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Ecology of mononchid nematodes from Spain Relationships between species and habitats

Domingo JIMENEZ GUIRADO *, Reyes PEÑA SANTIAGO **, María ARIAS *** and Antonio BELLO ***

* *Departamento de Biología Animal, Facultad de Ciencias, San Alberto Magno s/n, Universidad de Córdoba, 14004 Córdoba, Spain;*
** *Escuela Universitaria de Formación del Profesorado de E.G.B., Virgen de la Cabeza 2. 23008 Jaén, Spain, and*
*** *Centro de Ciencias Medioambientales, C.S.I.C., Serrano 115 dpdo., 28006 Madrid, Spain.*

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Summary – In this paper relationships between the mononchid nematodes more frequently found in continental Spain and fourteen habitat types are studied; data obtained from various general surveys have been subjected to multivariate statistical treatment on the basis of cluster and correspondence analyses. Species distribution makes it possible to establish four different habitat groups : *i)* aquatic and riverside habitats; *ii)* vegetable, fruit tree and ornamental gardens, marginal, uncultivated and abandoned crops; *iii)* extensive dry and irrigated lands, brush edges and degraded soils; *iv)* evergreen-oak, deciduous and coniferous woods and reforestations. The existence of species groups and relationships between the species and the habitats is also tested. *Mononchus aquaticus* and *M. truncatus* appear to be associated with aquatic environments, *Prionchulus muscorum, Coomansus parvus* and *Miconchus studeri* with natural woods and *Anatonchus tridentatus, Mylonchulus sigmaturus* and *Clarkus papillatus* with arable soils.

Résumé – ***Écologie des nématodes Mononchides d'Espagne. Relations entre espèces et habitats.*** – La présente étude concerne les relations entre les nématodes Mononchides les plus fréquents en Espagne continentale et des habitats de quatorze types différents; les données recueillies ont été traitées par une méthode statistique multivariée sur la base d'analyses en grappes et de correspondance. La répartition des espèces permet de retenir quatre groupes d'habitats (I : habitats aquatiques, sols de rives; II : jardins maraîchers ou d'ornement, vergers, terres non cultivées ou laissées à l'abandon; III : terrains cultivés de façon extensive, avec ou sans irrigation, haies sauvages et sols dégradés; IV : forêts de chênes-verts, de conifères ou de feuillus, zones de reforestation). L'existence de groupes d'espèces et les relations entre espèces et habitats ont été également étudiées. *Mononchus aquaticus* et *M. truncatus* paraissent liés aux milieux aquatiques; *Prionchulus muscorum, Coomansus parvus* et *Miconchus studeri* aux forêts naturelles; *Anatonchus tridentatus, Mylonchulus sigmaturus* et *Clarkus papillatus* aux sols cultivés.

Key-words : ecology, relationships, mononchid nematodes, Spain.

Although Boag (1974) had found significant quantitative differences in mononchid nematodes between coniferous and deciduous forests from Scotland, the first work on mononchid distribution in relation to soil and vegetation was carried out by Arpin (1979) who studied their occurrence in a restricted area of France with wet temperate climate. This study established the relationships between species or species groups and soil types. Later, the influence of different humus types on the intraspecific variability of *Prionchulus punctatus* and *Clarkus papillatus* was analysed by Arpin and Ponge (1984) and Arpin *et al.* (1988). Yeates (1987) also studied the distribution of mononchid species in improved pastures which had replaced original indigenous forests in New Zealand. No soil factor was clearly responsible for their distribution, but rainfall and species number seem to be correlated. Finally, Winiszewska-Ślipińska and Skwiercz (1987) studied the mononchs of the peat soils from Poland, finding remarkable differences between the natural habitats and the arable soils.

Relationships between other nematode taxonomic groups and environmental variables have been frequently analysed, mainly for economically important nematode species in arable areas (see e.g. Norton, 1978). In Spain, Navas *et al.* (1988) found *Xiphinema diversicaudatum* associated with uncultivated areas, while *X. pachtaicum* is associated with arable soils, mainly vineyards and fruit trees. The habitat concept used by these authors is broad and it is defined by the host plant or the potential vegetation. This criterion is followed in this paper where we consider the association between the most frequent mononchid species in continental Spain and fourteen different large habitat types.

Materials and methods

A total of 953 samples which yielded mononchs, collected from various laboratories and surveys during the last 30 years, were analysed, and species from 421 ecological units (locality-habitats) were studied; nearly 10 % were aquatic sites. Nematodes were extracted from a minimum of 300 cm^3 of soil per sample by Baermann or Flegg funnel techniques, except for samples from cultivated soils which were processed by the Seinhorst method. Specimens were fixed by addition of hot formaldehyde, F. A. 4:1 or F. G. 4:1 and mounted for study in lactophenol or anhydrous glycerin (Siddiqi, 1964).

Univariate and multivariate analyses were carried out with the fourteen mononchid species with high to moderate frequency. Less frequent species were excluded because they contribute little information to the analyses. According to the characteristics of the localities the samples were included in fourteen general habitats on the basis of vegetation types (Peinado Lorca & Rivas-Martínez, 1987) and soils (Guerra *et al.*, 1968). Variance analysis (ANOVA) was used to test significant differences between those habitats, and to show the species responsible for separation. Two different cluster analyses (UPGMA method) based on the Bray-Curtis distance or the Pearson correlation coefficient, and a correspondence analysis, respectively (Norton, 1978; Legendre & Legendre, 1979) were used to establish the relationships between the nematode species themselves and between the fourteen habitats studied, as well as to evaluate the relationships between nematode species and the habitats.

Results and discussion

The list showing the habitat types considered by their vegetation and soil types, and also bearing in mind the climatic and biogeographic locations of the samples, is the following :

AC. " Aquatics ". *a)* Muddy and sandy sediments from bed and bottom of streams, rivers and another freshwater bodies. Only some plants associated : *Carex* sp., *Juncus* sp., *Ranunculus* sp., *Typha* sp. and water cress *(Nasturtium officinale)*; *b)* Peat bogs with unidentified mosses and grasses on hydromorphic soils; *c)* Inundated rice fields *(Oryza sativa)* on alluvial soils.

SA. " Riverside groves ". It includes common ash *(Fraxinus excelsior)*, black poplar *(Populus nigra)* and alder groves *(Alnus glutinosa)*, as well as woods of southern ash *(Fraxinus angustifolia)* and bosks of willows (*Salix* spp.) and salt cedar (*Tamarix* sp.). Mainly gleic hydromorphic and alluvial soils.

CH. " Vegetable gardens ". Annual crops as lettuce *(Lactuca sativa)*, cabbage *(Brassica oleracea* var. *acephala)*, string bean *(Phaseolus vulgaris)*, broad bean *(Vicia faba* var. *equina)*, tomato *(Lycopersicon esculentum)*, pepper *(Capsicum annuum)*, potato *(Solanum tuberosum)*, eggplant *(Solanum melongena)*, onion *(Allium cepa)*, etc. Alluvial soils or not, transformed, with a relative large content of organic matter in the anthropic horizon. Frequently replacing the riverside vegetation.

CR. " Extensive irrigated lands ". Basin rivers and valleys used in extensive annual cropping of species as beet-root *(Beta vulgaris* var. *rapacea)*, cotton *(Gossypium herbaceum)*, maize *(Zea mays)* and tobacco *(Nicotiana tabacum)*. Alluvial, lithomorphic vertisol, vertic calcareous brown soil, etc.

FR. " Fruit orchards ". Irrigated gardens and lands with fruit trees : plum *(Prunus domestica)*, cherry *(P. cerasus avium)*, sour cherry *(P. cerasus cerasus)*, peach *(P. persica)*, apricot *(P. prunus armeniaca)*, apple *(Pyrus malus)*, pear *(P. communis)*, mandarin *(Citrus reticulata)*, orange *(C. sinensis)*, etc. Soils as CH and CR.

CO. " Ornamental gardens ". Urban areas (gardens and parks) with maple (*Acer* sp.), sour orange *(Citrus aurantium)*, cypress *(Cupressus sempervirens)*, oriental plane *(Platanus orientalis)*, red oak *(Quercus borealis)*, false acacia *(Robinia pseudoacacia)*, Chusan palm *(Trachycarpus fortunei)*, spindle *(Evonymus europaeus)*, elms (*Ulmus* sp.), etc.

CS. " Dry field crops ". *a)* Large areas used for cereal crops : wheat *(Triticum aestivum)* and barley *(Hordeum vulgare)*; *b)* Two important mediterranean crops : grapevine *(Vitis vinifera)* and olive *(Olea europaea)*. Different soil types : regosols, vertisols, rendzinas, brown soils (calcareous or not), brown fersiallitic soils, etc.

CE. " Marginal, uncultivated and abandoned crops ". Field crop edges settled by weeds and other plants : *Digitalis thapsi, Ecballium elaterium, Malva* sp., *Marrubium vulgare, Papaver* sp., *Portulaca oleracea, Urtica* sp., etc. Soils in the most part as CS and CR.

PR. " Grasslands and pastures ". Generally mountainous areas bearing anthropic action on the natural communities with the object of livestock exploitation. With abundant leguminous and gramineous plants and other unidentified grasses on lithosols, rendzinas, rankers, brown humid and subhumid earths, brown meridional earths, etc.

MA. " Brush edges and degraded soils ". Natural areas become from the woodland disturbances. It includes : *a)* brush boundaries and cleared forests on not degraded soils with hawthorn *(Crataegus monogyna)*, roses *(Rosa spp.)*, blackberries (*Rubus* spp.), etc.; *b)* brushwoods on degraded soils : moors and heaths (*Calluna vulgaris* and *Erica* spp.), growths of Spanish broom and furze (*Cytisus* spp.), evergreen shrub *(Quercus coccifera)*, cade *(Juniperus oxycedrus)*, dwarf fan palm *(Chamaerops humilis)*, rockrose *(Cistus ladanifer* and *Cistus* spp.), thyme (*Thymus* spp.) and thorny furze *(Echinospartum boissieri, Erinacea anthyllis, Ulex parviflorus)*. Soils as CA and SC.

SC. " Sclerophyllous forests ". Common evergreen oak forests *(Quercus ilex)*, pure or mixed with cork oak *(Q. suber)*, Lusitanian oak *(Q. faginea)* or savin *(Juni-*

perus thurifera) on brown meridional earths, regosols, calcareous brown soils, rendzinas, etc.

CA. " Deciduous forests ". *a)* Atlantic or subatlantic beech forests *(Fagus sylvatica)* on brown humid, brown podzolic earths or forest calcareous brown soils and rendzinas; *b)* Pyrenean oak forests *(Quercus pyrenaica),* pure or mixed with sessile oak *(Q. petraea)* and another species as common hazel *(Corylus avellana)* on humid rankers, brown subhumid and brown podzolic earths, etc., and southern ash *(Fraxinus angustifolia)* on rankers and brown meridional earths; *c)* Lusitanian oak forests *(Quercus faginea),* mixed with cork and evergreen oaks on brown meridional earths, calcareous brown soils, rendzinas, brown fersiallitic soils, etc.

CF. " Coniferous forests ". *a)* Red pine forests *(Pinus sylvestris)* especially on brown humid earths and rankers; *b)* Spanish black pine forests (*P. nigra* subsp. *salzmanni*) with Montpellier maple *Acer monspessulanum),* cade, oaks, etc., on lithosols, rendzinas and forest calcareous brown soils; *c)* growths of savin *(Juniperus thurifera)* and common juniper *(J. communis)* on rendzinic soils; *d)* Spanish fir forests *(Abies pinsapo)* on humic rendzinas anf forest calcareous brown soils.

RE. " Reforestations ". Disturbed natural areas, their vegetation replaced with plantations of pines (*Pinus* spp.) or gums (*Eucalyptus* spp.). Soils generally as SC, CA and CF.

Table 1 shows the frequencies of the mononchid species previously identified in corresponding habitats. These species are :

1. – *Clarkus papillatus* (Bastian, 1865) Jairajpuri, 1970.

2. – *Prionchulus muscorum* (Dujardin, 1845) Wu & Hoeppli, 1929.

3. – *Mylonchulus brachyuris* (Bütschli, 1873) Altherr, 1953.

4. – *Mylonchulus sigmaturus* (Cobb, 1917) Altherr, 1952.

5. – *Mononchus aquaticus* Coetzee, 1968.

6. – *Coomansus parvus* (de Man, 1880) Jairajpuri & Khan, 1977.

7. – *Anatonchus tridentatus* (de Man, 1876) De Coninck, 1939.

8. – *Miconchus studeri* (Steiner, 1914) Andrássy, 1958.

9. – *Prionchulus punctatus* (Cobb, 1917) Andrássy, 1958.

10. – *Mononchus truncatus* Bastian, 1865.

11. – *Iotonchus zschokkei* (Menzel, 1913) Altherr, 1950.

12. – *Mylonchulus brevicaudatus* (Cobb, 1917) Altherr, 1952.

13. – *Mylonchulus sessus* Jairajpuri, 1982.

14. – *Iotonchus rotundicaudatus* Peña Santiago & Jiménez Guirado, 1991.

Table 1. Frequencies of selected mononchid species in the different habitat types.

Habitats *	AC	SA	CH	CR	FR	CO	CS	CE	PR	MA	SC	CA	CF	RE
Especies														
C. papillatus	2	21	39	21	36	55	44	63	8	33	43	49	25	29
P. muscorum	1	4	2	0	2	0	0	3	33	15	45	43	55	14
My. brachyuris	2	9	20	21	7	14	17	3	50	21	5	1	2	0
My. sigmaturus	1	22	31	7	14	17	3	17	0	0	0	1	0	0
M. aquaticus	45	35	4	7	1	0	0	3	8	0	0	0	0	0
C. parvus	0	0	0	0	0	0	8	3	8	10	21	6	27	0
A. tridentatus	0	7	19	0	24	14	4	7	0	0	0	4	0	0
M. studeri	0	0	2	0	0	7	0	0	0	0	14	22	9	0
P. punctatus	5	10	0	0	3	7	0	7	0	5	0	4	5	0
M. truncatus	16	11	2	0	0	7	3	0	0	0	0	0	0	0
I. zschokkei	0	6	0	0	0	0	0	0	0	10	0	8	11	0
My. brevicaudatus	2	1	4	0	3	0	1	0	0	0	0	2	0	14
My. sessus	0	0	0	0	2	0	1	3	8	3	2	2	0	0
I. rotundicaudatus	0	0	0	0	5	0	1	0	0	10	0	0	1	0

* (AC) aquatic, (CA) deciduous forests, (CE) marginal, uncultivated and abandoned crops, (CF) coniferous forests, (CH) vegetable gardens, (CO) ornamental gardens, (CR) extensive irrigated lands, (CS) dry field crops, (FR) fruit orchards, (MA) brush edges and degraded soils, (PR) grasslands and pastures, (RE) reforestations, (SA) riversides, (SC) evergreen-oak forests.

The one-way ANOVA carried out with the habitats, taking into consideration the species, shows a significant difference ($P < 0.05$) in ten of them (Table 2). *A. tridentatus, I. zschokkei, My. brevicaudatus* and *My. sessus* are the only ones whose contribution to habitat separation is not significant. Most habitats appear classified in four main groups as can be observed in the dendrogram (Fig. 1) obtained with the Bray-Curtis coefficient which has supplied a good fit of the cluster to the data ($r = 0.78$). These groups are :

I. Aquatic and riverside habitats : AC, SA.

II. Vegetable, fruit trees and ornamental gardens, marginal, uncultivated and abandoned crops : CH, FR, CO, CE.

III. Extensive dry and irrigated land, brush edges and degraded soils : CR, CS, MA.

IV. Evergreen-oak, deciduous and coniferous woods : SC, CA, CF.

Reforestations (RE) can be added to the last group, while the grasslands and pastures (PR) are related with all groups except group I. It should be noted that group III is heterogeneous, representing two critical states (extensive dry and irrigated lands) and one intermediate and/or transitory environment between woods and grasslands.

The results of correspondence analysis with the data of Table 1 are plotted in Fig. 2 which represents the habitats with respect to the three first axes; the variation explained by axes I and II is 35.7 % and 23.6 % respectively. In this case the dry and irrigated lands are grouped with the rest of cultivated soils, while brushes and degraded soils come close to grasslands and reforestations. Both aquatic (46.5 %) and riverside (18.6 %) habitats, on the one hand, and coniferous woods (11.4 %), on the other, have a larger relative contribution to axis I which may be interpreted in part as a general moisture gradient, from wetter at left to drier sites at right of figure. This axis may also show, in part, stability or ripeness of soils, from less at left to more at

Table 2. Result of the one-way ANOVA between the habitats considered. Snedecor's F values are for significant differences ($P < 0.05$).

Species	F value
C. papillatus	2.91
P. muscorum	3.53
My. brachyuris	3.16
My. sigmaturus	3.69
M. aquaticus	1.92
C. parvus	4.45
M. studeri	4.54
P. punctatus	1.85
M. truncatus	3.10
I. rotundicaudatus	2.39

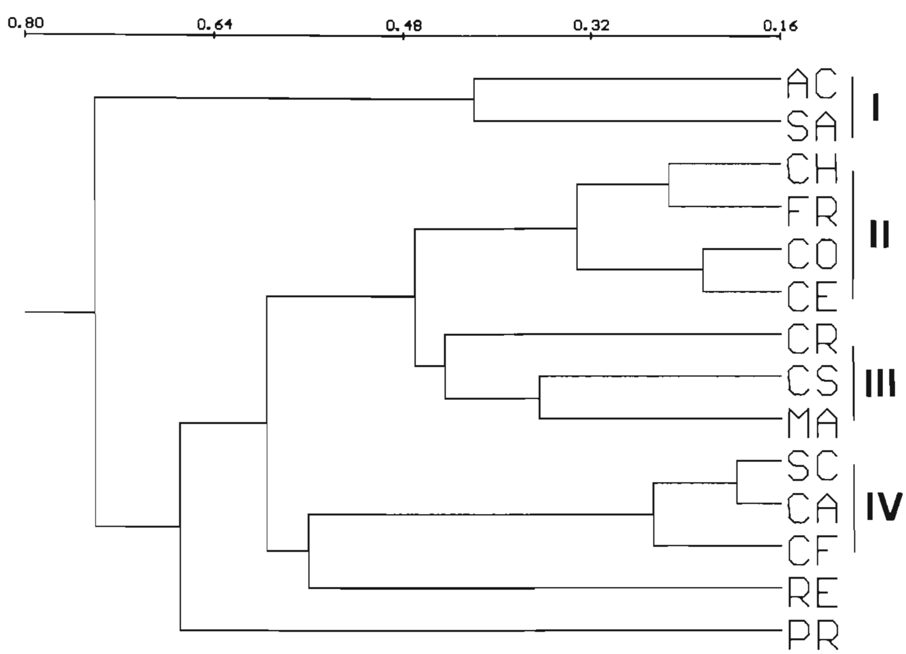

Fig. 1. Dendrogram of the fourteen habitats considered, obtained from cluster analysis (UPGMA method) based in the Bray-Curtis coefficient. (Abbreviations as in Table 1).

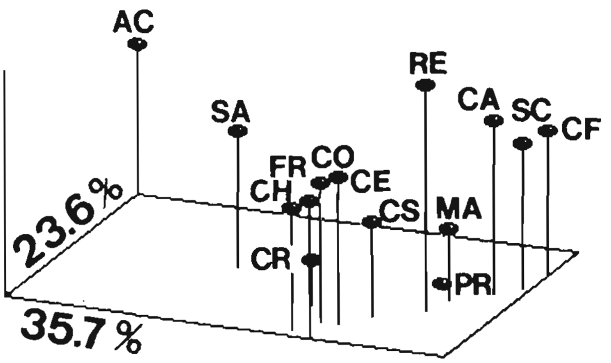

Fig. 2. Three-dimensional model, resulting from correspondence analysis, of the fourteen habitats considered. (Abbreviations as in Table 1).

right. Similarly, both aquatic habitats (22 %) and coniferous woods (14.7 %), on the one way, and fruit orchards (15.6 %) and vegetable gardens (15.5 %), on the other, have the greatest contribution with respect to axis II which separates, with good values, aquatic and forest habitats from a larger number of crops; this axis seems to separate natural or less disturbed environments from the most modified ones.

Fig. 3 shows relationships between nematode species and habitats in respect to two first axes already indicated; *M. aquaticus* (48.1 %), *P. muscorum* (16 %) and *M. truncatus* (15.6 %) are the species with the most contribution to the variation explained by axis I and, at the same time, this axis relates *M. aquaticus* and *M. truncatus* with aquatic habitats (group I) and *P. muscorum* and *C. parvus* with wooded habitats (group IV). Similarly, *P. muscorum* (19.8 %), *M. aquaticus* (18.7 %), *A. tridentatus* (17.4 %) and *My. sigmaturus* (15.8 %) are the species with a greater contribution with respect to axis II which associates *P. muscorum* with untransformed environments and *A. tridentatus* and *My. sigmaturus* with arable soils (group II). Despite that *A. tridentatus* has a non significant contribution to habitat separation in the univariate analysis it becomes associated here with soils of group II, mainly vegetable and fruit orchards (Table 1).

The results obtained with the Pearson correlation coefficient (see dendrogram Fig. 4), which has a good fit of the cluster to the data (r = 0.80), agree with those of the above analysis. Here, the species are segregated (at 0-0.15 level) into four different groups which are similar to those obtained with the correspondence analysis and *C. papillatus* and *M. studeri* are associated with groups II and IV respectively. Moreover, group III includes species apparently belonging to several habitats with intermediate locations in the gradients represented by both axes.

Thus, some species groups of mononchid nematodes can be established, not only on the basis of environmental variables according to Arpin (1979), Yeates

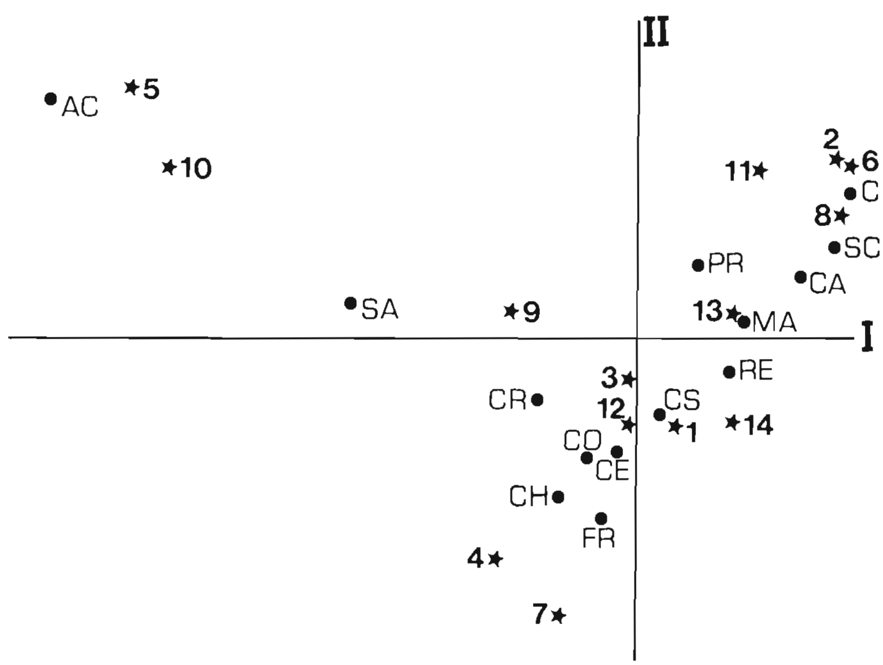

Fig. 3. Result from correspondence analysis on the plane defined by the two first axes. (Abbreviations as in Table 1 and species number: (1) *C. papillatus,* (2) *P. muscorum,* (3) *My. brachyuris,* (4) *My. sigmaturus,* (5) *M. aquaticus,* (6) *C. parvus,* (7) *A. tridentatus,* (8) *M. studeri,* (9) *P. punctatus,* (10) *M. truncatus,* (11) *I. zschokkei,* (12) *My. brevicaudatus,* (13) *My. sessus,* (14) *I. rotundicaudatus).*

(1987) and Winiszewska-Ślipińska and Skwiercz (1987), but also in relation to a broader concept of habitat based in plant or vegetation associated. *A priori,* a strong association between mononchid nematodes and plant species could not be expected as they do not have a direct feeding relationship, but if we consider that plant species are components and biological indicators of the habitat conditions, the results appear to be consistent and these relationships clear. Consequently, a first general analysis carried out with the fourteen mononchid species considered here in a relatively large geographic area (continental Spain) allows us to associate *M. aquaticus* and *M. truncatus* significantly with aquatic and riverside habitats, *P. muscorum, C. parvus* and *M. studeri* with untransformed forests and *A. tridentatus, My. sigmaturus* and *C. papillatus* with arable soils.

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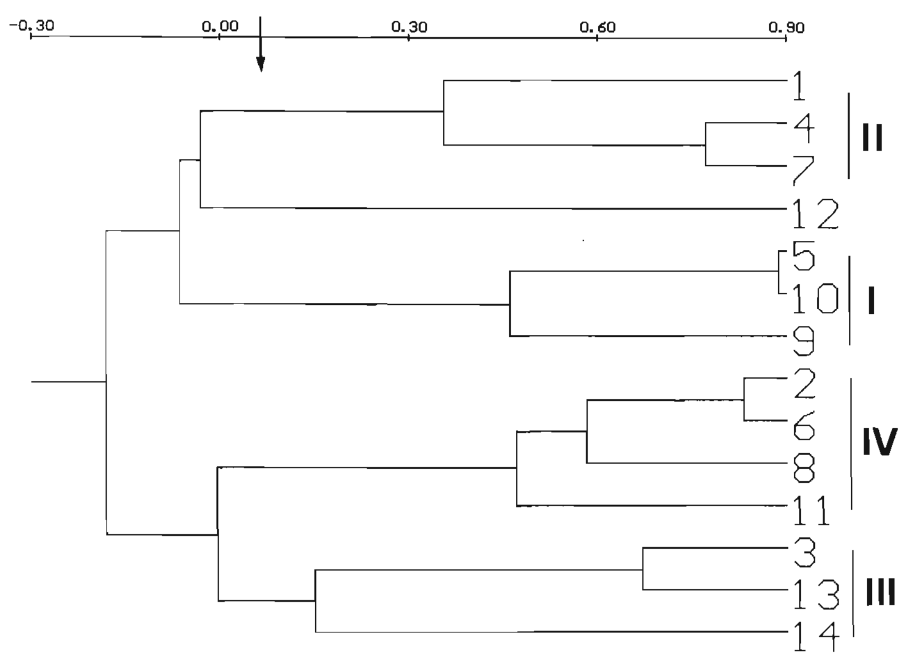

Fig. 4. Dendrogram of the fourteen mononchid species, obtained from cluster analysis (UPGMA method) based in the Pearson correlation coefficient. (Species number as in Figure 3.)