

MORPHOMETRIC VARIABILITY IN *RADOPHOLUS SIMILIS*

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Abstract : Morphometric studies were carried out to determine differences, if any, among the 12 populations of *Radopholus similis* collected from different localities of South India. Most of the measurements and ratios recorded in these studies fall within the range of measurements of *R. similis* reported previously. Out of the 39 characters/ratios examined, stylet length (C.V. 3.91%) and ratio 'V' (C. V. 3.10%) were the most stable characters in *R. similis*. The populations of adult and gravid females of a coconut population (C₁₇H) from host root showed that most of the measurements were higher in gravid females, indicating the need for recording the measurements of gravid females separately in all morphological studies. D² analysis of 39 characters of males and females grouped the 10 populations into three clusters and 12 populations fell into 4 clusters with population cultured on host root alone forming a separate cluster. Significant correlation was found between the pairs of characters constituting the ratio 'c' and body length of females and males and ratio V of females. Body length (BL) has been found to be a good descriptive ratio in *R. similis* where the correlations was highly significant between the constituting characters.

Key words : *Radopholus similis*, morphometrics, variability

The burrowing nematode, *Radopholus similis* is the most important nematode problem on coconut, arecanut, banana and black pepper in south India. Though considerable amount of work has been done on various aspects of this nematode in relation to these crops, no detailed studies were made so far on the morphology of the Indian populations. Preliminary observations revealed that the gravid females in a population always looked much bigger compared to adult and developing females. The populations from host root also looked bigger compared to the population cultured axenically on carrot discs. Therefore, an attempt was made to gain information on the extent of morphometric variation within conspecific populations of *R. similis* from India.

MATERIALS AND METHODS

Populations of *Radopholus similis* isolated from soil and root samples of coconut, arecanut, banana and black pepper growing in different areas of south India were collected during October-November and multiplied on respective host plants for a few generations initially and later cultured axenically on carrot discs for three to four generations to remove host effect, if any. In order to study the host effect, one particular population (designated as C₁₇) was cultured on coconut. Population developed from a single female of C₁₇ was used to study the extent of morphometrical variation (designated as C₁₇ P). Comparative study of measurements of adult and gravid females of coconut population from host root designated as C₁₇ H) was also done.

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From each culture, adult males/females were hand picked into a drop of sterile water on a glass slide and heat killed. A minimum of 20 specimens were observed for all characters under 40 x and 100 x objectives.

The differences in measurements between the 10 populations were statistically analysed. Separate analysis of the 12 populations (including the host population, C₁₇H and pure population, C₁₇P) were also made. Comparison study was made between males and females of C₁₇ carrot culture, host culture and single female culture.

Differences between the measurements of C₁₇ adult females and gravid females from coconut root was tested using Students 't'.

In order to study the similarities/differences between the populations, the D² values were calculated using the method suggested by Rao (1952).

The coefficient of correlation was calculated between the measurements constituting the ratios a, b', c, c'v, and BL/EP (Body length/Excretory pore from anterior end) in every population. The coefficients of variation (%) of the constituting terms of the ratios and of the ratios themselves were calculated.

RESULTS AND DISCUSSION

All characters of females and males of 12 populations of *R. similis* showed significant differences between the population measurements of the length of body, stylet, tail, spicule and gubernaculum and ratios such as a, b', c, c', and V, but found to be within the range of values reported earlier

(Table 1 & 2). The body width of male and female, length of oesophageal glands and length of hyaline area of female tail were slightly different from the range published earlier. Taylor (1969) reported 27.1 (23-34) microns as the body width of developing female, 16.5 (16-17) microns as the body width of male 132.9(113-150) microns as the length of glands and 13(11-18) microns as the hyaline part of tail in developing females. In the present study, the average value of female body width was 21.65(18-28) microns, of male was 17.81(13.21) microns, the length of glands was 159 (126-186) microns and hyaline part of tail in female was 9.25(5-15) microns in carrot cultures. The value of ratios presented here comes within the value of ratios reported by Sher (1968). To study the effect of host on morphometrics, one population C₁₇ was cultured on host root (coconut) (C₁₇H). Specimens from host root (coconut tissue) recorded the highest measurements for certain characters of males and females. The body width of female 26.50 from (20-34) comes within the range published by Taylor (1969) and some of the above characters exceeded further. This could be due to the high level of nutrients available in the host tissue as suggested by other workers (Van Weerdt 1958; Goodey, 1952; Bird & Mai, 1965; Tarte & Mai, 1976 and Saha & Khan, 1988).

The morphometrics of coconut population (C₁₇) cultured on host root, carrot disc and population multiplied from a single female on carrot disc showed that the body characters, ratios and c.v. per cent were higher in host culture (C₁₇H) for most of the characters and less in single female progeny (C₁₇P). On the basis of c.v. values, the stylet length and value of the ratio 'V' were found to be most stable characters

TABLE 1 Analysis of measurements recorded for *R. similis* females (n = 20)

Table of means

Sl No.	Population-code	Body** length (μm)	Body** width (μm)	Tail** length (μm)	Head** to vulva (μm)	Vulva** to tail (μm)	Head** to oes. glands (μm)	Head to oes. jn. (μm)	Ant.** end. to exc. pore (μm)	Stylet** length (μm)
1	C ₁	643.55 (615-722)	23.33 (20-27)	70.16 (63-79)	365.58 (329-424)	247.71 (254-298)	15.41 (126-161)	86.90 (77-106)	92.38 (89-96)	17.49 (17-18)
2	C ₁₁	616.10 (566-722)	22.94 (20-28)	62.53 (52-70)	348.15 (305-419)	263.05 (233-303)	153.88 (140-170)	84.63 (72-112)	88.06 (79-104)	18.04 (17-19)
3	C ₁₇	646.05 (585-711)	21.93 (20-25)	67.68 (59-75)	372.39 (329-401)	274.82 (242-317)	166.40 (154-186)	84.35 (77-100)	92.03 (79-98)	17.46 (17-19)
4	A ₂₁	651.05 (599-722)	20.42 (20-23)	68.22 (63-82)	367.13 (298-431)	280.08 (231-301)	161.11 (126-182)	84.75 (62-110)	92.89 (82-105)	17.54 (17-19)
5	A ₂₆	665.55 (590-739)	22.34 (19-25)	70.90 (62-78)	378.93 (339-447)	286.63 (247-326)	164.47 (150-179)	87.59 (79-119)	92.07 (82-100)	17.35 (17-18)
6	A ₄₀	675.35 (666-720)	21.04 (19-28)	71.50 (62-82)	387.00 (357-405)	289.46 (268-324)	168.01 (148-182)	78.61 (70-89)	95.30 (86-103)	17.94 (16-19)
7	B ₁	640.55 (562-687)	20.34 (19-24)	69.26 (65-75)	364.29 (322-396)	276.43 (235-298)	153.51 (133-168)	81.32 (73-93)	90.19 (84-96)	17.68 (17-19)
8	B ₃₅	628.00 (564-711)	20.29 (19-22)	70.79 (65-79)	354.33 (301-401)	265.15 (226-298)	159.10 (137-170)	81.88 (75-86)	97.81 (84-105)	18.01 (17-19)
9	P ₉	619.90 (550-619)	21.45 (19-27)	64.52 (62-71)	355.32 (319-389)	265.67 (232-301)	150.86 (138-179)	81.88 (73-93)	90.02 (79-98)	17.59 (17-19)
10	P ₁₃	653.45 (590-730)	22.44 (20-23)	68.17 (60-75)	372.97 (287-403)	280.33 (263-301)	162.11 (152-177)	80.50 (65-93)	91.69 (82-103)	17.21 (17-19)
	SE/PLOT	35.20	2.23	4.67	23.93	16.94	10.00	8.73	4.96	0.67
	G. Mean	643.95	21.65	68.37	366.61	275.63	159.01	83.20	92.25	17.63
	C.V. (%)	5.47	10.28	6.82	6.53	6.15	6.29	10.50	5.37	3.79
	C.D.	21.82	1.38	2.89	14.83	10.50	6.20	4.41	3.07	0.41
11	C ₁₇ P	591.13 (552-694)	21.27 (20-25)	61.52 (54-70)	336.92 (256-405)	259.06 (221-331)	152.15 (133-170)	78.61 (70-89)	89.59 (82-98)	16.74 (16-18)
12	C ₁₇ H	714.24 (650-809)	26.50 (20-34)	74.02 (63-82)	401.44 (359-457)	312.86 (263-3500)	166.73 (144-198)	89.70 (77-117)	93.04 (84-100)	17.81 (16-19)
For 12 populations										
	SE/PLOT	38.21	2.45	4.93	27.26	27.54	10.58	9.06	5.12	17.69
	G. Mean	645.07	22.03	68.03	366.62	278.65	159.10	83.28	93.09	17.81
	C.V. %	5.92	11.14	7.22	7.44	9.88	6.65	10.88	5.56	3.91
	C.D.	23.68	1.52	3.06	16.90	17.07	6.56	5.62	3.17	0.43

C - Coconut, A - Arecanut, B - Banana, P - Black pepper C₁₇P - Single female culture, C₁₇H - Culture on host root

Table 1 (Contd.)

Population-code	Phasmid ^{**} to anus (µm)	Phasmid ^{**} to tail (µm)	Width ^{**} at anus (µm)	Length ^{**} of hyaline tail terminus (µm)	a ^{**}	b ^{**}	c	C.I. ^{**}	G ^{**}	G ²	V	BL/EP ^{**}
1 C ₆	18.29 (13-21)	53.31 (45-60)	16.24 (14-19)	9.15 (8-10)	27.77 (23-34)	4.24 (4-5)	9.13 (9-10)	4.31 (4-5)	24.15 (21-28)	21.59 (17-25)	56.72 (54-59)	6.92 (7-7)
2 C ₁₁	17.41 (12-20)	51.08 (45-57)	15.66 (13-19)	8.40 (5-11)	28.86 (21-32)	3.97 (4-4)	9.31 (9-12)	4.29 (4-5)	22.47 (20-25)	21.49 (20-23)	56.82 (55-58)	6.92 (6-7)
3 C ₁₇	17.19 (14-21)	50.80 (47-58)	15.93 (14-19)	8.91 (7-11)	29.64 (23-33)	3.87 (4-4)	9.54 (9-10)	4.21 (4-5)	25.36 (21-30)	22.96 (20-27)	57.74 (54-59)	7.01 (7-7)
4 A ₂₁	20.57 (17-22)	51.09 (45-61)	15.64 (12-19)	9.53 (8-13)	31.01 (27-34)	4.05 (4-5)	9.44 (9-10)	4.41 (4-6)	23.94 (19-32)	21.56 (18-27)	57.15 (52-63)	6.93 (6-93)
5 A ₂₆	17.88 (13-21)	51.78 (45-56)	15.30 (14-19)	8.10 (5-11)	30.10 (30-37)	4.01 (3-5)	9.39 (9-10)	4.68 (4-5)	23.45 (18-28)	21.49 (18-24)	57.31 (56-60)	7.22 (7-8)
6 A ₄₀	20.30 (14-28)	49.47 (40-68)	16.33 (13-19)	8.49 (6-12)	32.20 (27-35)	4.02 (4-5)	9.48 (9-10)	4.43 (4-5)	23.76 (20-31)	21.59 (19-27)	57.36 (52-63)	7.10 (7-8)
7 B ₁	17.67 (12-22)	51.80 (42-63)	15.29 (13-16)	9.71 (7-13)	31.60 (24-36)	4.17 (4-5)	9.21 (7-10)	4.59 (4-5)	21.30 (19-27)	20.54 (17-28)	56.67 (53-58)	7.14 (7-7)
8 B ₃₅	18.15 (15-22)	51.50 (42-58)	15.12 (14-18)	8.65 (5-13)	30.64 (28-34)	3.93 (3-4)	8.81 (8-10)	4.69 (4-5)	23.15 (18-26)	20.57 (19-23)	56.65 (49-59)	6.41 (6-7)
9 P ₉	15.71 (13-19)	49.29 (43-54)	15.44 (14-17)	10.24 (8-11)	29.14 (28-32)	4.13 (4-5)	9.61 (9-10)	4.24 (4-5)	23.00 (20-25)	20.84 (19-23)	57.35 (56-60)	6.83 (6-8)
10 P ₆₇	15.49 (11-20)	53.13 (49-57)	16.23 (15-17)	11.08 (5-15)	28.03 (25-34)	4.02 (4-4)	9.58 (10-10)	4.20 (4-5)	22.79 (20-28)	21.71 (20-23)	57.03 (50-59)	7.08 (6-8)
SE/PLOT	3.15	4.89	1.36	2.38	3.24	0.29	0.56	0.42	2.55	2.66	1.68	0.38
G. Mean	17.86	51.33	15.72	9.23	29.90	4.04	9.35	4.41	23.34	21.43	57.04	6.96
C.V (%)	17.62	9.53	8.68	25.79	10.84	7.09	5.96	9.51	10.93	10.52	2.94	5.48
C.D.	1.95	3.03	0.85	1.47	2.01	0.18	0.35	0.26	5.58	1.40	1.04	0.24
C ₁₇ P	14.10 (10-22)	49.46 (47-58)	15.39 (14-16)	7.69 (6-10)	27.95 (23-32)	3.89 (3-4)	9.42 (9-11)	4.00 (4-5)	24.87 (22-28)	22.14 (18-21)	56.99 (48-60)	6.57 (6-7)
C ₁₇ H	21.23 (11-28)	52.42 (41-61)	17.96 (16-20)	9.05 (7-13)	28.25 (21-36)	4.21 (3-4)	9.65 (9-11)	3.92 (4-5)	22.77 (17-29)	19.92 (19-26)	56.52 (55-58)	7.43 (7-8)
For 12 populations												
SE/PLOT	3.58	5.21	1.36	2.28	3.14	0.31	0.60	0.41	2.70	2.27	1.71	0.40
G. Mean	17.83	51.26	15.88	9.08	29.69	4.04	9.38	4.33	23.41	21.37	56.99	6.97
C.V (%)	20.08	10.16	8.57	25.06	10.56	7.59	6.35	9.58	11.55	10.64	3.01	5.70
C. D.	2.22	3.61	0.84	1.41	1.94	0.19	0.37	0.26	1.68	1.41		0.25

* Significant at P = 0.05 ** Significant at P = 0.01

TABLE 2 : Analysis of measurements recorded for *R. similis* - males ($n = 20$)

Sl. No.	Popula- tion code	Body* length (μm)	Body** width (μm)	Head** height (μm)	Head width (μm)	Stylet length (μm)	Tail** length (μm)	Ant.** end. to exc. pore (μm)	Width** at Cloaca (μm)	Spiculae** length (μm)	Guber- naculum length (μm)
1	C ₆	581.45 (501-636)	16.76 (15-21)	5.31 (5-6)	7.98 (7-8)	12.29 (10-13)	71.51 (62-79)	88.43 (86-93)	13.95 (13-14)	17.91 (17-19)	9.93 (9-11)
2	C ₁₁	592.79 (501-644)	18.28 (16-21)	5.51 (5-6)	8.13 (7-8)	12.43 (10-13)	68.98 (65-78)	95.72 (82-109)	14.17 (13-15)	17.90 (17-19)	9.86 (9-11)
3	C ₁₇	581.17 (531-638)	19.58 (17-21)	5.46 (5-6)	7.93 (7-8)	12.32 (10-14)	69.03 (63-79)	95.00 (89-108)	14.70 (14-16)	17.82 (18-19)	9.66 (9-10)
4	A ₂₁	576.91 (550-606)	18.07 (18-21)	5.50 (5-6)	8.21 (7-8)	12.64 (12-14)	69.55 (65-75)	86.37 (84-89)	13.45 (13-14)	18.47 (17-19)	10.14 (9-10)
5	A ₂₆	606.27 (573-641)	17.54 (16-19)	5.60 (5-6)	7.95 (7-8)	12.50 (11-14)	71.05 (65-79)	91.22 (82-98)	13.95 (13-15)	18.43 (18-20)	9.79 (9-10)
6	A ₄₀	592.61 (538-671)	18.49 (16-21)	5.35 (5-6)	7.93 (7-8)	12.84 (12-14)	72.55 (64-84)	86.94 (78-93)	13.69 (13-14)	18.91 (18-20)	9.76 (9-10)
7	B ₁	585.63 (548-629)	15.62 (15-17)	5.64 (5-6)	8.18 (7-8)	12.46 (12-14)	62.29 (66-78)	87.79 (74-91)	13.30 (12-14)	10.57 (18-20)	9.67 (9-10)
8	B ₃₅	583.84 (552-636)	16.79 (15-19)	5.04 (5-6)	7.55 (8-8)	12.64 (12-14)	70.13 (65-77)	92.70 (86-98)	14.00 (13-14)	18.19 (18-19)	9.42 (9-10)
9	P ₉	585.61 (550-622)	18.51 (15-21)	5.60 (5-6)	7.93 (8-8)	12.68 (12-14)	66.60 (73-70)	90.33 (86-100)	14.14 (13-15)	17.96 (17-19)	9.93 (9-10)
10	P ₆₇	607.58 (559-636)	18.47 (17-21)	5.22 (5-6)	8.07 (8-8)	12.44 (12-14)	71.04 (61-77)	89.56 (84-100)	14.46 (13-16)	17.82 (18-19)	9.68 (9-10)
	SE/PLOT	29.48	1.36	0.39	0.45	0.77	4.28	4.69	0.81	0.84	0.51
	G. Mean	589.87	17.81	5.42	7.99	12.52	69.97	90.41	13.98	19.20	9.79
	C.V.(%)	5.00	7.61	7.21	5.63	6.11	6.11	5.19	5.78	4.62	5.23
	C.D.	18.27	0.84	0.24	0.28	0.47	2.65	2.91	0.50	0.52	0.32
11.	C ₁₇ P	572.01 (522-613)	17.26 (17-19)	5.13 (5-6)	8.12 (7-8)	12.73 (12-14)	68.29 (58-72)	93.08 (84-100)	13.80 (13-14)	18.05 (18-19)	9.75 (9-10)
12.	C ₁₇ H	672.55 (606-734)	20.85 (19-24)	5.23 (5-6)	7.93 (8-8)	12.41 (11-14)	81.94 (65-94)	98.01 (93-105)	14.84 (14-16)	18.29 (18-19)	9.75 (9-10)
	For 12 populations										
	SE/PLOT	30.87	1.36	0.40	0.45	0.75	5.12	4.63	0.78	0.80	0.51
	G. Mean	594.86	18.00	5.39	7.99	12.53	70.83	91.26	14.03	18.19	9.78
	C.V.(%)	5.19	7.57	7.50	5.65	6.00	7.23	5.08	5.58	4.38	5.18
	C.D.	19.13	0.84	0.25	0.28	-	3.17	2.87	0.49	0.49	0.31

C - Coconut, A - Arecanut, B - Banana, P - Black Pepper

C₁₇P - Single female culture, C₁₇H - Culture on host root

Figures in parentheses denote the range of values

Table 2 (Contd.)

Sl. No.	Population code	Bursa** length (µm)	Testis** length (µm)	Phasmid* to tail (µm)	Phasmid** to cloaca (µm)	Hyaline* area (µm)	a**	c**	T**	BL/EP	
1	C ₆	60.73 (44-73)	193.55 (164-218)	55.19 (43-63)	17.44 (15-23)	6.35 (5-9)	34.86 (26-42)	8.07 (8-9)	5.23 (4-6)	33.28 (32-35)	6.64 (6-7)
2	C ₁₁	68.34 (47-88)	199.34 (153-247)	51.87 (47-63)	18.71 (14-24)	5.95 (5-9)	32.54 (27-40)	8.55 (8-9)	4.87 (4-6)	33.57 (26-42)	6.19 (6-7)
3	C ₁₇	54.20 (47-65)	192.49 (144-252)	48.80 (42-55)	20.61 (15-26)	6.63 (5-9)	29.71 (26-33)	8.46 (8-10)	4.65 (4-5)	33.10 (25-42)	6.12 (6-7)
4	A ₂₁	60.65 (51-75)	227.70 (189-257)	50.35 (46-59)	21.83 (18-24)	6.53 (6-8)	32.09 (29-38)	8.30 (8-9)	5.24 (5-6)	39.07 (33-45)	6.71 (6-7)
5	A ₂₆	60.53 (51-75)	182.82 (140-218)	52.14 (49-56)	20.48 (18-28)	6.67 (5-9)	34.33 (29-39)	8.55 (8-9)	5.27 (5-6)	30.20 (24-36)	6.65 (6-7)
6	A ₄₀	61.49 (47-75)	188.14 (163-233)	53.05 (41-70)	22.25 (15-25)	7.13 (7-12)	32.76 (29-38)	7.93 (7-9)	5.39 (5-6)	32.46 (29-37)	6.82 (6-8)
7	B ₁	48.90 (47-56)	175.63 (154-195)	53.57 (43-65)	17.41 (14-25)	7.10 (5-9)	37.55 (33-40)	8.45 (8-9)	5.27 (5-6)	29.97 (27-31)	6.67 (6-7)
8	B ₃₅	53.25 (47-59)	178.15 (154-223)	53.45 (49-60)	17.01 (14-22)	5.87 (4-9)	34.97 (31-37)	8.33 (8-9)	5.01 (5-5)	30.74 (25-38)	6.31 (6-6)
9	P ₉	55.00 (42-75)	211.35 (142-234)	52.75 (45-61)	18.33 (14-22)	6.15 (4-8)	31.41 (31-41)	8.84 (8-9)	4.64 (4-5)	36.36 (31-38)	6.46 (6-8)
10	P ₆₇	60.20 (47-75)	199.20 (154-236)	53.69 (49-59)	17.59 (14-25)	5.83 (4-8)	33.00 (29-35)	8.38 (8-10)	5.03 (5-5)	32.68 (24-38)	6.80 (6-7)
	SE/PLOT	7.72	23.80	4.93	3.03	1.50	2.75	0.51	0.39	3.71	0.37
	G. Mean	58.33	194.84	52.48	19.17	6.42	33.32	8.39	5.06	33.14	6.54
	C.V. (%)	13.23	12.22	9.39	15.83	23.36	8.26	6.10	7.67	11.18	5.59
	C.D.	4.78	14.75	3.05	1.88	0.93	1.71	0.32	0.24	2.30	0.23
11	C ₁₇ P	50.99 (42-63)	177.60 (156-222)	48.74 (42-55)	19.27 (16-22)	5.05 (3-9)	33.17 (28-36)	8.44 (8-10)	4.99 (5-6)	31.14 (24-42)	6.10 (5-6)
12	C ₁₇ H	55.52 (42-68)	203.95 (146-287)	61.16 (54-68)	20.95 (18-25)	5.69 (5-8)	32.63 (31-37)	8.18 (8-9)	5.48 (5-6)	30.30 (22-37)	6.85 (6-7)
For 12 populations											
	SE/PLOT	7.83	25.00	4.97	2.93	1.50	3.30	0.55	0.50	3.92	3.92
	G. Mean	57.48	194.16	52.89	19.32	6.25	33.10	8.37	5.07	32.74	32.74
	C.V. (%)	13.63	12.95	9.40	15.15	24.04	9.96	6.60	9.92	11.98	11.98
	C.D.	4.86	15.58	3.08	1.81	0.93	2.04	0.34	0.31	2.43	2.43

* Significant at P = 0.05

** Significant at P = 0.01

(c.v. = 3.91% & 3.01%). Similar observations were reported in *Trichodorus christiei* (Bird & Mai, 1967) and *Pratylenchus zeae* (Saha & Khan, 1988). The above findings are in agreement with Roman & Hirschmann (1969). Characters like length of body, tail, stylet, spicule, gubernaculum, width of body, head height, head width, width at cloaca, anterior end to excretory pore opening, phasmid from tail terminus and ratios a, c, c', BL/EP (Body length/Excretory pore) of males and length of body, tail, head to vulva, vulva to tail, head to posterior end of oesophageal glands, body width at anus, anterior end to excretory pore and ratios b, c, c', BL/EP of females were also fairly stable exhibiting c.v. between four to ten percent. The bursa length, testis length, phasmid from cloaca and ratio T of males and body width, head to oesophago-intestinal junction, position of phasmid and ratios a, G¹, G², of females were relatively more variable with their c.v. greater than 10 to 20 per cent. The c. v. per cent of length of hyaline area and position of phasmid in male and female were more than 20 per cent. Variations of about 10 per cent from the average was common for most dimensions. This is in conformity with the findings of Taylor (1969), who reported about 15 per cent variation.

Out of the 28 *R. similis* populations collected and examined no specific and significant morphological variation could be detected.

The comparison study of adult and gravid female of coconut population (C₁₇H) from host root indicated that higher values were recorded for some of the measurements in gravid females (Table 3). This is in agreement with the observations of Taylor (1969), who reported females with eggs in one or both of the uteri average a little

longer and wider than developing females. The present study clearly brought out the need for recording measurements of gravid females separately in studies on *R. similis* and such approach was not made mostly in previous studies. For example, Ganguly & Khan (1986) reported that the population from Tamil Nadu exhibited maximum diversion from the remaining populations by having its extremely long body, differently shaped male lip region, pronounced vulval lips and other morphometric features. But, such type of differences were not seen in the present study with the axenic culture of Coimbatore population (B₃₅). However, the authors did not mention whether they measured gravid females and adult females separately or together. Because in the present study an average of 76 microns increase in body length of gravid females over adult females was noticed.

Tables 4a and 4b provide the inter and intra cluster D² values for 12 and 10 populations. The following observations are stressed on:

Cluster IV formed by population C₁₇H, remained aloof from all the other clusters. This is the only population extracted from host root (4a). The D² values from the other clusters were in the range 37.91 to 42.11. This was mainly because of the large values recorded for this population for body length, width, stylet length, tail length, length of testises, body width at cloaca, phasmid from tail end, anterior end to excretory pore and ratios of c' and BL/EP (all for male characters) and body length, body width, stylet length, head to vulva, head to oesophago-intestinal junction, head to posterior end of oesophageal glands, phasmid from tail and anus, body width at anus, vulva to tail and ratios of BL/EP, b' and c' (all relating females).

It is interesting to note that all populations relating to arecanut (A_{21} , A_{40} and A_{26}) remained away from the rest and formed cluster I. Both populations from banana namely population B_1 and B_{35} remained together, but population C_6 and P_{67} also joined with them to form a single cluster (cluster II).

Similarly population P_9 moved along with the population from coconut namely C_{11} , C_{17} and $C_{17}P$ to form cluster III. The five populations relating to coconut fell into three clusters. C_6 went along with the population relating to banana (B_1 and B_{35}) and pepper (P_{67}). $C_{17}H$ remained separate to form (cluster IV). The two populations coming from pepper namely P_{67} and P_9 fell into two clusters. This was because of the significant differences between them in body length, tail length, bursa length, head height, ratios of a , c' , T (all relating to males). There were significant differences among the female characters also between these two populations for body length, head to vulva, head to oesophageal glands and phasmid from tail. Host specificity of populations coming under each cluster, is found to be different reported in a separate publication. (Koshy & Jasy, 1991)

In the cluster analysis discussed above, all the 12 populations were considered together, among them $C_{17}P$ was coconut population cultured axenically on carrot disc from a single female and $C_{17}H$ was coconut population from host root. So the clustering pattern was re-examined with 10 populations, after excluding these two populations. Thus, 3 clusters were formed with same clustering patterns as before (Table 4b).

Coefficient of correlation of the pair of characters (Table 5 a & b) and coefficient of variation of ratio are given in Tables 5 - 6. Ratios a , b' , c' , were not significantly

correlated between the pairs of characters in most of the populations of males and females. This indicates that in *R. similis* body width and the length of oesophageal glands do not follow the elongation of the body. Tail length and body width at anus are not dependent on each other which is in agreement with the observations of Fortuner (1984) who reported ratio c is often valid in the case of *Helicotylenchus* spp. Similarly body length and position of excretory pore from anterior end also depend on each other. In most of the populations it is a valid ratio.

In the present study the value of the ratio V is valid and useful and very high correlation was seen between the pairs of characters which confirms the results of Wu (1960), Fortuner (1984), Ray et al. (1985); Khan & Singh, (1989) and Saha & Khan (1988).

Besides stylet length and vulva percentage, number of annules in head, width of annule and lateral lines of males and females, width of spicule and bursa of males, stylet knob height and width, distance of spear base to dorsal oesophageal gland opening, metacarpus length and width and metacarpus valve length and width of females were constant for these populations. According to Taylor (1969) the length of stylets, spicules and gubernacula were remarkably constant. However, there was a narrow range of variation observed for these characters in the present study.

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TABLE 3. Comparison between the measurements of C_{17} adult females and gravid females from coconut root (n=20)

Character	C_{17} adult Female	C_{17} gravid Female	T value
Body length	714.22 (636-762)	790.64 (678-825)	4.83**
Body width	26.50 (21-35)	34.47 (25-50)	4.43**
Tail length	74.02 (63-82)	80.19 (73-84)	3.42**
Head to post. end of oes. glands	166.73 (144-177)	173.24 (161-200)	1.47
Anterior end to excretory pore	93.04 (84-100)	97.31 (91-107)	2.21*
Stylet length	17.81 (17-19)	18.17 (17-19)	0.61
Head to vulva	401.44 (359-461)	421.85 (361-478)	1.93
Vulva to tail terminus	312.86 (263-350)	320.93 (290-362)	1.06
Body width at anus	17.96 (16-23)	21.99 (16-28)	4.26**
Length of hyaline tail terminus	9.56 (7-13)	9.33 (8-12)	0.63
a	28.25 (21-36)	22.20 (19-28)	4.17**
b'	4.21 (3-4)	4.31 (3-4)	0.96
c	9.65 (9-11)	9.44 (9-11)	0.96
c'	3.92 (4-5)	3.72 (3-5)	1.17
V	56.52 (55-58)	56.60 (56-57)	0.13
<u>BL</u>	7.48	7.69	1.35
<u>EP</u>	(6-8)	(7-8)	

TABLE 4 a. Composition of clusters and intra and inter cluster D^2 values for *R. similis* 12 populations

	Cluster	I	II	III	IV
I	(A ₂₁ , A ₄₀ , A ₂₆)	14.34	18.67	21.72	37.91
II	(C ₆ , B ₁ , B ₃₅ , P ₆₇)		15.20	20.40	38.22
III	(C ₁₁ , C ₁₇ , P ₉ , C ₁₇ P)			16.89	42.11
IV	(C ₁₇ H)				

TABLE 4 b. Composition of clusters and intra and inter cluster D^2 values for *R. similis* 10 populations

	Cluster	I	II	III
I	(C ₆ , B ₁ , B ₃₅ , P ₆₇)	14.74	23.55	23.58
II	(C ₁₁ , C ₁₇ , P ₉)		17.71	23.64
III	(A ₂₁ , A ₄₀ , A ₂₆)			20.61

Figures in parentheses denote the population constituting each cluster.