

# A computer method for identifying nematode species

**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

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

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 2

Species in the reference file of the genus *Merlinius*

Species	Compendium number
<i>M. adakensis</i> Bernard, 1980	1
<i>M. affinis</i> (Allen, 1955) Siddiqi, 1970	2
<i>M. alboranensis</i> (Tobar Jimenez, 1970) Siddiqi, 1970	3
<i>M. alpinus</i> (Allen, 1955) Siddiqi, 1970	4
<i>M. bavaricus</i> (Sturhan, 1966) Siddiqi, 1970	5
<i>M. bijnorensis</i> Khan, 1972	38
<i>M. bogdanovikatkjovi</i> (Kirjanova, 1941) Siddiqi, 1970	6
<i>M. brachycephalus</i> (Litvinova, 1946) Tarjan, 1973	7
<i>M. brevidens</i> (Allen, 1955) Siddiqi, 1970	8
<i>M. capitonis</i> Ivanova, 1983	39
<i>M. circellus</i> Anderson & Ebsary, 1982	9
<i>M. conicus</i> (Allen, 1955) Siddiqi, 1970	10
<i>M. curiosus</i> (Wilski, 1965) Sher, 1974	11
<i>M. djungaricus</i> (Razzhivin, 1974) Mahajan & Bello, 1986	

Table 3  
Species in the reference file of the genus *Tylenchorhynchus*

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

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

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	<i>Merlinius brevidens</i>		93.41						
21	<i>M. microdorus</i>		93.20	25	<i>M. paramonovi</i>		89.81		
39	<i>M. capitonis</i>		89.65	36	<i>M. undyferrus</i>		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				

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	<i>Merlinius brevidens</i>		91.98						
25	<i>M. paramonovi</i>		91.94	21	<i>M. microdorus</i>		90.34		
38	<i>M. bijnorensis</i>		88.47	5	<i>M. bavaricus</i>		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	<i>Merlinius brevidens</i>		93.03						
25	<i>M. paramonovi</i>		92.53	38	<i>M. bijnorensis</i>		87.80		

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 maximum values were given the same weighting as the minimum values.

The formulae adopted for estimating the similarity are :

$$S_R = \frac{\sum W_i \frac{[\min(X_{ij}, X_{ik}) + sd_i]}{[\max(X_{ij}, X_{ik}) + sd_i]} F_c}{\sum W_i} F_c \quad (1)$$

$$S_G = 1 - \frac{\sum W_i (|X_{ij} - X_{ik}|)/R_i}{\sum W_i} F_w \quad (2)$$

where  $X_{ij}$  and  $X_{ik}$  are the data values for species  $j$  and  $k$ ,  $R_i$  the range and  $sd_i$  the standard deviation, all of them for character  $i$ ,  $F_w$  and  $F_c$  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) Coefficient of Similarity is identical to this

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 *Tylenchorhynchus* 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

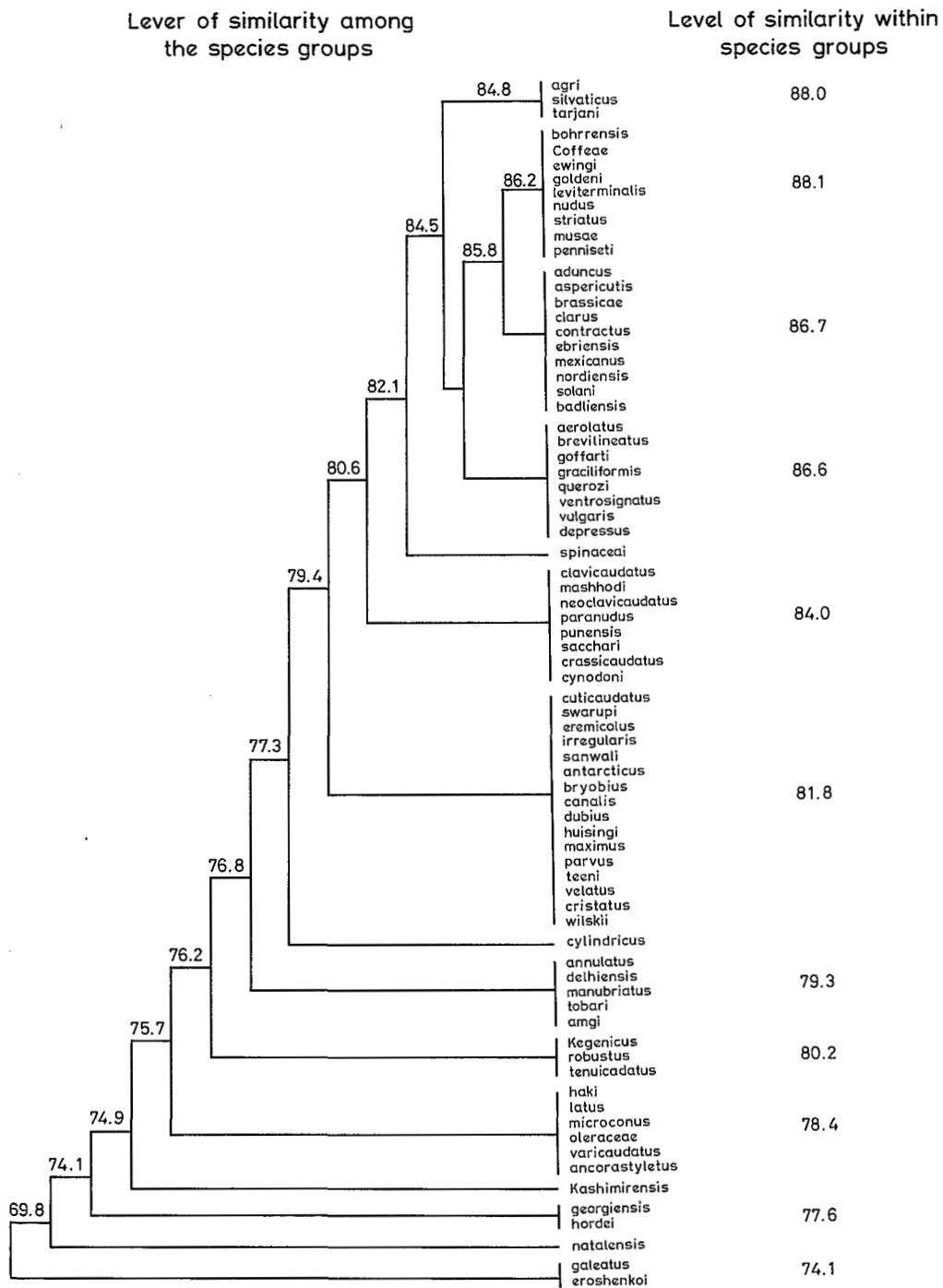


Fig. 1. Abridged dendrogram showing the relationship among *Tylenchorhynchus* species at different levels of similarity as computed by a cluster analysis with Formula (1) and the characters and weights given in Table 1.

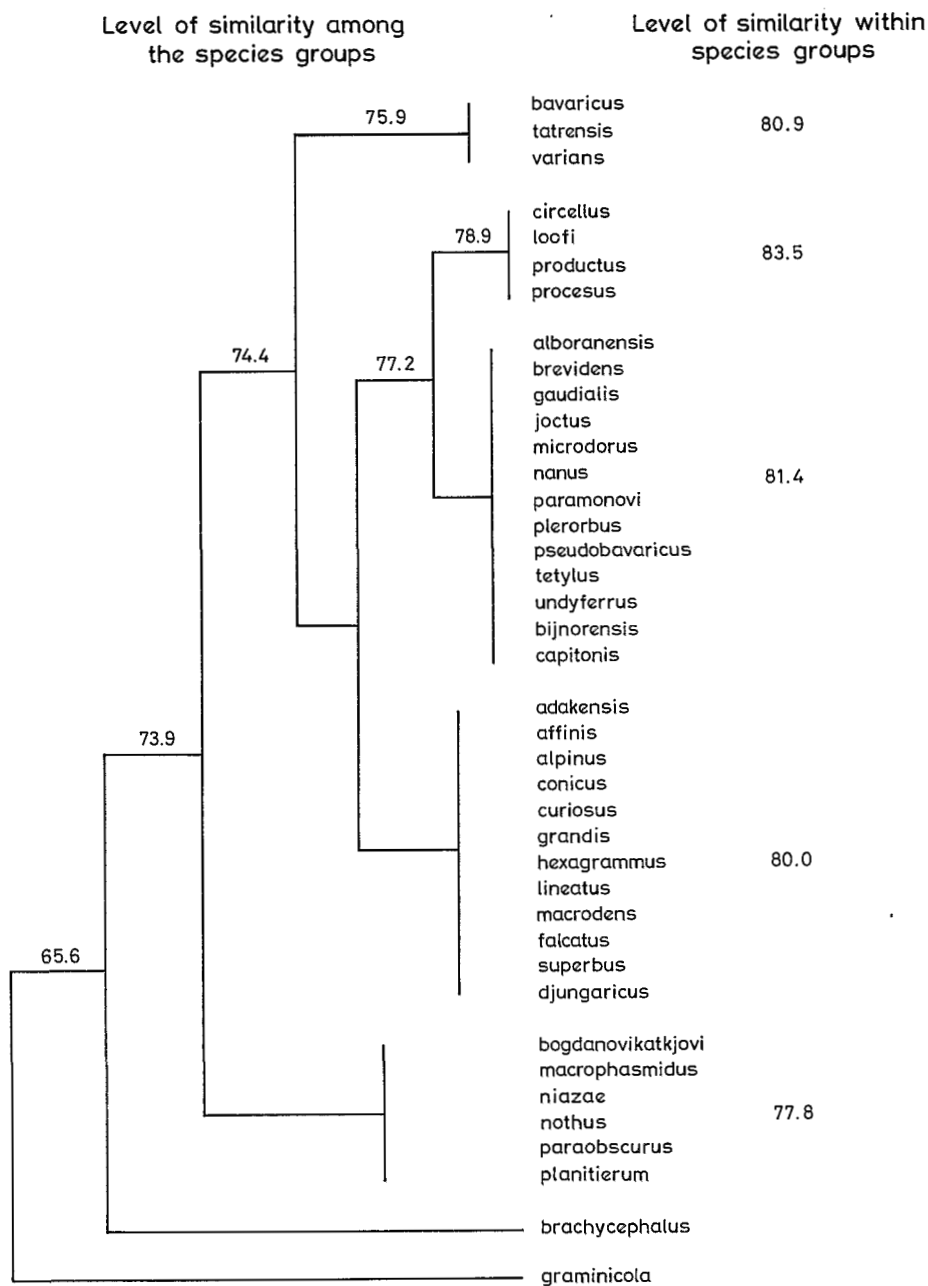


Fig. 2. Abridged dendrogram showing the relationship among *Merlinius* species at different levels of similarity as computed by a cluster analysis with Formula (1) and the characters and weights given in Table 1.

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