A computer method for identifying nematode species 2. Genera *Tylenchorhynchus* and *Merlinius* (Nematoda : Tylenchina)

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SUMMARY

Two computer programs for use when identifying *Tylenchorhynchus* and *Merlinius* species have been developed from an earlier program used with *Longidorus* species. The programs are simple to use and easy to edit in a personal computer. Nominal lists of the species in the two genera are tabulated. A cluster analysis also done revealed that several groups of species with generally similar morphology exists in each genus. The identity of a nematode specimen after being identified by using the computer programs can be confirmed by comparing it with the type specimens of the most similar species given by the programs and in the cluster analysis.

RÉSUMÉ

Une méthode informatique pour l'identification des espèces de nématodes 2. Les genres Tylenchorhynchus *et* Merlinius *(Nematoda : Tylenchina)*

Deux programmes d'ordinateur, dérivés d'un programme précédemment mis au point pour le genre *Longidorus*, ont été appliqués aux espèces des genres *Tylenchorhynchus* et *Merlinius*. Ces programmes sont simples, et aisés à introduire dans un ordinateur personnel. La liste des espèces de chaque genre est donnée. Une « analyse de groupes » a été réalisée, qui a révélé l'existence dans chaque genre de groupes d'espèces ayant une morphologie similaire.. L'identité d'un spécimen obtenue grâce au programme peut être confirmée en le comparant à des spécimens types appartenant aux espèces les plus proches, fournies par le programme et par l'analyse de groupes.

Methods provided in numerical taxonomy can help nematologists identify nematode species (Lima, 1965; Boag & Smith, 1983, 1984; Fortuner, 1983; Fortuner & Wong, 1984; Zancada & Lima, 1985). Rey, Andres and Arias (1988) described a program for use in a personal computer for the identification of species in the genus *Longidorus*. As this program can be easily edited we tried its use to assist in the identification of *Tylenchorhynchus* and *Merlinius* species.

Tylenchorhynchus Cobb, 1913 and *Merlinius* Siddiqi, 1970 include cosmopolitan species and both genera have undergone taxonomic reappraisal in recent years. After the publication of the manual on Tylenchorhychidae by Hooper (1978), a number of taxonomic changes were proposed by different workers (Siddiqi, 1979; Baldwin & Bell, 1981; Lewis & Golden, 1981; Sturhan, 1981; Anderson & Ebsary, 1982; Mulk & Siddiqi, 1982; Powers, Baldwin & Bell, 1983; Jairajpuri, 1984; Jairajpuri & Hunt, 1984; Skwiercz, 1984). As a result of these changes *Tylenchorhynchus* is the largest genus in the subfamily Tylenchorhynchinae with 77 nominal species which makes the compilation and use of a dichotomous key difficult and tedious. A similar situation exists with *Merlinius* which has 42 nominal species. So we undertook a study to establish whether the computer programs developed by Rey, Andres and Arias (1988) can be used with these two genera.

Recently, Fortuner and Luc (1987) revising Belonolaimidae (= Tylenchorhynchidae) gave a wider content to both genera; according to these authors, *Scutylenchus* is considered a junior synonym of *Merlinius*, and nine genera are considered as junior synonyms of *Tylenchorhynchus*, five of these synonymizations being new. These propositions are not followed here the manuscript having been written before publication of Fortuner and Luc's revision.

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Materials and method

The size of the programs, written in advanced Hewlett-Packard BASIC, is 6 800 bytes and that of the data bases 13 440 bytes for *Merlinius* 17 248 bytes for *Tylenchorhynchus*. The general description and operating procedures for these programs are similar to those of a program for identifying *Longidorus* species described by Rey, Andres and Arias (1988).

Characters

The characters chosen to identify nematodes in the genera *Tylenchorhynchus* and *Merlinius* are listed in Table I and include the standard de Man indices with others selected because of their relevancy and accessibility.

Quantitative characters, e. g. length of body, de Man indices, etc., were given maximum and minimum values, i. e., within-species ranges taken from the literature, and numeric codes were used with qualitative characters,

Table 1

List of characters for *Tylenchorhynchus* and *Merlinius*

	Characters	*Code*	*Status*	*Weights*
1- 3	Body length (mm)			0.9
3- 4	Ratio a			0.5
5- 6	Ratio b			0.2
7- 8	Ratio c			0.7
9-10	Ratio V			1.0
11	Lip region	1	Offset	0.7
		2	Continuous	
12-13	No. lip annules			0.6
14	Cephalic sclerotization	0	Inconspicuous	0.1
		1	Light	
		2	Moderate	
		3	Heavy	
15-16	Stylet length (µm)			
17	Inclination Stylet knobs	1	Anterior	0.4
		2	Lateral	
		3	Posterior	
18-19	No. tail annules			0.3
20	Tail shape	1	Conoid	0.8
		2	Subcylindrical	
		3	Cylindrical	
		4	Clavate	
21	Tail terminus shape	1	Acute	0.7
		2	Subcylindrical or blunt	
		3	Hemispherical	
22	Tail tip annulation	0	Smooth	0.9
		1	Annulated	
23-24	Ratio c'			1.0
25-26	Spicule length (µm)			0.8
27-28	Gubernaculum length (µm)			0.1

Table 2

Species in the reference file of the genus *Merlinius*

Species	*Compendium number*
M. adakensis Bernard, 1980	1
M. affinis (Allen, 1955) Siddiqi, 1970	2
M. alboranensis (Tobar Jimenez, 1970) Siddiqi, 1970	3
M. alpinus (Allen, 1955) Siddiqi, 1970	4
M. bavaricus (Sturhan, 1966) Siddiqi, 1970	5
M. bijnorensis Khan, 1972	38
M. bogdanovikatkjovi (Kirjanova, 1941) Siddiqi, 1970	6
M. brachycephalus (Litvinova, 1946) Tarjan, 1973	7
M. brevidens (Allen, 1955) Siddiqi, 1970	8
M. capitonis Ivanova, 1983	39
M. circellus Anderson & Ebsary, 1982	9
M. conicus (Allen, 1955) Siddiqi, 1970	10
M. curiosus (Wilski, 1965) Sher, 1974	11
M. djungaricus (Razzhivin, 1974) Mahajan & Bello, 1986	40
M. falcatus Eroshenko, 1981	29
M. gaudialis (Izatullaeva, 1967) Tarjan, 1973	12
M. graminicola (Kirjanova, 1951) Siddiqi, 1970	13
M. grandis (Allen, 1955) Siddiqi, 1970	14
M. hexagrammus (Sturhan, 1966) Siddiqi, 1970	15
M. joctus (Thorne, 1949) Sher, 1974	16
M. lineatus (Allen, 1955) Siddiqi, 1970	17
M. loofi (Loof, 1971) Siddiqi, 1979	18
M. macrodens (Allen, 1955) Siddiqi, 1970	19
M. macrophasmidus Khan & Darekar, 1978	20
M. microdorus (Geraert, 1966) Siddiqi, 1970	21
M. nanus (Allen, 1955) Siddiqi, 1970	22
M. niazae Maqbool, Fatima & Hashmi, 1983	23
M. nothus (Allen, 1955) Siddiqi, 1970	24
M. paramonovi Volkova, 1972	25
M. parobscurus (Mulvey, 1969) Tarjan, 1973	26
M. planitierum Eroshenko, 1984	27
M. plerorbus Anderson & Ebsary, 1982	28
M. processus Siddiqi, 1979	30
M. productus (Thorne, 1949) Sher, 1974	31
M. pseudobavaricus Saltukoglu, Geraert & Coomans, 1976	32
M. superbus (Allen, 1955) Siddiqi, 1970	33
M. tatrensis (Sabova, 1967) Tarjan, 1973	34
M. tetylus Anderson & Ebsary, 1982	35
M. undyferrus (Haque, 1967) Siddiqi, 1970	36
M. varians (Thorne & Malek, 1968) Siddiqi, 1970	37

Table 3

Species in the reference file of the genus *Tylenchorhynchus*

Species	*Compendium number*
T. aduncus de Guiran, 1967	1
T. aerolatus Tobar Jimenez, 1970	2
T. agri Ferris, 1963	3
T. amgi Kumar, 1961	71
T. ancorastyletus Ivanova, 1983	64
T. annulatus (Cassidy, 1930) Golden, 1971 = *T. martini* Fielding, 1956	4
T. antarcticus Wouts & Sher, 1985	5
T. aspericutis Knobloch, 1975	6
T. badliensis Saha & Khan, 1981	68
T. bohrrensis Gupta & Uma, 1980	7
T. brassicae Siddiqi, 1961	8
T. brevilineatus Williams, 1960 = *T. indicus* Siddiqi, 1961	9
T. bryobius Sturhan, 1968	10
T. canalis Thorne & Malek, 1968	11
T. clarus Allen, 1955 = *T. tener* Erzhanova, 1964	12
T. clavicaudatus Seinhorst, 1963	13
T. coffeae Siddiqi & Basir, 1959	14
T. contractus Loof, 1964	15
T. cuticaudatus Ray & Das, 1983	16
T. crassicaudatus Williams, 1960	69
T. cristatus Ivanova, 1983	63
T. cylindricus Cobb, 1913	17
T. cynodonti Kumar, 1981	72
T. delhiensis Chawla, Bhamburkar, Khan & Prasad, 1968	18
T. depressus Jairajpuri, 1982	62
T. dubius (Bütschli, 1873) Flipjev, 1936	19
T. ebriensis Seinhorst, 1963	20
T. eremicolus Allen, 1955	21
T. eroshenkoi (Eroshenko, 1984) Mahajan & Bello, 1986	65
T. ewingi Hopper, 1959	22
T. galeatus litvinova, 1946	23
T. georgiensis Eliashvili, 1971	24
T. goffarti Sturhan, 1966	25
T. goldeni Rashid & Singh, 1982	26
T. graciliformis Siddiqi & Siddiqui, 1983	27
T. haki Fotedar & Mahajan, 1971	28
T. hordei Khan, 1972	67
T. huisingi Paetzold, 1958	29
T. irregularis Wu, 1969	30
T. kashmirensis Mahajan, 1974	31
T. kegenicus Litvinova, 1946	32
T. latus Allen, 1955	33
T. leviterminalis Siddiqi, Mukherjee & Dasgupta, 1982	34
T. manubriatus Litvinova, 1945	35
T. mashhoodi Siddiqi & Basir, 1959 = *T. dactylurus* Das, 1960; = *T. digitatus* Das, 1960; = *T. elegans* Siddiqi, 1967; = *T. zeae* Sethi & Swarup, 1968	36
T. maximus Allen, 1955	37
T. mexicanus Knobloch & Laughlin, 1973	38
T. microconus Siddiqi, Mukherjee & Dasgupta, 1982	39
T. musae Kumar, 1981	73
T. natalensis Kleynhans, 1984	40
T. neoclavicaudatus Mathur, Sanwall & Lal, 1979	41
T. nordiensis Khan & Nanjappa, 1974	42
T. nudus Allen, 1955	43
T. oleraceae Gupta & Uma, 1982	44
T. parvus, Allen, 1955	45
T. paranudus Phukan & Sanwal, 1982	46
T. penniseti Gupta & Uma, 1981	76
T. punensis Khan & Lordello, 1976	47
T. querozi Monteiro & Lordello, 1976	48
T. robustus Thorne & Malek, 1968	49
T. sacchari Sivakumar & Muthukrishnan, 1982	50
T. sanwali Kumar, 1980	70
T. silvaticus Ferris, 1963	51
T. solani Gupta & Uma, 1981	52
T. spinaceae Singh, 1976	75
T. striatus Allen, 1955	53
T. swarupi Singh & Khera, 1978	74
T. tobari Sauer & Annells, 1981	54
T. tarjani Andrássy, 1969	55
T. teeni Hashim, 1984	56
T. tenuicaudatus Wouts & Sher, 1981	57
T. varicaudatus Singh, 1971	58
T. velatus Sauer & Annels, 1981	60
T. ventrosignatus Tobar, Jimenez, 1969	59
T. vulgaris Upadhyay, Swarup & Sethi, 1982	61
T. wilskii Kornobis, 1980	66

e. g. tail shape, inclination of the stylet knobs, etc. In the case of the qualitative multistate variables, a logical order was established as far as possible. When only a single value was known it was assigned to the maximum and minimum values of the range. In the case of a missing value, a code of — 1 was given. Data from descriptions other than the original authorities and also from our own observations have been included in the data files. *Merlinius kirjanovi*, *M. neohexagrammus*, and *Tylenchorhynchus bicaudatus* are not included in the data files because of the unavailability of data. Detailed Tables of the data files can be requested from the authors and Tables 2 and 3 give the species names with the correspondent compendium numbers.

Table 4

A sample OUTPUT of the programs when Formula (1) is used

Population 1									
1	.57	2	.74	3	17.00	4	28.00	5	4.40
6	6.20	7	9.40	8	15.90	9	54.00	10	58.00
11	2.00	12	5.00	13	6.00	14	2.00	15	13.00
16	16.00	17	3.00	18	40.00	19	40.00	20	2.00
21	3.00	22	0.00	23	2.60	24	3.50	25	21.00
26	21.00	27	8.00	28	8.00				
8	*Merlinius brevidens*		93.41						
21	*M. microdorus*		93.20		25	*M. paramonovi*		89.81	
39	*M. capitonis*		89.65		36	*M. undyferrus*		88.41	
Population 2									
1	.52	2	.60	3	26.00	4	35.00	5	4.20
6	4.60	7	11.00	8	14.00	9	54.00	10	60.00
11	2.00	12	6.00	13	7.00	14	2.00	15	15.00
16	17.00	17	3.00	18	— 1.00	19	— 1.00	20	2.00
21	3.00	22	0.00	23	2.90	24	3.70	25	— 1.00
26	— 1.00	27	— 1.00	28	— 1,00				
8	*Merlinius brevidens*		84.86						
25	*M. paramonovi*		84.52		21	*M. microdorus*		81.71	
36	*M. undyferrus*		79.49		28	*M. pleorbus*		79.46	
Population 3									
1	.50	2	.79	3	27.00	4	45.00	5	4.40
6	6.10	7	12.00	8	18.00	9	51.00	10	57.00
11	1.00	12	5.00	13	6.00	14	1.00	15	13.00
16	18.00	17	3.00	18	32.00	19	49.00	50	2.00
21	3.00	22	0.00	23	— 1.00	24	— 1.00	25	20.00
26	26.00	27	10.00	28	14.00				
9	*Tylenchorhynchus brevilineatus*		96.01						
25	*T. goffarti*		91.32		2	*T. aerolatus*		89.07	
61	*T. vulgaris*		87.50		59	*T. ventrosignatus*		87.39	
Population 4									
1	.54	2	.71	3	27.00	4	35.00	5	5.30
6	6.30	7	11.00	8	16.00	9	52.00	10	55.00
11	1.00	12	6.00	13	7.00	14	2.00	15	15.00
16	17.00	17	2.00	18	34.00	19	47.00	20	2.00
21	2.00	22	0.00	23	2.70	24	3.80	25	23.00
26	25.00	27	10.00	28	12.00				
25	*Tylenchorhynchus goffarti*		94.31						
61	*T. vulgaris*		93.16		9	*T. brevilineatus*		92.63	
2	*T. aerolatus*		92.21		53	*T. striatus*		91.08	
Population 5									
1	.45	2	.71	3	21.00	4	24.00	5	7.50
6	10.00	7	16.00	8	19.00	9	49.00	10	56.00
11	1.00	12	2.00	13	2.00	14	0.00	15	20.00
16	20.00	17	1.00	18	30.00	19	31.00	20	1.00
21	2.00	22	1.00	23	2.00	24	2.00	25	19.00
26	20.00	27	9.00	28	9.00				
21	*Tylenchorhynchus eremicolus*		87.79						
30	*T. irregularis*		87.55		38	*T. mexicanus*		85.67	
68	*T. badliensis*		85.02		8	*T. brassicae*		84.79	

Table 5

A sample OUTPUT of the programs when Formula 2) is used

Population 1									
1	.57	2	.74	3	17.00	4	28.00	5	4.40
6	6.20	7	9.40	8	15.90	9	54.00	10	58.00
11	2.00	12	5.00	13	6.00	14	2.00	15	13.00
16	16.00	17	3.00	18	40.00	19	40.00	20	2.00
21	3.00	22	0.00	23	2.60	24	3.50	25	21.00
26	21.00	27	8.00	28	8.00				
8	*Merlinius brevidens*		91.98						
25	*M. paramonovi*		91.94		21	*M. microdorus*		90.34	
38	*M. bijnorensis*		88.47		5	*M. bavaricus*		86.49	
Population 2									
1	.52	2	.60	3	26.00	4	35.00	5	4.20
6	4.60	7	11.00	8	14.00	9	54.00	10	60.00
11	2.00	12	6.00	13	7.00	14	2.00	15	15.00
16	17.00	17	3.00	18	— 1,00	19	— 1,00	20	2.00
21	3.00	22	0.00	23	2.90	24	3.70	25	— 1.00
26	— 1,00	27	— 1,00	28	— 1,00				
8	*Merlinius brevidens*		93.03						
25	*M. paramonovi*		92.53		38	*M. bijnorensis*		87.80	
21	*M. microdorus*		86.38		5	*M. bavaricus*		84.57	
Population 3									
3	.50	2	.79	3	27.00	4	45.00	5	4.40
6	6.10	7	12.00	8	18.00	9	51.00	10	57.00
11	1.00	12	5.00	13	6.00	14	1.00	15	13.00
16	18.00	17	3.00	18	32.00	19	49.00	50	2.00
21	3.00	22	0.00	23	— 1,00	24	— 1,00	25	20.00
26	26.00	27	10.00	28	14.00				
9	*Tylenchorhynchus brevilineatus*		99.62						
25	*T. goffarti*		93.78		54	*T. tobari*		91.09	
61	*T. vulgaris*		90.70		59	*T. ventrosignatus*		89.93	
Population 4									
1	.54	2	.71	3	27.00	4	35.00	5	5.30
6	6.30	7	11.00	8	16.00	9	52.00	10	55.00
11	1.00	12	6.00	13	7.00	14	2.00	15	15.00
16	17.00	17	2.00	18	34.00	19	47.00	20	2.00
21	2.00	22	0.00	23	2.70	24	3.80	25	23.00
26	25.00	27	10.00	28	12.00				
61	*Tylenchorhynchus vulgaris*		93.69						
25	*T. goffarti*		93.47		9	*T. brevilineatus*		90.50	
2	*T. aerolatus*		90.49		59	*T. ventrosignatus*		90.16	
Population 5									
1	.45	2	.71	3	21.00	4	24.00	5	7.50
6	10.00	7	16.00	8	19.00	9	49.00	10	56.00
11	1.00	12	2.00	13	2.00	14	0.00	15	20.00
16	20.00	17	1.00	18	30.00	19	31.00	20	1.00
21	2.00	22	1.00	23	2.00	24	2.00	25	19.00
26	20.00	27	9.00	28	9.00				
30	*Tylenchorhynchus irregularis*		85.47						
21	*T. eremicolus*		85.00		38	*T. mexicanus*		82.80	
8	*T. brassicae*		82.45		63	*T. cristatus*		82.36	

Weighting and identification

All characters values were weighted (Tab. 1) by using the method of Rey, Andres and Arias (1988) and with the quantitative characters, the maximun values were given the same weighting as the minimun values.

The formulae adopted for estimating the similarity are :

$$S_R = \frac{\sum Wi \dfrac{[min(X_{ij}, X_{ik}) + sd_i]}{/\,[max(X_{ij}, X_{ik}) + sd_i]}}{\sum Wi} Fc \qquad (1)$$

$$S_G = 1 - \frac{\sum Wi\,(|X_{ij} - X_{ik}|)/Ri}{\sum Wi} F_w \qquad (2)$$

where X_{ij} and X_{ik} are the data values for species j and k, Ri the range and sd_i the standard deviation, all of them for character i, Fw and Fc are correction factors for the missing characters.

The formula (1) derived by Rey, Andres and Arias (1988) from the coefficient of similarity of Pinkham and Pearson (1976) was used in the programs. Gower's (1971) *General Coefficient of Similarity* with the addition of a correction factor for the missing values (Rey, 1987) is presented for comparative purposes (formula 2).

Cluster Analysis

The species were subjected to a cluster analysis by the *Unweighted Group Average Linkage Method* (Sneath & Sokal, 1973) with weighted characters as given in Table 1 and using Formula (1) as index of similarity. The program to perform the clustering is similar to the one given by Orloci (1978).

Results and conclusions

A sample output with Formula (1) is given in Table 4 for five populations taken from the literature and from our own collection. A similar output based on formula (2) and with the same populations is given in Table 5.

Population 1 with a complete data set and population 2 with several data missing gave the correct result : *M. brevidens*. Population 3 was correctly identified as being most similar to *T. goffarti* but it is suspected of being a new species because of certain characters which were not included in the reference file. Population 5 is a simulation in which data for the species *T. sanwali* were removed from the reference file and then entered into the computer as a test species. The results obtained had a low level of similarity with the nearest species *T. eremicolus* which supports the assignment of *T. sanwali* to specific status.

Summaries of dendrograms produced by the cluster analysis are given for each genus (Figs 1 and 2) and they reveal the existence of several groups of species with generally similar morphology. The two most similar species in both genera (not shown in the figures) were *M. grandis* and *M. lineatus* and *T. coffeae* and *T. musae* with similarity levels of 94.0 and 95.1 respectively. The furthest species in genus *Merlinius* are *M. brachycephalus* and *M. graminicola* and those in *Tylen chorhynchus* are *T. galeatus* and *T. eroshenkoi.*

The output of the computer can be cross-checked with the nearest species included in the cluster groups given in Figures 1 and 2. Any species considered as new should be compared with those in the same cluster group as well as those in the computer output of the programs. For example, the species *T. sanwali* is evidently new but has been compared with *T. nudus, T. varicaudatus* and *T. brassicae* while in fact it is closer to *T. eremicolus* and *T. irregularis* as well as *T. brassicae.*

The programs used here for identifying *Tylenchorhynchus* and *Merlinius* are examples which show that the program used by Rey, Andres and Arias (1988) to identify *Longidorus* species can be adapted for use with other nematode genera. These programs are designed to aid the taxonomist in identifying nematode species, not as a substitute. However, if the worker introduces different parameters to the program, too few data are taken from a specimen or morphometric data are imprecise, correct identification will not be made by this or any other method.

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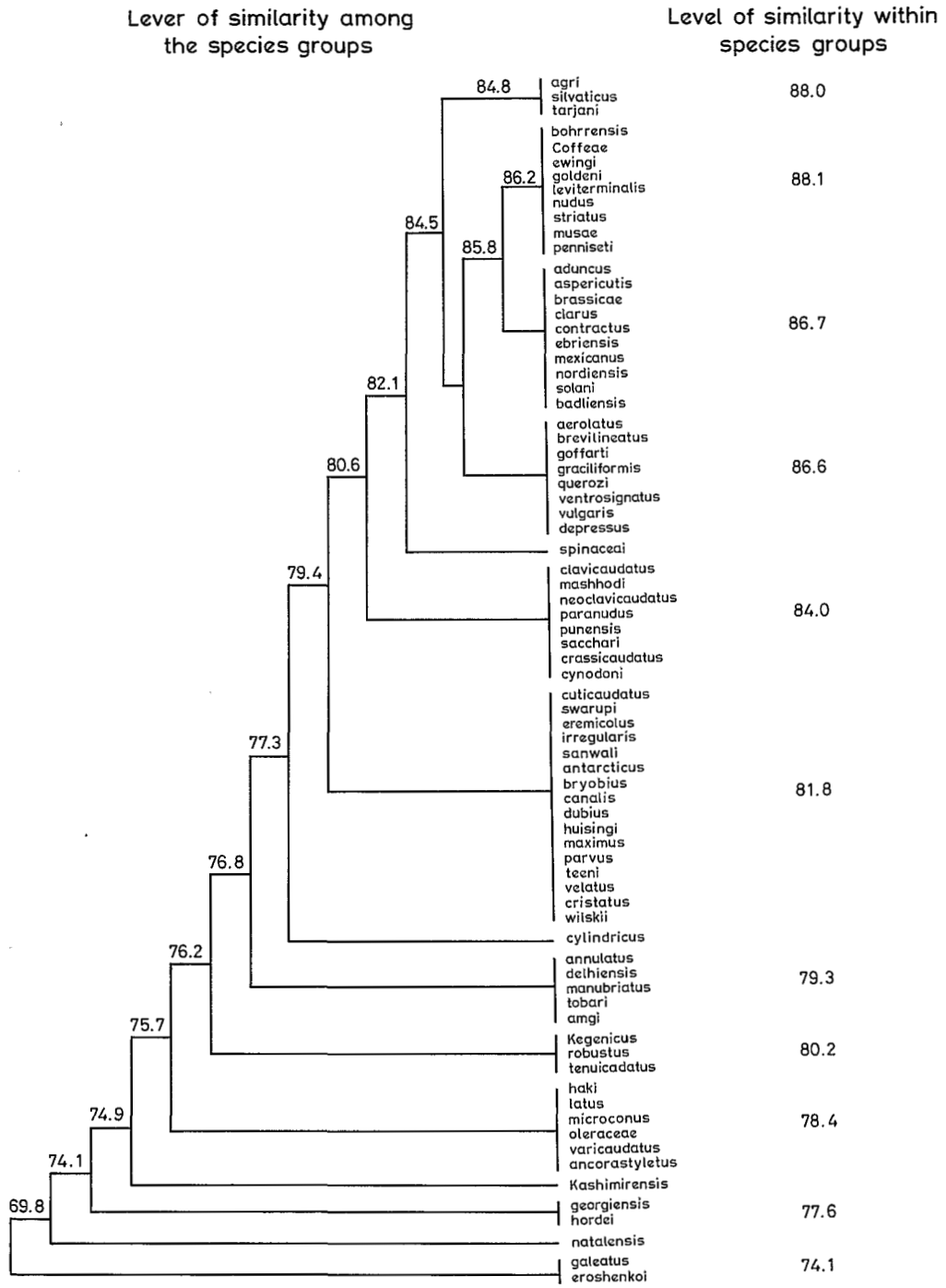

Fig. 1. Abridged dendrogram showing the relationship among *Tylenchorhynchus* species at different levels of similarity as computed by a cluster analysis with Formula (1) and the characters and weights given in Table 1.

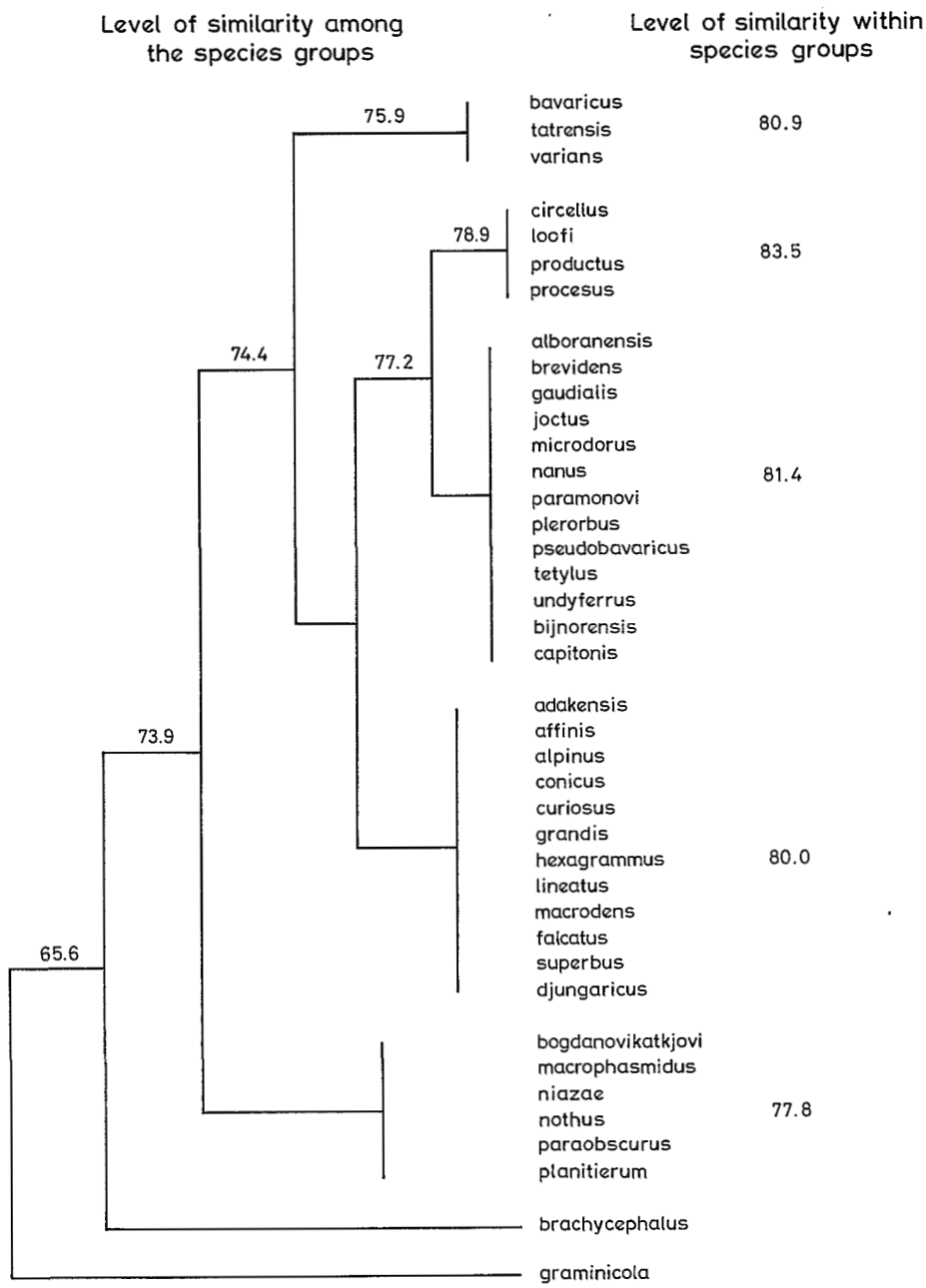

Fig. 2. Abridged dendrogram showing the relationship among *Merlinius* species at different levels of similarity as computed by a cluster analysis with Formula (1) and the characters and weights given in Table 1.

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