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Spatial Distribution of Dorylaimid and Mononchid Nematodes from Southeast Iberian Peninsula: Chorological Relationships among Species

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Abstract: The spatial distribution of 138 Dorylaimid and Mononchid species collected in a natural area from the Southeast Iberian Peninsula was studied. A chorological classification was used to examine distribution patterns shared by groups of species. Eighty species were classified into 14 collective and 16 individual chorotypes. The geographical projections of several collective chorotypes are illustrated along with their corresponding distribution maps. The importance of this analysis to nematological study is briefly discussed.

Key words: biogeography, chorotypes, Dorylaimids, Iberian Peninsula, Mononchids, spatial distribution.

Nematodes are one of the most abundant and widely distributed invertebrate animal taxa in edaphic habitats, in which several million individuals and up to 100 species may occur per m^2 (Yeates, 1972, 1979; Yeates and Bongers, 1999). The description and delimitation of the distributional ranges of taxa are known as chorology, biogeography, or faunistics (Lincoln et al., 1998). Although many nematode species share habitat and geographical area, their chorological relationships have been infrequently addressed. Spatial distribution of nematodes has been investigated either to compare nematode faunas in different habitats or to analyze the geographical range of a particular species (Ferris and Ferris, 1985). One main goal of modern biogeography is pattern definition, a prerequisite for process identification (Myers and Giller, 1988). An important question is: Are the organisms independently distributed or are there common distribution patterns shared by groups of species (Real et al., 1992)?

In 1978, Baroni-Urbani et al. introduced a new biogeographical concept—the chorotype. A chorotype is an assemblage of species distributed in a similar pattern. Later, Birks (1987) suggested that a major purpose of biogeographical quantitative analysis "is to detect . . . biotic elements (groups of taxa with similar distributions)." A chorotype (or biotic element) is a biogeographical concept that refers to comparison of geographical distributions of taxa at medium or large spatial scales, and may be represented on a map.

Dorylaimid and Mononchid species are important components of the nematode edaphic fauna and are particularly sensitive to environmental disturbances (Bongers, 1990; Johnson et al., 1974). The geographical distribution of Dorylaimids and Mononchids are not well understood, and few data on chorological relationships among these nematodes are available. Previous studies have focused on several topics: (i) characterization of assemblages of nematode species, based on their distribution in several habitat types, with no spatial relationship among species established (Arpin, 1979; Jiménez-Guirado et al., 1993; Lazarova et al., 2000; Schmitt and Norton, 1972; Zullini, 1970); (ii) use of analytical methods to study the distribution of different nematode taxocoenoses, with attention to relationships among sites rather than species (Ferris et al., 1972; Hánel, 1993, 1996; Jiménez-Guirado et al., 1995; Johnson et al., 1972; Popovici, 1995; Ruess, 1995); and (iii) geographical distribution of various nematode taxa without use of analytical procedures to compare spatial ranges of species (Alphey and Taylor, 1986; Boag et al., 1992; Ferris and Ferris, 1972; Yeates et al., 1994).

The chorological relationships among species were investigated as part of a nematological project addressing the taxonomy and distribution of Dorylaimid and Mononchid nematodes in the Sierra Mágina Natural Park, Southeast Iberian Peninsula (Spain). The main objective was to identify and characterize Dorylaimid and Mononchid chorotypes. We propose a new approach for the study of nematode distributions focused on relationships among species, using new analytical methods (Ferris, 1993).

Materials and Methods

Site description: The Sierra Mágina Natural Park is a protected natural area situated in southern Jaén, an Andalucian province in the Southeast Iberian Peninsula, occupying approximately 19,000 ha (Fig. 1). It forms part of the northern Betic Mountains, whose relief includes moderately high summits and deep valleys and elevation ranging from 660 to 2,100 m. Climatic conditions are Mediterranean but are clearly modulated by elevation effect. Lithology of the region is dominated by sedimentary carbonate rocks such as limestones, marls, and dolomites. A wide series of soil types occur in the region, including carbonate cambisols, regosols, lithosols, and others, with inclusions of phaeozems and rendzines. Such abiotic heterogeneity leads to a high plant diversity with three bioclimatic levels (oro-, supra-, and mesomediterranean) and 21 distinct plant communities registered in the area. Martín-García et al. (2002) offer additional information concerning abiotic conditions of the region.

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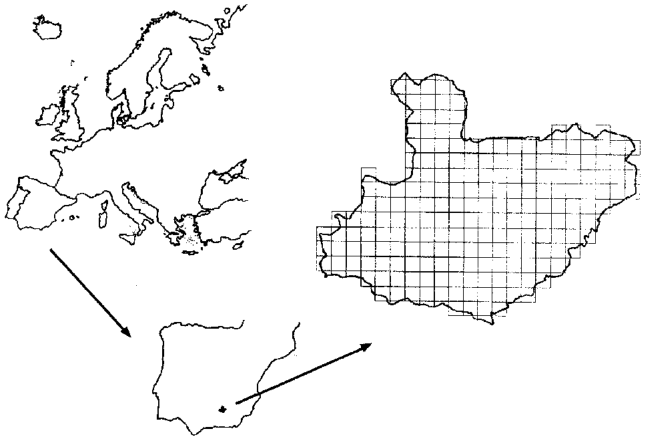

FIG. 1. Geographical location of the studied area (Sierra Mágina Natural Park, Southeast Iberian Peninsula) and its division with Universal Transversal Mercator (UTM) 1 × 1-km grid.

Sampling: The area was divided in 203 Operational Geographic Units (OGU) of 1 km^2, which correspond to the division obtained by the Universal Tranversal Mercator (UTM) 1 × 1-km grid (Fig. 1). Soil samples (about 1 kg) were collected using the following protocol: four cores were taken at 0 to 25-cm depth in a 5 × 5-m squared area situated in the center of the respective OGU. The cores were mixed in the laboratory before nematode extraction. Every OGU was visited only once, either in spring or autumn—the most suitable seasons in temperate regions (Zullini, 1975). The survey was conducted over 3 years. A portion of each soil sample was used for nematological characterization and the rest for physico-chemical and edaphic analyses. Several abiotic (elevation, slope, and orientation) and biotic (plant species) factors were recorded.

Laboratory techniques: Nematodes were extracted from 100 cm^3 of soil by Flegg's (1967) method. After extractions, nematodes were killed by heat, fixed in 4% formalin, transferred to lactophenol, and finally mounted in anhydrous glycerin according to Siddiqi (1964).

Analytical procedures: Once the nematode (Dorylaimid and Mononchid) species were identified, the "sample x species" data matrix was completed. A chorological classification protocol (Carmona et al., 1999; Real et al., 1992) was followed to establish relationships among species. Briefly, such a protocol includes several steps. First, the Baroni-Urbani and Buser's (1976) index of similarity was used to calculate the similarity matrix. This index takes into consideration double absences and has an associated table of critical significance values. Secondly, the Unweighted Pair-Group Method using arithmetic Averages (UPGMA) was used to derive a suitable algorithm of classification (Sneath and Sokal, 1973). Third, a graphical representation of the chorological relationships among species was visualized in a dendrogram (phenogram). Finally, statistical significance of the associations obtained was tested by using the table of probabilities ($P \leq 0.05$) for the Baroni-Urbani and Buser's index of similarity and applying a "G-test" of independence to each branching node of the dendrogram (McCoy et al., 1986). A detailed description of the classification analysis of species may be found in Márquez et al. (1997). The diversity data had a normal distribution that allowed statistical analysis without transformation. The SPSS computer program (SPSS Inc., Chicago, IL) was used for mathematical analysis.

RESULTS

A total of 9,153 nematode specimens were mounted and studied from the 203 soil samples, and 138 species belonging to 48 genera (including mononchs) were identified. The complete list of these species, together with their absolute and relative frequencies, is presented in Table 1. Dorylaimid diversity (species richness) per soil sample ranged from 0 to 24, with median value of 11.6 (Fig. 2).

The dendrogram that illustrates chorological relationships among the species includes 80 species classified into 14 collective chorotypes: groups of species with a significantly ($P < 0.05$) similar distribution pattern in the studied area (Fig. 3). Sixteen individual chorotypes also were detected, representing individual species whose distributions were significantly ($P < 0.05$) different from all other chorotypes. Fifty-eight species did not belong to any chorotype (Fig. 3), indicating that, instead, they follow a gradual substitution pattern in space.

The distribution pattern of a particular chorotype can be projected on a map of the area. Such a graphical projection reveals distinct distribution patterns that can be characterized and explained. An example is illustrated in Figure 4, in which the geographical distribution of three collective chorotypes is presented: chorotypes I and IV were mainly present in the southern half of the studied area, whereas chorotype VIII was predominant in the peripheral portion of the area. Moreover, chorotype IV was especially concentrated in the south-central region, and chorotype I was more dispersed.

DISCUSSION

Little analytical information on the chorological relationships among nematode taxa is available. One remarkable exception is the contribution by Navas et al. (1990), who distinguished eight chorotypes in the Euromediterranean area. Zullini (1970) observed significant associations among several Dorylaimid species in an Italian natural area. The present results do not readily compare to Navas et al. (1990) because the taxa and geographical areas assessed are different. However, the results are consistent with Zullini (1970) in that two of his significantly associated species, *Mesodorylaimus bastiani* and *Allodorylaimus holdemani,* form part of one of the collective chorotypes identified here.

Our results indicate that it is possible to identify regu-

TABLE 1. Absolute (AF) and relative (RF) frequencies of Dorylaimid and Mononchid species in the studied area.

Species	AF	RF (%)
Aporcelaimellus obtusicaudatus	162	79.8
Allodorylaimus paragrnuliferus	113	55.6
Axonchium giennense	97	47.7
Xiphinema turcicum	89	43.8
Longidoreela murithi	87	42.8
Eudorylaimus sp. 4	79	38.9
Microdorylaimus modestus	77	37.9
Labronema angeloi	65	32.0
Clarkus papillatus	64	31.5
Aporcelaimellus amylovorus	61	30.0
Aporcelaimellus sp. 1	59	29.0
Ecumenicus monohystera	59	29.0
Dorylaimellus egmonti	57	28.0
Tylencholaimus proximus	54	26.6
Takamangai eroshenkoi	47	23.1
Funaria millani	46	22.6
Discolaimiun dubium	42	20.6
Mylonchulus brachyuris	42	20.6
Allodorylaimus holdemani	38	18.7
Talanema avolai	38	18.7
Eudorylaimus sp. 5	37	18.2
Microdorylaimus longicollis	35	17.2
Takamangai ettersbergensis	35	17.2
Longidorella macramphis	34	16.7
Enchodelus brevidentatus	33	16.2
Nygolaimus brachyuris	32	15.7
Paraxonchium carmenae	31	15.2
Paravulvus teres	30	14.7
Coomansus parvus	29	14.3
Chitwoodiellus parafuscus	28	13.7
Takamangai sp. 2	26	12.8
Prionchulus muscorum	25	12.3
Xiphinema pachtaicum	25	12.3
Tylencholaimus teres	24	11.8
Eudorylaimus subdigitalis	23	11.3
Eudorylaimus leuckarti	22	10.8
Paravulvus hartingii	22	10.8
Aporcelaimus sp.	19	9.35
Pungentus engadinensis	19	9.35
Dorylaimellus sp. B	17	8.37
Nygolaimus diversus	17	8.37
Eudorylaimus sp. 2	16	7.88
Dorylaimellus monticolus	14	6.89
Discolaimus major	13	6.40
Eudorylaimus sp. 1	13	6.40
Eudorylaimus arcus	13	6.40
Mesodorylaimus bastinai	13	6.40
Nygolaimus seguranus	13	6.40
Microdorylaimus cf. drepanoideus	12	5.91
Discolaimus agricolus	11	5.41
Dorylaimellus globatus	11	5.41
Eudorylaimus sp. 3	11	5.41
Dorylaimoides cylindricaudatus	10	4.92
Discolaimoides cf. bulbiferus	9	4.43
Longidorella parva	9	4.43
Takamangai sp. 1	9	4.43
Microdorylaimus cf. thornei	8	3.94
Dorylaimellus parvulus	7	3.44
Dorylaimeelus sp. A	7	3.44
Dorylaimoides ornatus	7	3.44
Enchodelus cf. saxifragae	7	3.44
Eudorylaimus bombilectus	7	3.44
Iotonchus rotundicaudatus	7	3.44
Microdorylaimus sp. A	7	3.44
Takamangai kaszabi	7	3.44
Mesororylaimus americanus	6	2.95
Prodorylaimus sp.	6	2.95
Tylencholaimellus cinctus	6	2.95
Tylencholaimus minutus	6	2.95
Dorylaimeelus cf. arcuicaudatus	5	2.46
Dorylaimoides limnophilus	5	2.46
Dorylaimoides teres	5	2.46
Nygolaimus parabrachyuris	5	2.46
Discolaimoides cf. tenuis	4	1.97
Eudorylaimus rugosus	4	1.97
Labronema pulchrum	4	1.97
Nygolaimus tenius	4	1.97
Paravulvus acuticaudatus	4	1.97
Tylencholaimellus auringiensis	4	1.97
Carcharodiscus olearum	3	1.47
Diphtherophora cf. obesa	3	1.47
Dorylaimoides baeticus	3	1.47
Dorylaimoides sp.	3	1.47
Epidorylaimus lugdunensis	3	1.47
Eudorylaimus centrocercus	3	1.47
Eudorylaimus cf. silvaticus	3	1.47
Eudorylaimus sp.	3	1.47
Longidorella cf. macramphis	3	1.47
Mesodorylaimus cf. pseudobastiani	3	1.47
Miconchus studeri	3	1.47
Microdorylaimus sp. B	3	1.47
Nygolaimus anneckei	3	1.47
Nygolaimus baeticus	3	1.47
Takamangai cf. nothus	3	1.47
Tylencholaimellus loofi	3	1.47
Tylencholaimellus paracinctus	3	1.47
Tylencholaimus ibericus	3	1.47
Aporcelaimellus sp. 2	2	0.98
Clavicaudoides clavicaudatus	2	0.98
Diphtherophora perplexans	2	0.98
Dorydorella bryophila	2	0.98
Dorylaimellus neocapitatus	2	0.98
Dorylaimoides rotundicephalus	2	0.98
Dorylaimoides striatus	2	0.98
Eudorylaimus cf. conicaudatus	2	0.98
Longidorus sp.	2	0.98
Mesodorylaimus cf. aegypticus	2	0.98
Mesodorylaimus litoralis	2	0.98
Nygolaimus sp.	2	0.98
Opistodorylaimus sylphoides	2	0.98
Tylencholaimellus polonicus	2	0.98
Tylencholaimus intermedius	2	0.98
Tylencholaimus terrestris	2	0.98
Allodorylaimus thymophilus	1	0.005
Aporcelaimellus cf. adriaani	1	0.005
Belondira tarjani	1	0.005
Carcarodiscus procerus	1	0.005
Diphtherophora brevicolle	1	0.005
Discolaimoides filiformis	1	0.005
Dorylaimoides cf. arcuatus	1	0.005
Enchodelus sp.	1	0.005
Mesodorylaimus aberrans	1	0.005
Mesodorylaimus ibericus	1	0.005
Mesodorylaimus ornativulvatus	1	0.005
Mesodorylaimus sp.	1	0.005
Mononchus aquaticus	1	0.005
Oxydirus sp.	1	0.005
Paratrichodorus teres	1	0.005
Paraxonchium cf. leptocephalus	1	0.005
Paraxonchium loofi	1	0.005
Sectonema cf. heynsi	1	0.005
Takamangai mediana	1	0.005
Trichodorus giennensis	1	0.005
Tylencholaimellus montanus	1	0.005
Tylencholaimellus raskii	1	0.005
Tylencholaimus cf. americanus	1	0.005
Tylencholaimus constrictus	1	0.005
Vanderlindia hispanica.	1	0.005

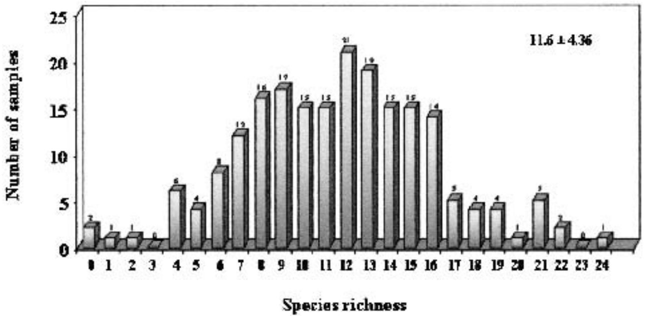

FIG. 2. Species richness of Dorylaims and Mononchs per soil sample in the studied area.

larities (patterns) in the spatial distribution of nematodes, but further studies are needed to determine if such patterns exist at larger scales. First, in relation to taxonomic scale, only a portion of the nematocoenose was analyzed. If the entire nematode fauna inhabiting every soil sample were included, multiple chorotypes containing wider representation of species might be detected. Second, if the spatial scale was magnified (i.e., if the nematode fauna of different provinces, regions, and countries were known and compared), the chorotypes may provide more convincing information.

Nematode chorotypes may be useful tools. Since a chorotype indicates species groups of ecological significance in similar ranges, species assemblages rather than separate species may be used for four purposes: (i) once a chorotype is well defined, detection of a particular species indicates or suggests the existence of other(s) particular species in the same area (Boag and Topham, 1985)—an interesting possibility for agricultural research; (ii) species identification for ecological or plant protection studies may be facilitated by the specification of chorotypes for a geographical area; (iii) chorotypes provide information for conservation of biodiversity by identifying areas of overlapping chorotypes and high levels of species richness (Birks, 1987; Real et al., 1992); and (iv) because Dorylaimid species are sensitive to soil disturbances, they are considered bioindicators of soil health (Bongers, 1990; Bongers and Bongers, 1998; Johnson et al., 1974), and dorylaimid chorotypes could be used for identification of environmental stress.

The major inconvenience of chorotypes is that their identification requires high-quality data of species distribution in many localities. Additionally, faunistic information available from the literature often is scattered and sometimes unreliable. Although data are usually provided by extensive surveys, the information compiled in regional faunas, ecological studies, and plant-parasitic species surveys is also useful. As databases of species distributions, particularly plant parasites, increase in size and quality, the use of analytical methods to study chorological relationships will be of increasing importance.

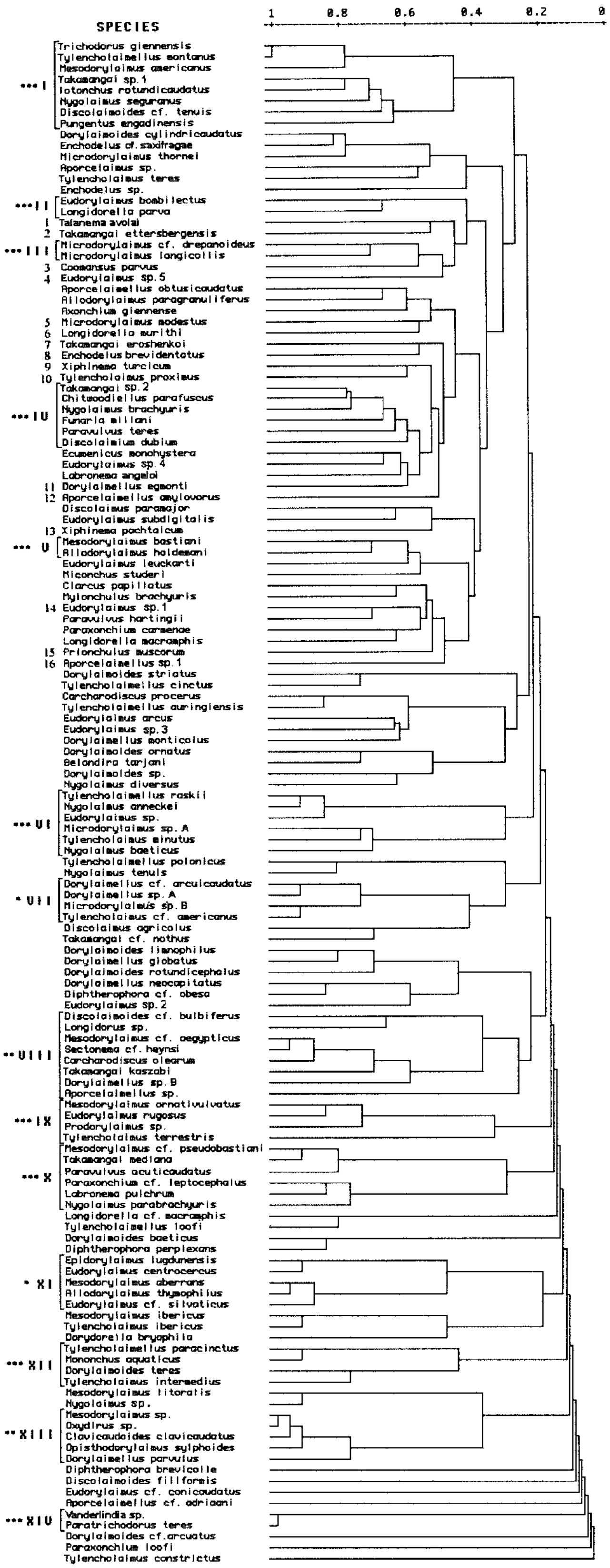

FIG. 3. Dendrogram of the distributional similarities of the Dorylaimid and Mononchid species in Sierra Mágina Natural Park, Southeast Iberian Peninsula. Collective chorotypes in Roman figures; individual chorotypes in Arabic figures. *$P > 0.05$; **$P < 0.01$; ***$P < 0.001$.

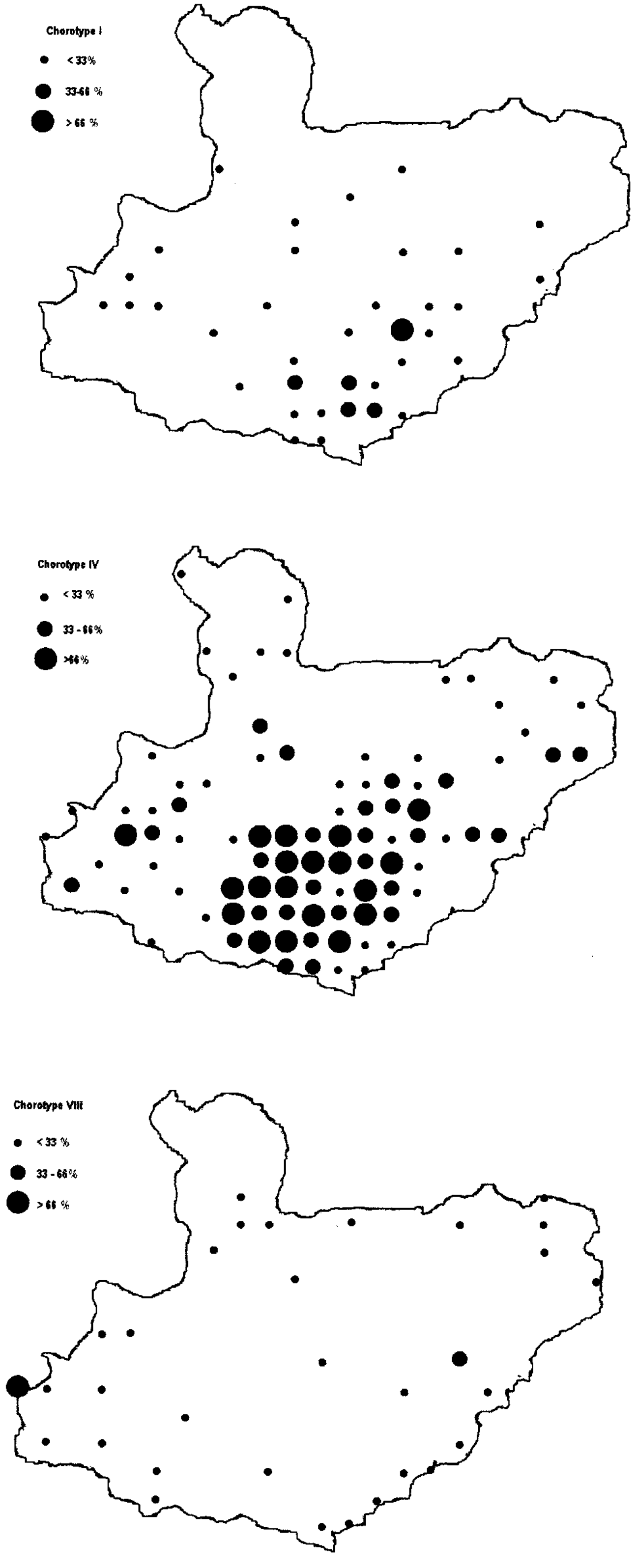

FIG. 4. Geographical projection of three collective chorotypes (circle diameter indicates the percentage of species forming part of the same chorotype that are found in the corresponding Operational Geographic Unit (OGU).

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