	37.30	36.41	29.14	37.06	32.15	32.68	28.15	31.93	30.55	30.91	clay loam
17.43	16.45	15.07	16.39	59.00	60.98	64.71	70.75	18.50	21.02	17.23	19.53	22.50	18.00	18.06	9.72	sandy loam
	17.10 ± 3.17				50.59 ± 11.78				26.80 ± 6.34				22.61 ± 7.25			
19.47	13.58	16.43	18.45	3.29	1.45	2.95	3.84	47.34	42.03	44.57	46.16	49.37	56.52	52.48	50.00	silty clay
27.73	22.24	35.17	24.43	37.18	35.15	34.82	29.02	48.14	39.97	46.12	49.05	14.68	24.88	19.06	21.93	loam
15.80	11.17	13.49	12.64	45.06	40.16	39.01	36.18	51.36	47.76	49.29	50.40	3.58	12.08	11.70	13.42	loam
21.64	20.43	19.58	18.59	6.16	1.40	1.92	2.17	47.14	46.18	44.58	40.06	46.70	52.42	53.50	57.77	silty clay
	19.43 ± 5.93				19.99 ± 17.39				46.26 ± 3.25				33.76 ± 19.26			

in the studies of their interactions. This paper proposes a description of the horizontal distribution pattern of these species in *Abies* woods from southern Spain.

Material and methods

Study sites

Five main geographic zones were chosen for this study : Ronda, Parauta, Yunquera, Genalguacil-Estepona (province of Málaga) and Grazalema (province of Cádiz). In Ronda (Cañada del Cuerno) there were four sites (1, 2, 3, 4) on dolomitic rocks, at an approximate altitude of 1500 m, in ancient and residual, pure fir stands. In Parauta there were four sites (5, 6, 7, 8) on limestone and marble, with an altitude of 1100 m, in a mixed wood with *Quercus ilex* L., *Q. suber* L. and *Q. faginea* Lamk. plus reforestations of *Pinus pinaster* Ait. The three sites at Yunquera (9, 10, 11) were on limestone, marble or dolomitic rocks, at about 1200 m. These are expanding stands with reforestations of *Pinus halepensis* Mill. and *P. pinaster.* Genalguacil-Estepona (Los Reales) provided three sites (12, 13, 14) which were on peridotites, at 1200-1400 m, in a forest in regressive condition with reforestations of *P. pinaster.* In Grazalema there were four sites (15, 16, 17, 18) on limestone, at about 1100 m, in old stabilized fir wood mixed with *Q. faginea.* For geological information see Delannoy (1987) and Mudarra *et al.* (1989). According

Table 2. *Relative abundance (%), with regard to total nematode number, of the* Xiphinema *species found in each sampling site.* (a = *autumn*, w = *winter*, s = *spring*, u = *summer*).

Zone/Site	*X. sphaerocephalum*				*X. pachtaicum*				*X. diversicaudatum*				*X. turcicum*			
	a	w	s	u	a	w	s	u	a	w	s	u	a	w	s	u
Ronda																
1	1	3	3	1	0	0	0	0	0	0	0	0	0	0	0	0
2	4	3	3	1	0	0	0	0	0	0	0	0	0	0	0	0
3	1	1	3	1	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	1	2	3	0	0	0	0	0	1	1	1	0
Parauta																
5	1	7	6	1	0	0	0	0	0	0	0	0	0	0	0	0
6	3	6	7	5	0	0	0	0	0	0	0	0	0	0	0	0
7	10	8	6	6	0	0	0	0	0	0	0	0	0	0	0	0
8	8	12	8	7	0	0	0	0	1	0	0	0	0	0	0	0
Yunquera																
9	10	5	6	2	0	0	0	0	0	0	0	0	0	0	0	0
10	3	5	13	8	0	0	0	0	0	1	0	0	0	0	0	0
11	10	3	3	6	0	0	0	0	0	0	0	0	0	0	1	0
Genalguacil-Estepona																
12	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
13	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Grazalema																
15	4	3	3	1	0	0	0	0	0	0	0	0	0	0	0	0
16	1	3	3	1	0	0	0	0	0	0	0	0	0	0	0	0
17	5	2	3	1	0	0	0	0	0	0	0	0	0	0	0	0
18	4	1	4	2	0	0	0	0	0	0	0	0	0	0	0	0

to Corral *et al.* (1985) and Mudarra *et al.* (1989) the soils from Ronda and Grazalema were classified as humic and calcic cambisols or rendzinic soils, whereas at Yunquera and Parauta there were mainly eutric cambisols, and at Genalguacil-Estepona there were chromic cambisols and eutric regosols.

For each sampling site, the following seven edaphic factors or variables were determined by conventional methods : pH (Guitián Ojea & Carballas Fernández, 1976), organic matter (Sims & Haby, 1971), N, C : N ratio, and sand, silt and clay percentages (Duchaufour, 1975). The terminology for soil texture classes employed here is consistent with that of Soil Survey Staff (1975).

Nematode sampling

A total of 72 soil samples were collected quarterly between November 1992 and August 1993 around fir trees, in the 0-20 cm layer. Nematodes were extracted from 1000 cm^3 of soil per sample by the Flegg (1967) funnel method, and were fixed by gradually applying heat and F.G 4 : 1, processed in lactophenol and mounted in anhydrous glycerin.

Data analysis

The variables were subjected to one-way analysis of the variance (ANOVA), as the univariate method for testing significant differences between the sampling zones. The normality of the variables was tested (Afifi & Clark, 1990) prior to multivariate analysis. Finally, the *log (x + 1)* transformation was used because it scarcely modifies the results and provides the best fit for Gaussian distribution. Edaphic data was submitted to cluster analysis, using the Bray-Curtis distances (Q mode analysis) and the unweighted pair group with arithmetic means (UPGMA) clustering method (Sneath & Sokal, 1973; Legendre & Legendre, 1979; Digby & Kempton, 1987). In addition, data was submitted to correspondence analysis (CA), using the sampling sites as observations or subjects in the space of biological and environmental variables. Eigenvalues and eigenvectors of the between variables correlation matrix were computed using the Pearson's correlation index.

Results

Table 1 shows the analytical results for the four seasons at the eighteen sampling sites, indicating the soil textural classification in each site. Table 2 reports the

Table 3. *Average values of the edaphic variables and relative abundance of* X. sphaerocephalum *(XS) throughout the different seasons. Computed t statistical for significant differences only.* * P < *0.05* ** P < *0.01.* (a = *autumn,* w = *winter,* s = *spring,* u = *summer).*

Variable	Season				Significant differences between seasons
	a	w	s	u	
pH	7.27	6.97	6.88	7.02	a-w 2.12 * a-s 2.60 *
O.M.	18.43	9.56	10.99	11.15	a-w 2.74 ** a-s 2.25 * a-u 2.19 *
N	0.45	0.31	0.30	0.33	
C : N	20.41	15.52	18.43	16.68	a-w 3.21 ** a-u 2.50 *
Sand	27.59	24.48	25.72	25.38	
Silt	43.32	41.12	41.85	42.49	
Clay	29.07	34.38	32.41	32.11	
XS	3.61	3.44	3.94	2.38	

abundance, relative to total number of nematodes, of the four *Xiphinema* species found in this study. *X. sphaerocephalum* generally had a higher frequency of occurrence and relative density and was the *Xiphinema* species most capable of data analysis. The remaining *Xiphinema* species found were discarded from the statistical analyses because of their low frequency of occurrence. Table 3 shows the average values of the edaphic variables considered and the relative abundance of *X. sphaerocephalum* throughout the seasons. It is noted from this table that no significant seasonal differences are established in the soil texture variables and the populations of this species. Apparently, from a general point of view and bearing in mind that sampling was quarterly throughout one year, the populations seem to remain in a very steady state or the fluctuations appear unrelated to seasonal factors. Reproduction in these populations of *X. sphaerocephalum* is probably parthenogenetic; only one male with obscure or not developed testes was observed among several hundred females.

The study of the correlations between the variables reveals barely any significant result *(P < 0.01).* As was expected, organic matter and nitrogen content and clay and sand fractions were significantly correlated ($r = + 0.91$ and $- 0.74$ respectively) and silt percentage was correlated to the relative abundance of *X. sphaerocephalum* ($r = + 0.63$).

The resuls of the one-way ANOVA (Table 4) showed significant differences between the five sampling zones studied for pH, sand and silt content and relative abundance of *X. sphaerocephalum.* It is interesting to note that, in addition to geographical separation, the differences between the zones could be explained by soil texture characteristics.

Table 4. *Result of the one-way ANOVA of the differences in the edaphic variables and relative abundance (%) of* X. sphaerocephalum *(XS) between the five sampling zones studied for the entire year.* (‡ *not significant* † *near* P < *0.05* * P < *0.05* ** P < *0.01* *** *P < 0.001.* a = *autumn,* w = *winter,* s = *spring,* u = *summer.* 1 = *Ronda,* 2 = *Parauta,* 3 = *Yunquera,* 4 = *Genalguacil-Estepona,* 5 = *Grazalema).*

Variable/Season		F ratio	Significant differences between zones
pH	a	17.39 ***	1-2/1-3/1-4/2-4/2-5/3-4/3-5/4-5
	w	22.16 ***	1-2/1-3/1-4/2-4/2-5/3-4/3-5/4-5
	s	12.93 ***	1-2/1-4/2-3/2-4/2-5/3-4/4-5
	u	13.95 ***	1-2/1-4/2-4/2-5/3-4/4-5
O.M.	a	1.31 ‡	–
	w	2.19 ‡	–
	s	0.91 ‡	–
	u	1.18 ‡	–
N	a	1.04 ‡	–
	w	1.23 ‡	–
	s	1.09 ‡	–
	u	0.73 ‡	–
C : N	a	0.65 ‡	–
	w	0.74 ‡	–
	s	0.58 ‡	–
	u	0.84 ‡	–
Sand	a	2.91 †	1-4/2-4/4-5
	w	2.63 †	2-4/4-5
	s	3.51 *	1-4/2-4/3-4/4-5
	u	4.82 *	1-4/2-4/3-4/4-5
Silt	a	8.31 **	1-2/1-5/2-3/2-4/3-4/4-5
	w	13.01 ***	1-2/2-3/2-4/2-5/3-4/4-5
	s	15.61 ***	1-2/1-4/1-5/2-3/2-4/2-5/3-4/4-5
	u	19.89 ***	1-2/1-4/1-5/2-3/2-4/2-5/3-4/4-5
Clay	a	0.54 ‡	–
	w	0.37 ‡	–
	s	0.57 ‡	–
	u	0.80 ‡	–
XS	a	3.78 *	1-3/2-4/3-4
	w	14.56 ***	1-2/2-3/2-4/2-5/3-4
	s	6.51 **	1-2/1-3/2-4/2-5/3-4/3-5
	u	6.46 **	1-2/1-3/2-4/2-5/3-4/3-5

The dendrogram constructed from the cluster analysis made from the edaphic data matrix, denoted a fairly good fit to the data (correlation coefficient, $r = 0.70$; usually ranging from *0.60* to *0.95*) and classified the sampling sites into five groups (Fig. 1), which appear clearly defined at about 0.20 level. In accordance with the separation sequence of this dendogram, group V contains only soils with a sand content of more than

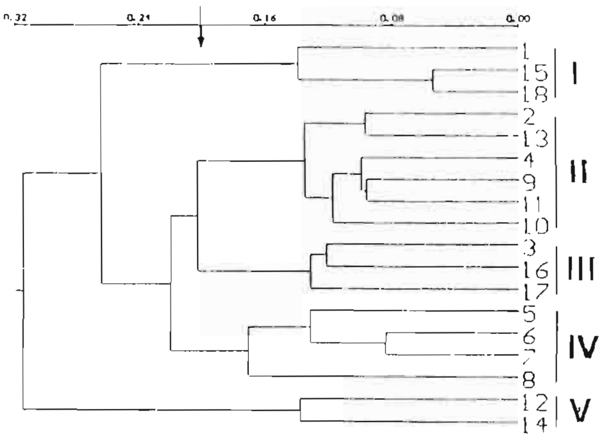

Fig. 1. Dendrogram from cluster analysis (UPGMA method) based in the Bray-Curtis distances obtained with the edaphic variables for the eighteen sampling sites. (Site numbers as in Table 1). Group I : clay > 50 %; Group II : clay 50-25 %; Group III : clay < 25 %; Group IV : silt > 50 %; Group V : sand > 50 %.

50 %, corresponding with two sites of the Genalguacil-Estepona zone; on the other hand, group I includes the soils with sand content lower than 6 % and clay content above 50 %, corresponding with some sites in Ronda and Grazalema; group IV comprises only samples from Parauta zone which are characterized by a silt content above 50 %; group III contains remaining sites restricted to the same zones as group I but with clay content lower than 25 %; and group II refers to remaining sites, including those of Yunquera area, with clay content that varies from 25 % to 50 %. From this cluster analysis, the sites appear classified mainly by soil textural descriptors and less by the geographic locations of the zones. Group IV, which consists of the whole of the sampling sites in Parauta zone, stands out from the rest.

The CA performed with the same edaphic data plus the relative abundance de *X. sphaerocephalum* is plotted in Fig. 2 on the plane defined by axes I and II, which accounted for respectively 53.0 % and 22.7 % of the total variance present in the data. Both axes explained 75.7 % of the total variance. Axis I may be construed as a gradient established by the population level, in relative abundance, of this *Xiphinema* species, which had the largest relative contribution (70.2 %) to this axis. Second in contribution is the sand content (27.6 %), which means that axis I represents in part a soil texture gradient. The highest population densities are on the right side of the figure and at the opposite end of the axis is the sand content: soils with higher sand percentages are located to left side of the figure. Axis II is clearly more closely linked to the soil texture gradient than axis I; it is defined by the sand percentage and also by the clay

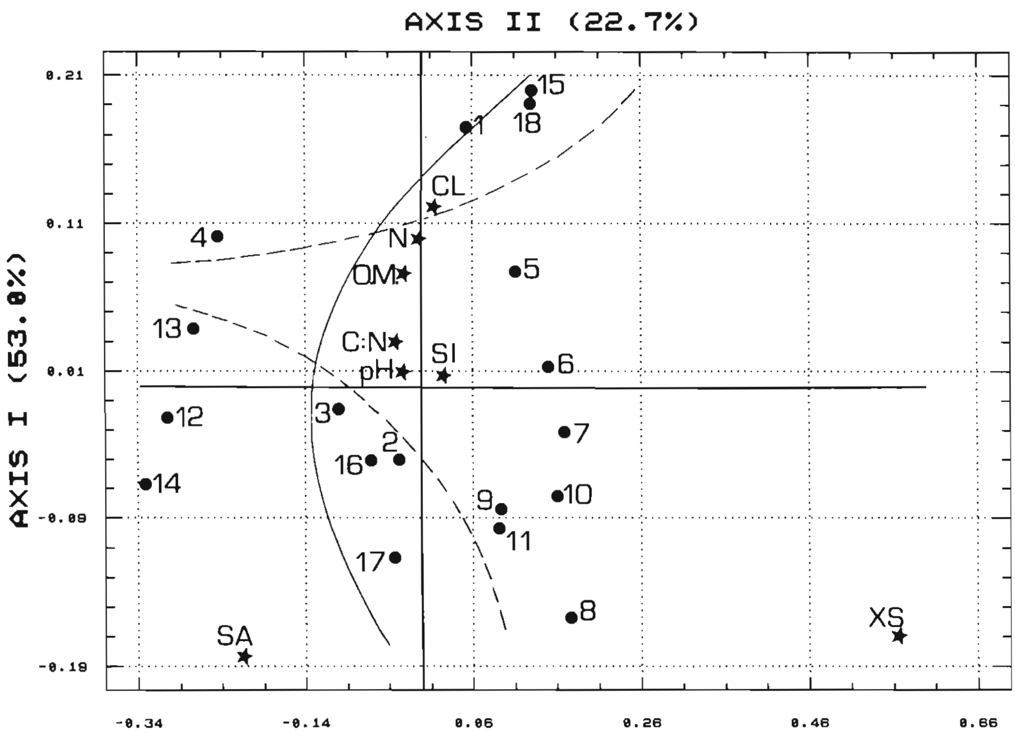

Fig. 2. Plot of the mean scores of the eighteen sampling sites (●) and the edaphic variables and relative abundance (★) of X. sphaerocephalum *(XS), resulting from correspondence analysis, on the plane defined by the two first axes. (Site numbers and variables as in Table 1).* Sites in the top : clay > 40 %; Sites in the lower left corner : sand > 30 %; Sites in the right side : silt > 35 %.

content of the soils. The relative contribution of these edaphic variables to this axis was respectively 45.1 % and 20.2 %, while the contribution of the relative abundance of *X. sphaerocephalum* was 21.0 %. This axis segregated the clayey soils at the top of the figure from the more sandy soils.

Discussion

XIPHINEMA SPHAEROCEPHALUM

These populations of *X. sphaerocephalum* showed a behaviour similar to that of another *Xiphinema* species in Israel (Cohn, 1969) and *X. pachtaicum* in southern France (Dalmasso, 1970). Dalmasso extended such biological aspects to other European species, which suggests that reproduction occurs in a restricted time, so that population state depends on its own development rather than on external seasonal factors. This should explain the slight differences between seasons in the Table 2 and the not significant differences for XS variable in the average values of Table 3.

Two important consequences are derived from the univariate analyses, the positive correlation between the relative abundance of this *Xiphinema* species and the silt content of soils and the significant differences between the geographic zones in these relative population densities and the edaphic variables pH, sand and silt content (Table 4). The five groups obtained from the cluster analysis are not strictly in agreement with the five sampling zones. Nevertheless these groups mostly agree with a textural classification of the soils. Thus, group I are the fine-textured or clayey soil while the rest (except site 4) are the loamy soils which can be separated in the following clusters : group II corresponding to moderately fine-textured (slightly clayey) soils, group III mostly to medium textured soils, group IV to moderately fine-textured (slightly silty) soils and group V to moderately coarse-textured (most sandy) soils after classification of Soil Survey Staff (1975). This good classification (Fig. 1) differs from the site ordination (Fig. 2) obtained in the correspondence analysis because the SX variable was included in the analysis in order to establish the relationships between these relative densities and the edaphic variables. However it is possible to find some concordance between both projections. Thus, groups I (sites 1, 15, 18) and V (sites 12, 14) appear defined in a similar way in both analyses. Group I, the fine-textured or clayey soils, shows low densities of this nematode species in the Ronda and Grazalema zones, and group V, the moderately coarse or sandy soils, is characterized by the total absence of *X. sphaerocephalum* in the Genalguacil-Estepona area. Group III (sites 3, 16, 17) exhibits the more favorable or balanced edaphic conditions (Duchaufour, 1975), medium textured or the loam texture in soils, but this *Xiphinema* species is found here at low population levels. Group IV (sites 5, 6, 7, 8) and group II in part (sites 9, 10, 11) are joined in intermediate locations linked to soil silt content. These sites, that show the higher relative abundance of this species, correspond to moderately fine-textured within loamy soils, mainly silty clay loam and silt loam textures, which represents an unfavorable condition (unpermeable, unaerated soils) that would not exist if it could be amended by high organic matter content in soils. All the latter sites belong to Parauta and Yunquera zones. In summary, the sites with clay and sand content of more than 40 % and 30 % respectively are separated by dashed lines in the upper part and the lower left corner in Fig. 2. Those with silt content of more than 35 %, separated by the solid line, are at the right side and they include the sites (6, 7, 8, 9, 10, 11) with higher population levels of this species. Consequently, in the fir woodlands studied, *X. sphaerocephalum* is widespread in soils developed on limestone and other calcareous rocks, and is not present in the sampled area of peridotites, that is to say, in the most sandy textures. There is a tendency for populations to increase as the silt percentage increases, with the result that it clearly prefers more silty textured soils.

XIPHINEMA PACHTAICUM

X. pachtaicum appears without any doubt strongly associated with sampling site 4, an open or cleared place which is located on the left side in fig. 2 because of the absence of *X. sphaerocephalum*. The soil has a clayey texture, is closer to a more calcic mull humus type and is rather affected by Mediterranean dry climatic conditions. This corresponds with previous conclusions (Cohn, 1969; Dalmasso, 1970; Navas *et al.*, 1988).

XIPHINEMA DIVERSICAUDATUM

X. diversicaudatum seems to be an amphimictic species (males frequent) associated with sandy textured soils (sites 12, 13), but during this study it was found occasionally at sites 8 and 10, which correspond to silt-loam and silty clay loam textures. The species is not only associated with sandy soils; its occurrence increases as the silt content increases, as observed by Navas *et al.* (1988) for other areas in Spain. The acid pH values could explain this situation in part, although no similar results were obtained relative to organic matter content since there were high values of this edaphic factor in the all sampling sites.

XIPHINEMA TURCICUM

Finally, *X. turcicum* appears at sampling site 4 during the different seasons, which could indicate a strong association with this site as occurs for *X. pachtaicum*. However, nothing can be concluded because *X. turcicum* is always numerically low and no information is currently available for comparaison.

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References

AFIFI, A. A. & CLARK, V. (1990). *Computer-aided multivariate analysis.* New York. Van Nostrand Reinhold Co., 505 p.

ARIAS, M., NAVAS, A. & BELLO, A. (1985). Nematodos ectoparásitos y transmisores de virus de la familia Longidoridae. Su distribución en España continental. *Boln Serv. Plagas,* 11 : 275-337.

ARIAS, M., NAVAS, A. & BELLO, A. (1986). Analysis of the geographical distribution of *Xiphinema diversicaudatum* and *X. pachtaicum* in relation to the environmental factors in Spain. *Nematol. medit.,* 14 : 7-13.

BELLO, A., TOPHAM, P. B., ALPHEY, T.J. W. & DALE, A. (1986). Biogeographical classification of some plant-parasitic nematode species groups in Spain. *Nematol. medit.,* 14 : 55-72.

COHN, E. (1969). The occurrence and distribution of species of *Xiphinema* and *Longidorus* in Israel. *Nematologica,* 15 : 179-192.

CORRAL, L., GONZÁLEZ, J. L., MÉRIDA, J. & PANEQUE, G. (1985). Estudio de los suelos forestales de la Serranía de Grazalema (Cádiz, España). I. Morfología, características químicas generales y clasificación. *An. Edaf. Agrobiol.,* 43 : 1253-1269.

DALMASSO, A. (1970). Influence directe de quelques facteurs écologiques sur l'activité biologique et la distribution des espèces françaises de la famille des Longidoridae (Nematoda - Dorylaimida). *Annls Zool. Écol. anim.,* 2 : 163-200.

DELANNOY, J.-J. (1987). *Inventaire bio-géographique des espaces naturels d'Andalousie.* Sevilla & Madrid, A.M.A. & Casa de Velázquez, 50 p.

DIGBY, P. G. N. & KEMPTON, R. A. (1987). *Multivariate analysis of ecological communities.* London, Champman & Hall, 206 p.

DUCHAUFOUR, P. (1975). *Manual de edafología.* Barcelona, Toray-Masson S. A., 476 p.

FLEGG, J. J. M. (1967). Extraction of *Xiphinema* and *Longidorus* species from soil by a modification of Cobb's decanting and sieving technique. *Ann. appl. Biol.,* 60 : 429-437.

GUITIÁN OJEA, F. & CARBALLAS FERNÁNDEZ, T. (1976). *Técnicas de análisis de suelos.* Santiago de Compostela, Ed. Pico-Sacro, 288 p.

LAMBERTI, F., CASTILLO, P., GÓMEZ-BARCINA, A. & AGOSTINELLI, A. (1992). Descriptions of six new species of *Xiphinema* (Nematoda, Dorylaimida) from the Mediterranean region. *Nematol. medit.,* 20 : 125-139.

LEGENDRE, L. & LEGENDRE, P. (1979). *Écologie numérique. 2. La structure des données écologiques.* Paris & Montréal, Masson & Cie/Presses de l'Université du Québec, 247 p.

MUDARRA, J. L., BARAHONA, E., BAÑOS, C., IRIARTE, A. & SANTOS, F. (1989). *Mapa de suelos de Andalucía. Esc. 1/400.000.* C.S.I.C., I.A.R.A., 95 p.

NAVAS, A., BELLO, A. & ARIAS, M. (1988). Ecology and potential distribution of *Xiphinema diversicaudatum* and *X. pachtaicum* (Nematoda : Longidoridae) in continental Spain. *Nematologica,* 34 : 314-330.

PEÑA SANTIAGO, R. & JIMÉNEZ MILLÁN, F. (1986). Sobre la distribución de *Xiphinema italiae* y *X. turcicum* en Andalucía Oriental, España. *Nematol. medit.,* 14 : 15-22.

ROCA, F. & BRAVO, M. A. (1993). The occurrence of *Xiphinema sphaerocephalum* Lamberti *et al.* and *X. hispanum* Lamberti *et al.* (Nematoda : Longidoridae) in Portugal with descriptions of *X. lanceolatum* sp. n. and *X. lapidosum* sp. n. *Fundam. appl. Nematol.,* 16 : 455-465.

SIMS, J. R. & HABY, V. A. (1971). Simplified colorimetric determination of soil organic matter. *Soil Sci.,* 112 : 1137-1141.

SNEATH, P. H. A. & SOKAL, R. R. (1973). *Numerical taxonomy. The principles and practice of numerical classification.* San Francisco, W. H. Freeman & Co., 573 p.

SOIL SURVEY STAFF (1975). *Soil Taxonomy. A basic system of soil classification for making and interpreting soil surveys.* Soil Conservation Service. U. S. Department of Agriculture. Agriculture Handbook n° 436, 754 p.