

Morphometrical variability in *Helicotylenchus* Steiner, 1945. 5 : On the validity of ratios

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SUMMARY

The validity and use of ratios in species of *Helicotylenchus* were studied. The criteria of validity used by several authors are discussed, and the test proposed by Roggen and Asselberg (1971) is rejected. A ratio is here considered as taxonomically valid when the characters which constitute it are biologically related. This biological relationship must be verified by the study of the significance of the correlation between the two characters. In addition to its validity, a ratio is considered useful when its variability in a sample is lower than the variability of its constituent characters. In the samples of populations of *Helicotylenchus* spp. studied, V is always valid and useful ; a, c, and c' are often valid but rarely useful ; b, b' and m are valid in only half the samples and most often are not useful. Ratio o is meaningless, useless, and must not be used. It is concluded that ratios a, b, b', c, c' (but not ratio o) can be given in descriptions of species of *Helicotylenchus*, but the values of the measurements constituting the ratios must also be given. Only ratio V can be given instead of its constituent characters.

RÉSUMÉ

Variabilité morphométrique chez *Helicotylenchus* Steiner, 1945.
5 : Sur la validité des rapports biométriques

La valeur et l'utilisation des rapports biométriques ont été étudiées chez des espèces du genre *Helicotylenchus*. Les critères de validité utilisés par divers auteurs ont été discutés et le test de validité des rapports proposé par Roggen et Asselberg (1971) est rejeté. Un rapport est ici considéré comme taxonomiquement valide lorsque les caractères qui le constituent sont biologiquement liés. Cette relation biologique doit être vérifiée par l'étude de la signification de la corrélation entre les deux caractères. Indépendamment de sa validité, un rapport est ici considéré comme utile lorsque sa variabilité dans un échantillon est plus faible que la variabilité des caractères qui le constituent. Parmi les échantillons de populations de *Helicotylenchus* spp. ici étudiés V est toujours valide et utile ; a, c et c' sont souvent valides mais rarement utiles ; b, b' et m ne sont valides que dans la moitié des échantillons et sont le plus souvent inutiles. Le rapport o ne représente rien et est inutile. Il ne doit donc pas être calculé. En conclusion, les rapports a, b, b', c, c' (mais non le rapport o) peuvent apparaître dans les descriptions des espèces d'*Helicotylenchus* mais les valeurs des mesures qui constituent ces rapports doivent aussi être calculées. Seul le rapport V peut être fourni en remplacement des caractères qui le constituent.

De Man (1880) formulated the characters — body diameter, length of esophagus, and length of tail — of the nematode *Alaimus primitivus* as ratios α , β and γ (now named a, b, and c) of the body length. The demanian ratios have now been in use for a century and have survived Cobb's (1913) later proposal of a descriptive system for nematodes. Of Cobb's formula, only coefficient V (distance head-vulva as a percentage of body length) is still in use. Other ratios were later added to the demanian ratios. The most commonly used in the descriptions of species of *Helicotylenchus* are : b' : body length/distance head to end of esophageal glands (Sher, 1963) ; c' : tail length/tail diameter at anus level (Sher, 1966) ; m : stylet cone/stylet length (%) (Andrássy, 1962) ; and o : distance dorsal gland opening (d.g.o.) to stylet base/stylet length (%) (Perry, in Perry, Darling & Thorne, 1959).

A ratio X/Y is only one among all possible functions of X and Y. Kermack and Haldane (1950), Angervall and Carlström (1963), Roggen and Asselberg (1971), have shown that other functions, such as the line of organic correlation, show the general trend of relationships between two variables better than a ratio. Those other functions have never been accepted by nematode taxonomists. Nematologists continue using ratios because of tradition and because ratios are easy to compute. The present study does not propose any new function of X and Y. It shows the biological, mathematical, and practical limitations of the function still in wide usage : the demanian ratio.

There are two main reasons for using a ratio instead of the actual measurements :

— a ratio describes the relationship which exists (or is supposed to exist) between two characters. If

ratio "a" is calculated in addition to the length and the diameter of a nematode, it will describe another character : the shape of the specimen.

— a ratio is believed to be less variable than its constituent characters. Many characteristics are subjected to a great intraspecific variability. This reduces their taxonomic value when they are used for differentiating related species. If the ratios calculated from such characters were more constant within a species, they would be better tools for taxonomy and identification than the measurements themselves.

Until recently, these properties of ratios have been taken for granted by the authors. Only during the last twenty years have some studies been published which discuss the biological meaning and usefulness of the ratios.

In *Helicotylenchus*, a few authors have studied the growth of several species. Some (Yeates, 1973 with *H. pseudorobustus*; Zuckerman and Strich-Harari, 1963 with *H. multincinctus*) did not consider the validity of the ratios. Yuen (1966) observed that, in old females of *H. vulgaris*, the length of the esophagus, measured to the end of the glands, increased little with an increase of the body length. She also observed that the tail length increased in proportion to the body length at all stages. Azmi and Jairajpuri (1978) studied allometric variations in *H. indicus*. They concluded that ratios V, a, and o (and also G, length of anterior genital branch/body length) are the least variable ratios. From Table 1 (of the same authors), it can be seen that only ratio V (but not ratios b, b', and c) has a smaller coefficient of variability (C.V.) than its constituent measurements.

Studies were also published on other plant-parasitic nematode genera : Goodey (1952); Wu (1960), Cayrol and Legay (1967), Fortuner (1982) on *Ditylenchus*; Geraert (1965) on *Paratylenchus*; Bird (1967), Bird and Mai (1968) on *Trichodorus*; Terenteva (1967) on *Meloidogyne*; Miller (1969) on *Heterodera*; Román and Hirschmann (1969), Tarte and Mai (1976) on *Pratylenchus*; Rau and Fassuliotis (1970) on *Belonolaimus*; Monoson (1971), Kline (1976) on *Aphelenchus*; Tobar-Jimenez (1971) on *Tylenchorhynchus*, Bajaj and Jairajpuri (1977) on *Xiphinema*. In most cases, V was the best ratio; ratio a was also often accepted; and ratios b and b' were generally rejected. The validity of ratios c and c' depended upon the genus studied, and sometimes on the species.

Wu (1960) was the first to discuss de Man's ratios in a mathematical manner. She calculated the coefficients of correlation between pairs of variables in a population of *Ditylenchus destructor* and plotted the regression lines on a graph. The ratios for which the correlation was not significant were rejected and the use of ratios was restricted to the cases where the regression line passed through the origin. Only ratio

V was found to comply to these two conditions. Geraert (1968) accepted the same criteria—significant correlation of the pair of variables, and regression line passing through the origin—in his comprehensive study of the morphometric relations in nematodes. Roggen and Asselberg (1971) made a theoretical approach to the problem. Again, they proposed that a ratio K between two characters X and Y can only be used when the regression line passes through the origin. Then B, the Y-intercept, is equal to zero and the equation of the regression line is of the form $Y = AX$. The ratio K is then equal to A, the slope of the regression line. They concluded that this condition is verified when the coefficients of variability (C.V.) of X and Y are equal, and they proposed to test this equality by a t-test.

In two previous publications (Fortuner, 1979; Fortuner & Quénehervé, 1980), the present author discussed the value of the ratios in various samples of *Helicotylenchus dihystra* (Cobb, 1893) Sher, 1961. The test proposed by Roggen and Asselberg (1971) was used in these studies. Some practical and theoretical considerations have since cast doubts on the validity of this approach. The previous conclusions of the present author (Fortuner, 1979; Fortuner & Quénehervé, 1980) must be reevaluated. Other samples can now be added to those studied earlier: samples from field populations of *H. dihystra*, *H. pseudorobustus* (Steiner, 1914) Golden, 1956, and samples from other species of the genus *Helicotylenchus* studied in two other publications on the variability of the taxonomic characters (Fortuner, Merny & Roux, 1981; Fortuner, Maggenti & Whittaker, 1984).

Material and Methods

The origin and composition of the samples analyzed are indicated in Table 1. Several statistical parameters were calculated :

COEFFICIENT OF CORRELATION OF PEARSON (SPSS program "Pearson Corr", Nie *et al.*, 1975).

This coefficient was calculated between the measurements constituting the ratios a,b,b',c,c',m,o and V, in every sample in Table 1. The significances were calculated at 5% and 1% levels (one-tailed tests). The coefficients of correlation are given in Table 2.

COEFFICIENTS OF VARIABILITY, (SPSS program "Condescriptive", Nie *et al.*, 1975)

The C.V. were calculated only when the terms of a ratio were correlated. The C.V. of the constituting terms of the ratios, and of the ratios themselves are given in Table 3.

Table 1
Description of the samples used in the present study

Sample # size	Species	Origin	References
a 42	<i>H. dihystra</i>	Single ♀ inoculation ; rice ; Senegal	Fortuner (1979)
b 20	<i>H. dihystra</i>	Single ♀ inoculation ; rice ; Ivory Coast	Fortuner & Quénéhervé (1980) sample a
c 20	<i>H. dihystra</i>	Single ♀ inoculation ; sugarcane ; Ivory Coast	Fortuner & Quénéhervé (1980) sample b
d 20	<i>H. dihystra</i>	Single ♀ inoculation ; corn ; Ivory Coast	Fortuner & Quénéhervé (1980) sample c
e 20	<i>H. dihystra</i>	Single ♀ inoculation ; pepper ; Ivory Coast	Fortuner & Quénéhervé (1980) sample d
f 19	<i>H. dihystra</i>	Field population ; cocoa ; Madagascar	Fortuner, Merny & Roux (1981) sample A
g 20	<i>H. dihystra</i>	Field population ; banana ; Canary Isl.	Fortuner, Merny & Roux (1981) sample B
h 18	<i>H. paracanalisis</i>	Field population ; forest ; Ivory Coast	Fortuner, Merny & Roux (1981) sample M
i 17	<i>H. morasii</i>	Field population ; savanna ; Ivory Coast	Fortuner, Merny & Roux (1981) sample L
j 20	<i>H. pseudorobustus</i>	Field population ; moss ; Switzerland (topotypes)	Fortuner, Maggenti & Whittaker (1984) sample A1
k 20	<i>H. pseudorobustus</i>	Field population ; philodendron ; California	Fortuner, Maggenti & Whittaker (1984) sample G1
l 9	<i>H. phalerus</i> (= <i>H. pseudorobustus</i>)	Field population ; turf ; Canada	Fortuner, Maggenti & Whittaker (1984) sample phal
m 14	<i>H. bradys</i> (= <i>H. pseudorobustus</i>)	Field population ; soybean ; U.S.A.	Fortuner, Maggenti & Whittaker (1984) sample brad

Table 2
Coefficients of correlation between each pair of characters constituting the ratios a, b, b', c, c', m, o, V in the studied samples

Sample	n	Significance for one-tailed test :		L/∅ m a	L/∅ e b	L/gl b'	L/t c	T/∅ a c'	co/st m	dgo/st o	vulva/L V
		5%*	1%**								
a	42	.257	.358	.358**	.444**	.111	.395**	.528**	.439**	.071	.829**
b	20	.378	.516	.621**	.181	.487*	.612**	.499*	.346	.418*	.955**
c	20	.378	.516	.805**	.535**	.606**	.522**	.529**	.078	.042*	.957**
d	20	.378	.516	.511*	.749**	.594**	.635**	.511*	.306	.034	.961**
e	20	.378	.516	.579**	.735**	.503*	.806**	.525**	-.077	.762**	.977**
f	19	.389	.528	.831**	.816**	.702**	.513*	.298	.822**	-.002	.948**
g	20	.378	.516	.350	.231	.315	.657**	.652**	.638**	-.332*	.975**
h	18	.400	.542	.730**	.746**	.403*	.482*	.737**	.758**	.421*	.965**
i	17	.412	.558	.950**	.332	.315	.818**	.780**	.858**	-.344	.970**
j	20	.378	.516	.269	.451*	.595**	.579**	.103	.362	.189	.923**
k	30	.306	.423	.755**	.372*	.030	.414*	.328*	.653**	-.039	.877**
l	9	.582	.750	.444	.788**	.781**	.606*	.485	.578	.059	.926**
m	14	.458	.612	.345	.292	.379	.144	.610*	.862**	.211	.958**

EQUATION OF THE REGRESSION LINES (Minitab System Ryan *et al.*, 1981)

The equation were calculated only when the terms of a ratio were correlated. The values of slope and intercept are given in Table 4. The mean value of the corresponding ratios are also given in Table 4.

GRAPHS

For some ratios (a,b,b',m, and V) a few graphs were drawn to show various patterns of distribution of the representative points in some selected samples. The regression lines are indicated in the graphs.

Results

RATIO A

This ratio—body length/body maximum diameter—represents the shape of the nematode, fat or slim, stubby or elongate. Among the thirteen samples studied, the two measurements constituting ratio a are highly correlated in eight samples, correlated at 5% level in another sample and the correlation was not significant in four samples (Tab. 2). Ratio a generally reduces the biological variability. Its C.V. is smaller than the C.V. of its constituent measurements in six samples. In three other samples, there is no

Table 3
Usefulness of ratios — Coefficients of variability ($C.V. = \frac{s}{\bar{x}} \times 100$) of the significant ratios and their constituent characters

Sample	Characters										Ratios							
	L	sm	oe	co. gl.	T.	sa.	sty	cone	dgo.	vulva	a	b	b'	c	c'	m	o	V
a	3.71	4.47	3.74	—	9.60	4.48	1.68	3.19	—	3.86	4.75	3.91	—	8.64	8.12	2.92	—	2.26
b	7.72	7.77	—	3.03	10.70	7.15	1.40	—	9.12	6.09	6.50	—	6.89	8.06	9.26	—	8.65	2.66
c	5.67	5.98	4.04	4.34	8.66	6.41	—	—	—	4.79	3.63	4.86	4.61	7.58	7.32	—	—	1.78
d	6.81	8.80	3.73	4.11	9.48	4.94	—	—	—	6.38	7.79	4.77	5.48	7.41	8.00	—	—	1.85
e	8.62	6.08	5.30	4.59	9.00	6.65	3.51	—	16.72	8.37	7.04	6.01	7.58	5.66	7.85	—	14.38	1.75
f	8.77	8.29	7.17	6.14	18.34	—	3.96	6.37	—	9.06	5.05	5.27	6.32	16.13	—	3.70	—	2.87
g	7.78	—	—	—	9.70	10.50	2.73	3.33	—	7.22	—	—	—	7.49	10.00	2.64	—	1.89
h	9.36	9.53	3.25	2.67	14.41	9.14	3.83	4.97	8.40	8.68	6.92	7.33	8.64	12.88	9.80	3.14	7.56	2.47
i	10.81	8.34	—	—	24.62	7.93	3.05	7.48	—	9.90	4.03	—	—	17.04	19.05	5.19	—	2.70
j	7.56	—	5.09	5.97	10.64	—	—	—	—	6.69	—	6.98	6.10	9.05	—	—	—	2.91
k	5.11	5.76	4.59	—	8.06	7.38	1.91	2.89	—	4.84	3.85	5.33	—	7.52	8.76	3.35	—	2.45
l	5.67	—	4.78	5.05	9.08	—	—	—	—	5.47	—	3.45	3.57	7.57	—	—	—	2.12
m	5.66	—	—	—	13.26	8.07	3.08	5.70	—	4.48	—	—	—	—	11.21	3.56	—	1.87

Table 4
Parameters of the equation of the regression line and value of the ratios

Sample	length/diameter			length/esophagus			length/eso. glands			length/tail			tail/tail diameter			cone/stylet			head-vulva/length		
	slope	inter-cept	ratio a	slope	inter-cept	ratio b	slope	inter-cept	ratio b'	slope	inter-cept	ratio c	slope	inter-cept	ratio c'	slope	inter-cept	ratio m	slope	inter-cept	ratio V
a	8.5	471	28.7	2.7	375	6.0	—	—	—	4.9	569	32.2	1.6	-3	1.4	0.35	1.7	42	0.54	58	62.1
b	16.3	240	26.5	—	—	—	5.6	-151	4.5	18.7	350	42.6	0.8	4	1.1	—	—	—	0.49	100	64.9
c	20.9	161	27.3	4.5	170	5.9	3.9	142	4.9	15.0	451	44.2	0.8	4	1.1	—	—	—	0.51	83	62.9
d	10.5	369	26.7	7.7	-224	5.6	4.5	10	4.6	19.2	332	42.3	1.1	0.3	1.2	—	—	—	0.58	39	63.9
e	24.3	135	29.7	7.4	-144	6.2	5.0	43	5.3	32.9	171	42.7	0.9	5	1.2	—	—	—	0.60	24	63.2
f	25.2	58	28.0	5.7	-13	5.6	4.6	-16	4.5	11.4	440	46.2	—	—	—	0.63	-3.7	48	0.60	19	63.1
g	—	—	—	—	—	—	—	—	—	25.7	305	49.1	0.6	5	0.9	0.38	2.7	49	0.58	40	63.8
h	16.7	209	23.4	12.3	-844	5.7	6.1	-304	4.4	24.8	507	80.3	0.6	-1	0.5	0.45	0.3	46	0.54	47	60.4
i	31.8	-119	25.8	—	—	—	—	—	—	15.1	328	43.5	2.6	-17	1.0	0.97	-9.8	46	0.56	36	63.4
j	—	—	—	4.1	289	6.6	4.1	188	5.4	19.7	450	48.4	—	—	—	—	—	—	0.50	86	61.6
k	18.8	218	28.1	2.3	387	5.6	—	—	—	9.1	487	34.7	0.5	12	1.3	0.49	0.2	50	0.52	69	62.2
l	—	—	—	5.4	45	5.8	4.0	84	4.5	13.9	425	37.0	—	—	—	—	—	—	0.54	44	60.1
m	—	—	—	—	—	—	—	—	—	—	—	—	1.3	0	1.3	0.77	-7.6	48	0.45	104	59.1

diminution of the variability (Tab. 3), but also the coefficients of correlation were low in these three samples (a,d,e). None of the regression lines pass close to the origin (Tab. 4). It should be noted that the slope of each equation is different from the value of ratio a in the corresponding sample. The difference is the smallest in sample f; in this sample, the regression line passes the closest to the origin. Four examples of the distribution of the representative points are shown in Fig. 1 A-D. In Fig. 1 A, the correlation between the two measurements is low. The points are arranged in a round cloud. In Fig. 1 B, the correlation is barely significant; the correlation is much better in Fig. 1 C and D. In the last two samples (i and f) the correlation is very high, the variability is greatly reduced and the regression lines pass reasonably close to the origin.

RATIOS B AND B'

Both ratios link the length of the esophageal structures (distance from head to esophago-intestinal junction for b, and to end of glands for b') to the body length. This presupposes that when the body length varies, the length of the esophagus varies in the same manner. There is little difference in ratios b and b' among species of the genus *Helicotylenchus*, and it is not possible to derive specific differences from these ratios. The measurements constituting ratio b are highly correlated in seven samples, correlated at 5% level in two other samples. For ratio b', the corresponding numbers are five and three (Tab. 2). The C.V. of the ratios are lower than those of the constituent measurements only in sample f for ratio b and in sample l for both ratios (Tab. 3). The correlations in samples f and l are excellent and the regression lines pass close to the origin (Tab. 4).

Fig. 1, E-G show the representative points in sample k (correlation weak or not significant), h (correlation better, regression lines far from the origin), and f (excellent correlation, line close to the origin, and reduction of the variability).

RATIO c

This ratio—body length/tail length—is smaller for species with a long tail, higher for species with short tail, as in the species of *Helicotylenchus*. Because of this inverse relationship (short tail = higher value of c), ratio c is not easy to visualize. Length of tail and length of body are significantly correlated in all samples except m (Tab. 2) but, except in sample e and (to a lesser extent) in samples g and j, the C.V. of the ratios are not lower than those of their constituent measurements (Tab. 3). Sample e has the highest coefficient of correlation for ratio c, and the regres-

sion line passes closest to the origin (Tab. 4). Because they present no additional information, the representative graphs are omitted for ratio c.

RATIO c'

This ratio—tail length/tail diameter at level of anus—is the equivalent for the tail to what ratio a is for the body: it represents the proportions of the tail, filiform to stubby. In ten samples out of thirteen, the two measurements constituting ratio c' are significantly correlated but the significance is usually weak (Tab. 2). This ratio never reduces the variability (Tab. 3). In some samples (d, m) the regression line passes very close to, or through, the origin.

Figure 2A shows the representative points in sample i where the correlation is high but the regression line is far from the origin. In Figure 2C (sample m) the regression line passes through the origin but the correlation is relatively low. The best reduction of variability is achieved in sample g (Fig. 2 B) where the regression line passes not far from the origin and the correlation is high. In sample m, where the line goes through the origin, the slope of the regression line is equal to ratio c'.

RATIO m

This ratio—length of stylet cone/total length of the stylet (%)—is easy to visualize: the cone is m percent of the stylet. Its two constituent characters can be assumed to be related because they are both part of the same structure. Surprisingly, the level of the statistical correlation is low; only half of the samples show a significant correlation (Tab. 2). This might be due to the errors of measurements. The resolution of a microscope is about 0.5 μ m. This is high when compared to the difference between smallest and highest values for the cone length (about 1.5 to 2.5 μ m), and a specimen can easily be assigned to the wrong class. The variability is reduced by ratio m only in three samples: f, g and h. In sample i the correlation is very good but the regression line passes far from the origin (Tab. 4) and the C.V. for ratio m is higher than the C.V. of its constituent measurements (Tab. 3).

RATIO o

In *Helicotylenchus*, the dorsal esophageal gland opens into the lumen of the esophagus more posteriorly than is generally the case among the tylenchids. Golden (1956) used this characteristic to differentiate *Helicotylenchus* from *Rotylenchus* with dorsal gland opening (d.g.o.) closer to the stylet base. Perry (in Perry, Darling & Thorne, 1959) found this character not useful for generic differentiation but he proposed

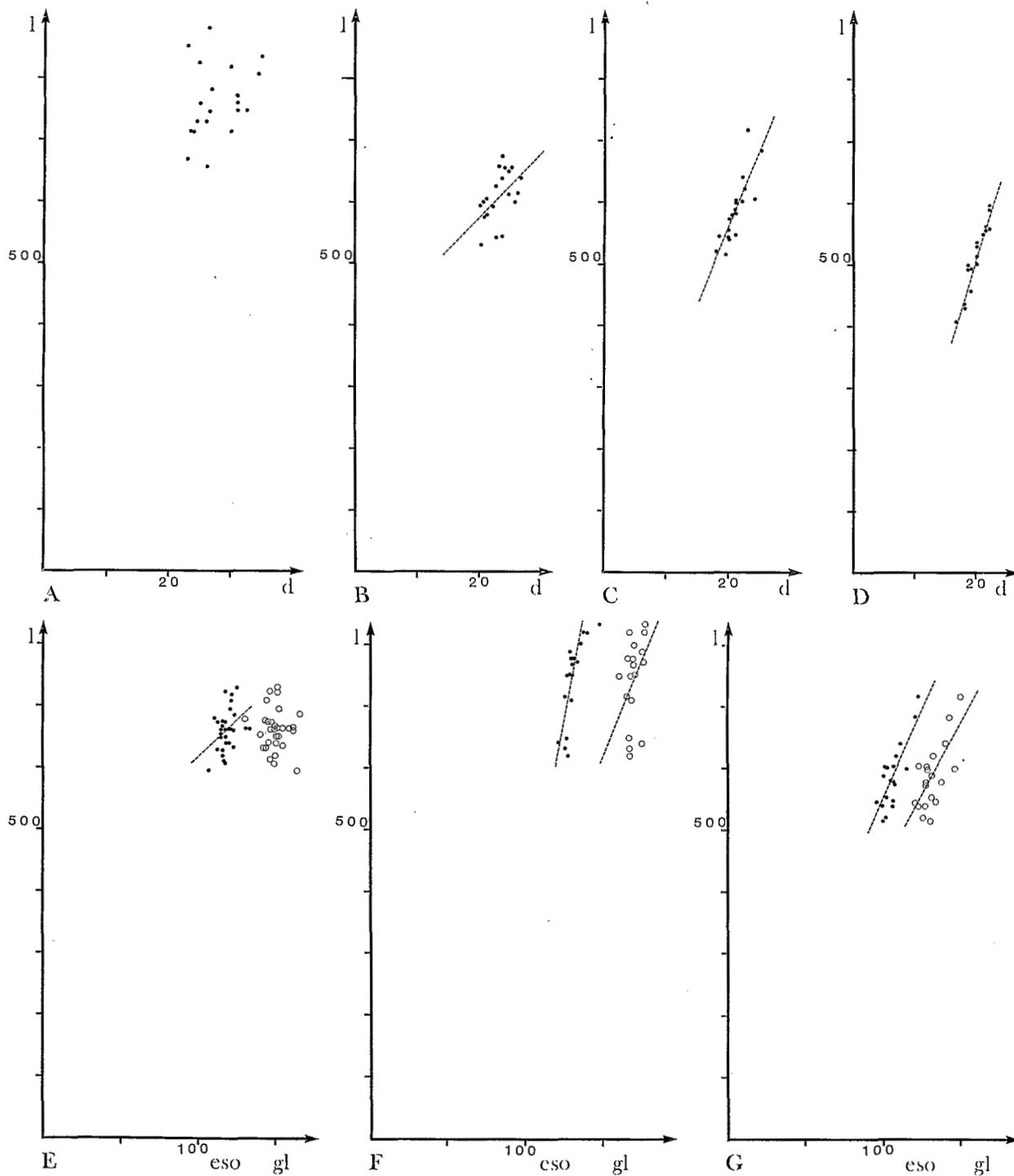


Fig. 1 : Representative points of ratios a, b, b' in some selected samples. A-D : ratio a ; E-G : ratios b (black dots) and b' (white dots). A = sample j ; B : sample d ; C : sample f ; D : sample i ; E : sample k ; F : sample h ; G : sample f — l : body length ; d : body diameter ; eso : distance head to esophago-intestinal junction ; gl : distance head to end of esophageal glands, Measurements in μm .

to use it to identify certain species within *Helicotylenchus*. Because "the terminology for this character is lengthy and awkward", he proposed the symbol 'o' for the ratio distance from stylet base to d.g.o./stylet length (%). The correlation for ratio o is generally far from significant (Tab. 2) and it does not reduce the variability (Tab. 3).

RATIO V

Ratio V—distance head—vulva/body length (%)—is a very good descriptive ratio. The correlation

between the constituent measurements is always very high (Tab. 2), and the C.V. of ratio V is always smaller than the C.V. of its constituents (Tab. 3). The regression lines always pass close to the origin (Tab. 4). Fig. 2 D-E shows that the representative points are all close to the regression lines, and are arranged in an almost straight line. Table 4 shows that, in spite of these near perfect conditions, the relation between the two measurements is not in the form $Y = AX$ but $Y = AX + B$. As a consequence the slope "A" is different from the ratio "V" (Tab. 4).

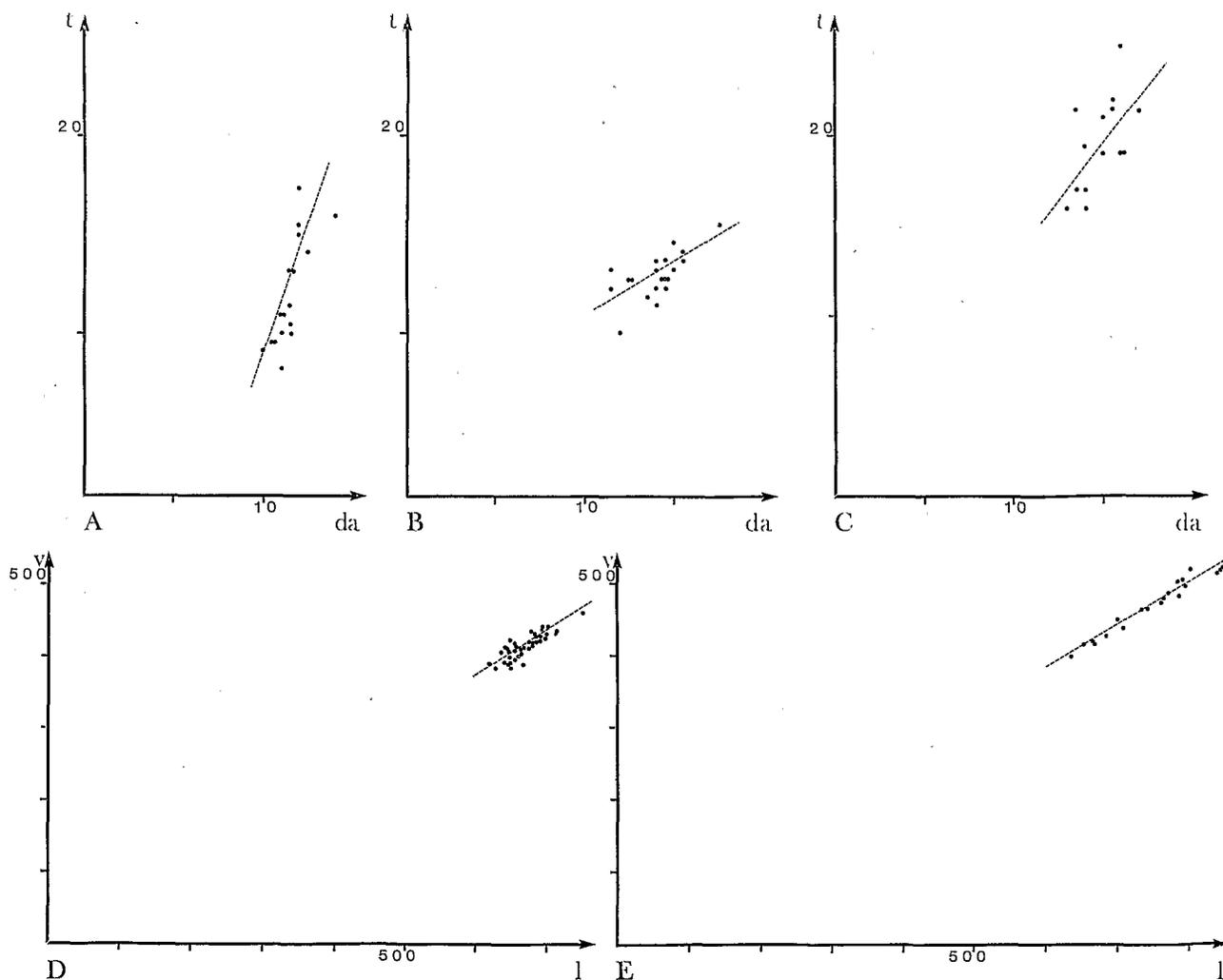


Fig. 2: Representative points of ratios c' , and V in some selected samples. A-C: ratio c' ; D-E: ratio V. A: sample i; B: sample g; C: sample m; D: sample a; E: sample e — t: tail length; da: tail diameter at anus level; v: distance head to vulva; l: body length. Measurements in μm .

Discussion

A ratio represents a relationship between the measurements of two biological characters. For the ratio to be biologically meaningful, the two characters must be related in some way. This relationship can be deduced from the nature of the characters, and must be verified by a study of the coefficient of correlation of the pair of characters.

Ratio a, for example, relates length and diameter of a nematode. It can be supposed that these measurements will vary together to preserve the characteristic shape of the species. This supposition is verified for *Helicotylenchus* when we found that the pair of measurements constituting ratio a are often significantly correlated. The pairs of characters for ratios c and c' are also significantly correlated in most samples, even if the levels of significance are generally lower than those for ratio a.

Ratio V evaluates the position of the vulva along the body. It has been shown that the number of epidermal cells in front and behind the vulva is genetically determined and constant in a given species. Because growth will affect equally all epidermal cells, the relative position of the vulva will remain constant (Geraert, 1979). This is verified in the present samples by the very high correlation always presented by the pairs of characters constituting ratio V.

Other ratios were proposed using unrelated characters. The pairs of measurements for ratios b and b' are weakly correlated in more than half the samples studied. As shown by some previous authors (Wu, 1960; Geraert, 1978, etc.) the length of the esophagus does not follow the elongation of the body in mature adults. Ratios b and b' have little value for taxonomic purposes because differentiation between species rely on comparisons between adult specimens. Ratios b and b' can be calculated out of respect for a century-old tradition, but the actual value of the length of esophagus and esophageal glands must be given.

There is no reason to suppose that stylet length and distance d.g.o./stylet vary together, and even when they are shown to do so in a particular sample, it would be difficult to find a biological reason for this peculiar behavior. Ratio o ties together the measurements of two structures not biologically related to each other. It was proposed only for the sake of more convenient writing. The coefficients of correlation for ratio o are generally far from significance. This ratio must not be used at all for descriptions and identifications of species. The value of the distance d.g.o./stylet must absolutely be given. The awkwardness of the terminology can be circumvented by the use of an abbreviated formula such as: "d.g.o. at $x\mu\text{m}$ from stylet".

The ratio of two measurements of an organ describes the relative proportions this organ, e.g., ratio a describes the general shape of the body, and ratio c' that of the tail. Giving ratios instead of measurements discards information about the actual size of organs. This loss of information may be acceptable for taxonomic descriptions when shape is significant and size is not. For example, the body length of *Ditylenchus myceliophagus* doubles under varying diet conditions (Fortuner, 1982). If, under similar conditions, the general shape of body and tail could be proved to remain constant, or nearly constant, ratios a and c' could be taxonomically significant. In the instance of *D. myceliophagus*, ratios were shown to vary under external factors (Cayrol & Legay, 1967). In *Helicotylenchus*, as in most plant-nematode genera, the variations of body size with the diet is kept within a smaller range (Fortuner & Quénéhervé, 1981). Ratios are still an easy way to describe body and organ proportions, but the actual measurements must be given.

Independently of its descriptive power, a ratio can be useful in reducing the variability of the measurements. Following Wu (1960) it has been assumed by many authors that the regression line between the pair of characters constituting a ratio must pass through the origin. However, this condition should not be taken as an absolute prerequisite for the use of a ratio. When the regression line does not pass through the origin (its equation is on the form $\bar{Y} = AX + B$), the ratio $K = \frac{\bar{Y}}{\bar{X}}$ is different from the slope A of the regression line. The ratio K is then a variable of its own, with its own mean value ($K \neq A$) and standard deviation, it is distinct from X and Y and it varies in the sample within certain limits. The ratio will probably not reduce the variability, but this should not bar us from using it if it describes some interesting morphological characteristics. Ratio a, for example, when compared to its constituent characters, reduces the variability in only half the samples studied. However, because of its good descriptive power, it can be used, provided that the value of the actual measurements is also given. Similarly, ratio c can be calculated but the tail length must also be given.

In the few cases when the regression line passes through the origin, its equation becomes of the form $Y = AX$ where A, the slope, is a constant. Here the mean value of the ratio K is equal to A. The cloud of points representing each pair of characters (X,Y) in the sample is seen from the origin along its smallest dimension. However, this is not enough to make the ratio K a constant. If the smallest dimension of the cloud of point is too large, the ratio will still be quite variable. In other words, even if the mean value K

of a ratio is equal to the constant value A, the ratio can still vary in the sample around its mean value K and it will not be itself a constant. In ratio c' for example, some of the regression lines are not far from the origin and even pass exactly through it as in sample m. However, the correlation of the pair of characters constituting ratio c' is never very high, and the points representing it never fit the regression line closely. In these conditions, it is not surprising that ratio c' never reduces the variability. It can be given for its good descriptive powers but its constituent characters must also be given in taxonomical descriptions. This may not be true for other genera. In *Xiphinema* for example, c' is a near-constant ratio (Southey, pers. comm.). Naturally, the best reduction in variability occurs when the two conditions—high correlation and line through the origin—are met, or nearly met. In ratio V, the correlation is very high and the points fit the regression line very closely. In addition, the regression lines are never very far from the origin. Ratio V is always very useful in reducing the intra-specific variability, and it is the only ratio that can be given instead of its constituent measurements. However, even for this very good ratio, there is a small variation within the sample. If the points perfectly fitted the regression line, and if the regression line exactly passed through the origin, the ratio V would become a constant, with the same value for all specimens in the sample. This never happens in nature.

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