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Rothamsted Experimental Station Report for 1968 - Part 2



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8. Nematode Population Studies on Broadbalk

D. C. M. Corbett, R. D. Winslow and R. M. Webb

D. C. M. Corbett, R. D. Winslow and R. M. Webb (1969) 8. *Nematode Population Studies on Broadbalk* ; Rothamsted Experimental Station Report For 1968 - Part 2, pp 157 - 174 - **DOI:** <https://doi.org/10.23637/ERADOC-1-2>

8. NEMATODE POPULATION STUDIES ON BROADBALK

D. C. M. CORBETT, R. D. WINSLOW* & R. M. WEBB

The nematodes in Broadbalk soil have been studied sporadically and for short periods only; the cereal cyst-nematode, *Heterodera avenae* Woll. briefly during 1954 and 1955 and again recently, and the migratory nematodes first in 1960 and 1961 and again since 1966 with Yuen (1966) studying those in section IA during work on nematodes in the Wilderness.

Cereal cyst-nematode

In June 1954 Hesling sampled the fallow strip (section IV) (*Rothamsted Report for 1954*, p. 97), by taking a trowelful of soil every twelve paces up the midline of each plot. From the bulk sample obtained for each plot, he took two 200 g sub-samples and extracted the nematodes from each separately (Table 8·1A): later that year he sampled the whole field (Table 8·1B)

TABLE 8·1
Cereal cyst-nematode surveys—cysts/100 g. soil

Plot No.	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	3	2B	2A
<i>A. June 1954</i>																			
Sub-sample (a)	—	0	0	0	0	0	0	0	1·0	1·5	3·5	0	0	0	0	0	0	10·5	16·5
(b)	—	0	0	0	0	0	0	0	0·5	4·5	0	0	0	0	0	0	0	9·0	14·5
<i>B. Oct.–Nov. 1954</i>																			
1954 Crop year																			
Section																			
I 3rd	0	0	0	0	0	1	2	0	0	5	1	0	0	1	0	0	0	14	16
II 2nd	0	0	0	0	0	2	1	3	4	5	1	12	11	0	1	0	12	11	
III 4th	—	0	0	0	0	1	10	0	8	10	12	1	23	17	0	0	1	6	1
IV Fallow	—	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	0	6	8
V 1st	—	1	0	0	1	0	0	1	0	0	0	1	0	1	0	0	0	2	3
<i>C. April 1968</i> Empty cysts—95%, Partly full cysts—2%, Full cysts—3%																			
1967 Crop year																			
Section																			
IA Continuous	—	—	—	—	—	—	—	—	0·8	1·0	0·8	0·1	1·5	1·5	—	—	—	—	—
IB 1st	—	—	—	—	—	—	—	—	2·5	2·3	5·5	0·3	1·3	2·9	—	—	—	—	—
II Fallow	—	—	—	—	—	—	—	—	1·3	1·8	2·7	3·2	2·6	0·2	—	—	—	—	—
III 2nd	—	—	—	—	—	—	—	—	4·2	1·0	1·2	1·8	7·3	6·5	—	—	—	—	—
IV 3rd	—	—	—	—	—	—	—	—	0·8	0·3	1·5	1·1	4·0	0·9	—	—	—	—	—
VA 4th	—	—	—	—	—	—	—	—	0·0	1·5	0·3	1·0	1·0	0·0	—	—	—	—	—

(*Rothamsted Report for 1955*, p. 111). The cereal cyst-nematode was present in much of the field with some local concentrations in the middle (sections II and III, plots 7 to 14). The discontinuities in the distribution made it impossible to associate numbers of the nematode with any treatment, but it occurred in the FYM plots of all sections. The populations estimated were thought unlikely to affect yields, especially as most cysts were empty.

Williams in 1968 (*Rothamsted Report for 1968*) examined the areas

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where Hesling's survey had shown the nematode to be most concentrated by taking 20 cores with a 1-in. diameter auger at random from plots 7 to 12 in sections IA, IB, II, III, IV and VA. Within the limits of experimental error, his results (Table 8.1C) showed that cysts were slightly fewer than in 1955, but there had been some spread up and down the field. He found few cysts, 95% of which were empty, and thought yields were unaffected.

Migratory nematodes

Three species of the root-lesion nematode are present in large numbers: *Pratylenchus thornei* Sher & Allen, *P. minyus* Sher & Allen and *P. sp.*, which seems not to have been described previously. The relative numbers of each species vary widely, but *P. thornei* usually outnumbers *P. minyus* which is more abundant than *P. sp.* The proportion of *P. thornei* increases with depth, from 2.8 times as numerous as *P. minyus* at 0–5 in. to 4.9 times as numerous at 20–25 in. Differences in the proportions of the nematodes between sections was also noted; *P. thornei* was 9.1, 2.0 and 5.4 times as numerous as *P. minyus* in sections IA, II and III respectively. *Paratylenchus microdorus* Andrassy is also plentiful but rarely outnumbers *Pratylenchus*. Three species of *Tylenchorhynchus* occur: *T. icarus* Wallace & Greet, *T. macrurus* (Goodey, 1932) and *T. brevidens* Allen; also *Helicotylenchus digonicus* Perry and *H. vulgaris* Yuen. *Pratylenchoides crenicauda* Winslow occurs sporadically over the field in small numbers, as also does *Trophurus imperialis* Loof. In addition to these, there are numerous other stylet bearing nematodes including *Boleodorus thylactus* Thorne and species of *Tylenchus* Bastian, *Ditylenchus* Filipjev, *Aphelenchus* Bastian, and *Aphelenchoides* Fischer.

Plot populations. The first survey of migratory nematodes was in 1960. Plots 2B, 3, 5, 7, 10, 11 and 13 in section IB (fourth-year wheat) were sampled in February, May, August and November. Soil samples were taken from top and bottom of each plot, thoroughly mixed and 12.5 ml from each extracted through 'Scottie' brand tissue on small sieves in water. The results in Table 8.2 and all subsequent tables show nematode numbers in different genera and groups of genera, transformed to $\log(x + 1)$, except for *Pratylenchus* in roots, given as $\log(x + 0.1)$. 'Others' consist mainly of particle feeders in the Rhabditidae and Plectidae, with some predaceous Mononchidae. Dorylaimidae are excluded because numbers fluctuated widely from sample to sample. The standard error in Table 8.2 was derived from the interaction of plots with duplicate samples.

Numbers of different genera fluctuated during the year in all plots, from many in February followed first by a decline to few in May, then usually increasing to high numbers again in August and then reaching a peak in November. The Aphelenchs were an exception with most present in February and fewest in August. In August *Pratylenchus* were fewest and in November *Pratylenchus*, *Paratylenchus*, *Tylenchorhynchus* and *Helicotylenchus* were fewest in plot 3. Numbers of other parasitic genera did not differ significantly between plots at any other sampling date, but grouped as Total Parasites plot 3 had fewest in both

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TABLE 8.2
Log numbers of nematodes/litre soil. Section IB, 1960

Month	Plots							S.E.
	2B	3	5	7	10	11	13	
<i>Pratylenchus</i>								
Feb.	3.89	3.58	3.69	3.49	3.53	3.53	3.57	0.101
May	2.44	2.30	2.44	2.41	2.68	2.60	2.21	0.206
Aug.	3.55	3.37	3.53	3.56	3.59	3.69	3.91	0.067
Nov.	3.96	3.28	3.88	3.83	3.93	4.13	4.02	0.212
<i>Paratylenchus</i>								
Feb.	3.34	2.94	3.25	3.18	3.10	3.05	3.16	0.131
May	3.01	3.08	2.75	2.86	2.88	2.86	2.78	0.070
Aug.	3.80	3.73	3.83	3.81	3.77	3.87	3.94	0.080
Nov.	3.42	2.97	3.48	3.52	3.65	3.80	4.01	0.181
<i>Tylenchorhynchus</i>								
Feb.	2.93	2.55	2.83	3.35	3.03	2.75	3.04	0.147
May	1.10	2.29	1.30	2.21	1.25	2.15	1.10	0.986
Aug.	2.86	2.73	2.75	3.07	3.07	2.68	2.68	0.149
Nov.	2.70	2.38	3.26	3.42	3.36	3.05	2.79	0.260
<i>Helicotylenchus</i>								
Feb.	3.19	2.89	3.51	3.33	3.05	2.95	2.82	0.159
May	1.19	2.21	2.21	2.06	2.30	1.25	0.95	0.818
Aug.	2.51	2.66	3.19	3.43	3.24	2.94	3.20	0.059
Nov.	3.00	2.88	3.80	3.72	3.58	3.39	3.46	0.135
<i>Tylenchus/Ditylenchus</i>								
Feb.	3.97	3.71	3.76	3.66	3.86	3.75	3.76	0.077
May	2.81	3.01	2.86	2.78	2.92	2.36	2.92	0.238
Aug.	3.54	3.68	3.63	3.80	3.69	3.26	3.56	0.070
Nov.	3.81	3.42	3.82	3.74	3.99	3.52	3.72	0.060
<i>Aphelenchus</i>								
Feb.	2.96	3.22	3.08	3.26	3.59	3.49	3.28	0.160
May	2.63	3.03	2.75	2.83	3.20	2.76	2.85	0.262
Aug.	2.62	3.08	3.13	3.36	3.15	3.10	3.32	0.100
Nov.	2.81	3.20	3.11	3.17	3.39	3.18	3.24	0.154
<i>Others</i>								
Feb.	4.15	4.21	4.04	4.12	4.20	4.04	4.19	0.128
May	3.72	3.71	3.58	3.46	3.45	3.48	3.46	0.123
Aug.	4.14	4.19	3.98	4.08	3.98	3.97	4.04	0.059
Nov.	4.11	4.20	4.62	4.12	4.06	4.19	4.20	0.086
<i>Total parasites</i>								
Feb.	4.11	3.80	4.03	3.98	3.85	3.82	3.85	0.077
May	3.16	3.28	3.07	3.12	3.23	3.16	2.95	0.102
Aug.	4.04	3.94	4.10	4.15	4.11	4.14	4.28	0.058
Nov.	4.13	3.60	4.28	4.26	4.29	4.37	4.39	0.181
<i>Other Tylenchus incl. Aphelenchus</i>								
Feb.	4.01	3.84	3.84	3.81	4.05	3.94	3.88	0.088
May	3.03	3.33	3.17	3.12	3.39	2.90	3.26	0.184
Aug.	3.59	3.78	3.76	3.94	3.81	3.49	3.76	0.061
Nov.	3.85	3.63	3.90	3.86	4.09	3.70	3.85	0.067
<i>All nematodes</i>								
Feb.	4.57	4.50	4.47	4.48	4.55	4.44	4.51	0.089
May	3.90	3.97	3.81	3.75	3.85	3.75	3.76	0.106
Aug.	4.46	4.48	4.45	4.56	4.46	4.43	4.56	0.041
Nov.	4.54	4.43	4.85	4.60	4.65	4.66	4.69	0.061

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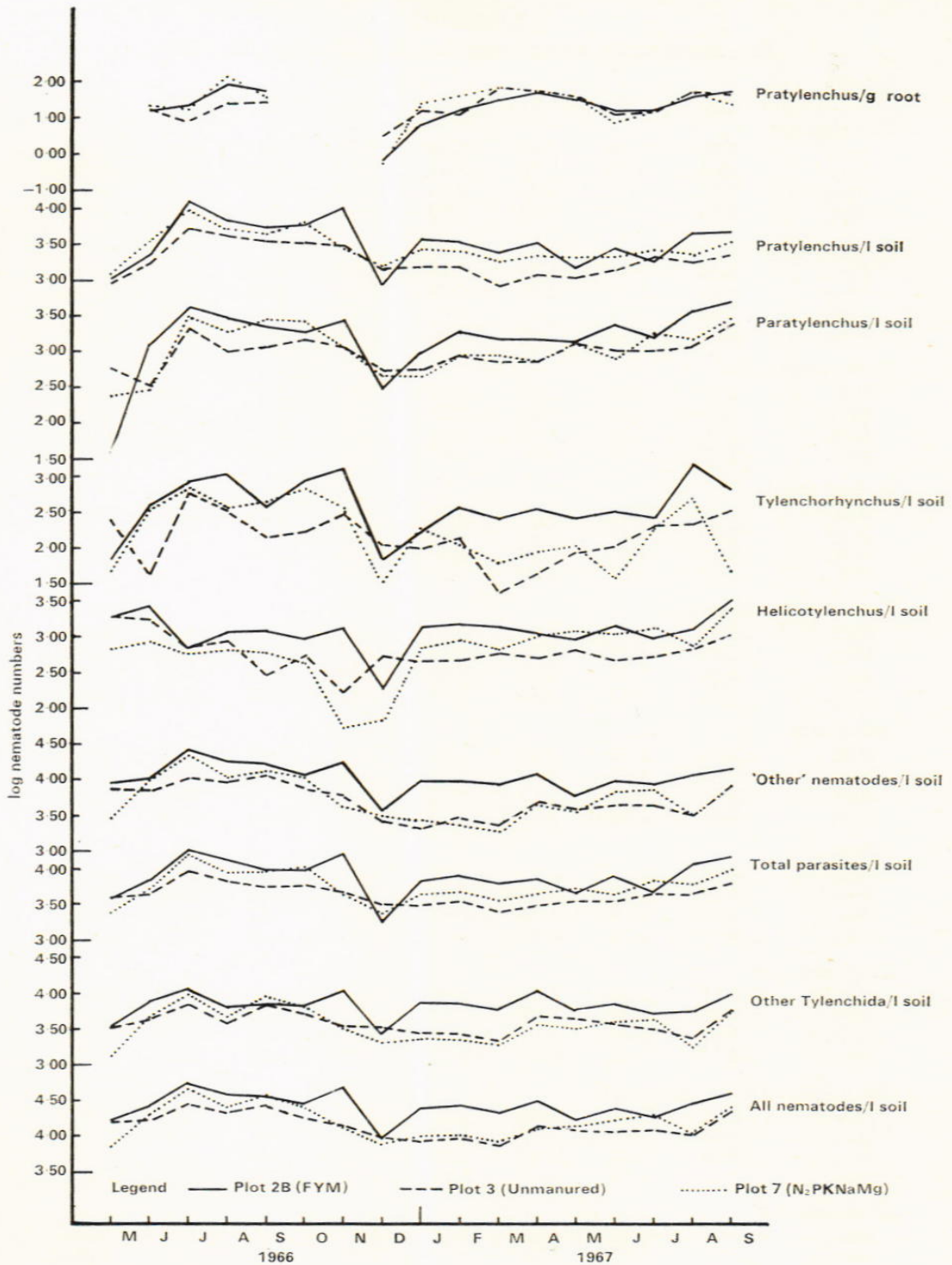


FIG. 8.1. Nematode population changes in the plots sampled, 1966-67.

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August and November. *Tylenchus/Ditylenchus* group were most numerous in plot 2B in February, in plot 7 in August and in plot 10 in November. Plot 11 had fewest in May and August, and plot 3 in November; plot 11 had slightly more than plot 3, but both had significantly fewer than any other plots. Aphelench numbers fluctuated less than other nematodes, and differed also in being most numerous in February, with some plots

TABLE 8-3
Log numbers of nematodes/litre soil, 1961

Month	Sections					Plots				
	IA	IB	II	III	S.E.	2B	3	7	10	S.E.
<i>Pratylenchus</i>										
Feb.	3.22	3.38	3.51	2.93	0.162	3.40	3.09	3.25	3.30	0.162
May	3.10	3.48	3.04	2.05	0.313	2.26	3.10	3.19	3.11	0.313
<i>Paratylenchus</i>										
Feb.	3.20	3.12	3.53	2.58	0.189	3.13	2.85	3.41	3.04	0.189
May	3.18	3.34	3.28	2.65	0.076	3.02	3.14	3.29	3.00	0.076
<i>Tylenchorhynchus</i>										
Feb.	2.04	2.72	1.77	2.20	0.429	1.70	1.64	2.50	2.89	0.429
May	2.67	2.78	1.68	1.58	0.445	1.99	2.25	2.52	1.95	0.445
<i>Helicotylenchus</i>										
Feb.	2.93	3.13	2.70	2.52	0.142	2.65	2.75	2.84	3.05	0.142
May	2.56	3.29	2.22	1.51	0.291	2.23	2.51	2.06	2.78	0.291
<i>Tylenchus/Ditylenchus</i>										
Feb.	3.37	3.48	3.43	3.12	0.168	3.35	3.30	3.22	3.52	0.168
May	3.22	3.66	3.30	3.06	0.061	3.17	3.48	3.33	3.26	0.061
<i>Aphelenchs</i>										
Feb.	2.88	3.17	3.01	1.99	0.334	2.21	2.90	2.83	3.10	0.334
May	2.71	2.84	2.80	1.34	0.358	1.97	2.90	1.97	2.86	0.358
<i>Others</i>										
Feb.	4.23	4.10	4.14	3.79	0.074	4.19	4.10	4.01	3.96	0.074
May	3.71	3.92	3.83	3.66	0.074	3.91	3.83	3.77	3.60	0.074
<i>Total parasites</i>										
Feb.	3.69	3.77	3.89	3.33	0.153	3.73	3.44	3.78	3.72	0.153
May	3.58	3.92	3.53	2.99	0.067	3.29	3.55	3.65	3.53	0.067
<i>Other Tylenchs, incl. Aphelenchs</i>										
Feb.	3.50	3.66	3.60	3.25	0.127	3.46	3.46	3.41	3.68	0.127
May	3.36	3.72	3.43	3.14	0.059	3.24	3.59	3.40	3.42	0.059
<i>All nematodes</i>										
Feb.	4.44	4.39	4.43	4.04	0.077	4.38	4.32	4.29	4.30	0.077
May	4.08	4.37	4.13	3.86	0.049	4.09	4.17	4.13	4.04	0.049

showing a slight increase in August but others a decline with populations only increasing again by November. Plot 2B consistently had fewest and plot 10 most on three out of the four sampling dates. Numbers of 'Other' nematodes did not fluctuate much, and in February and May populations in different plots did not differ significantly from one another. In August plots 2B and 3 had more than plots 5, 10 and 11, which had fewest. In November plot 5 had most and plot 10 fewest.

In 1966 and 1967 only three plots were sampled: 2B, 3 and 7 (Tables 8.4,

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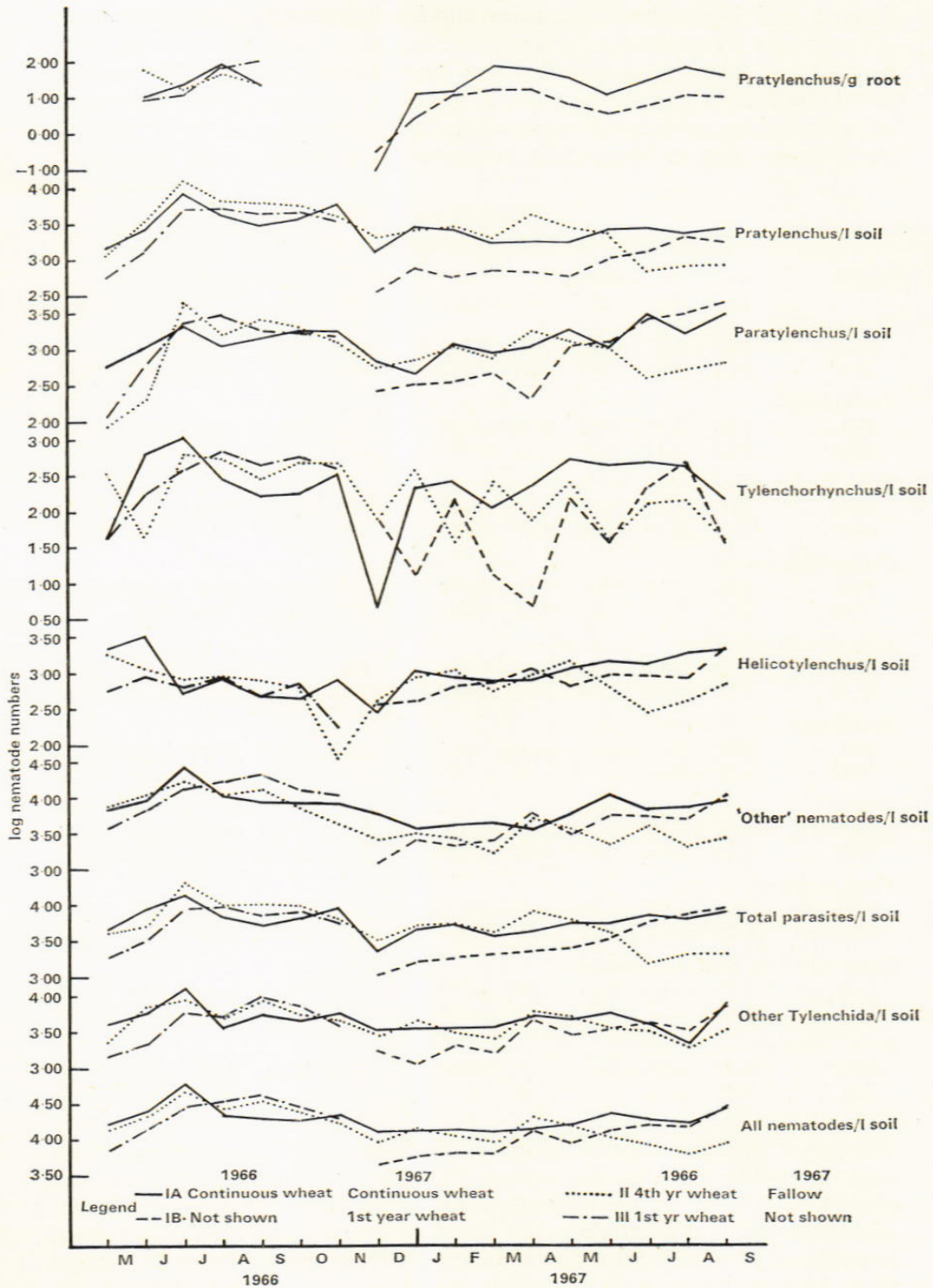


FIG. 8-2. Nematode population changes on part of the fallow cycle, 1966-67.

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8.5, 8.6 and 8.7; Fig. 8.1). A feature of these samples is the large decrease in numbers of all genera of nematodes in plot 2B in December 1966. The reason for this is unknown.

In 1966 *Pratylenchus* were fewer in the roots of plants grown in plot 3 (unmanured) than in 2B (FYM) or 7 (N₂PKNaMg) (Fig. 8.1). This was not so in 1967 when there was no difference between plots in numbers

TABLE 8.4
Log numbers of Pratylenchus spp. in roots and soil

Month	1966 Crop				1967 Crop										
	Sections				Sections										
	IA	II	III	S.E.	IA	IB	II	III	IV	VA	S.E.	2B	3	7	S.E.
Numbers/g root transformed to log(x + 0.1)															
June	1.02	1.77	0.92	0.255								1.20	1.20	1.31	0.255
July	1.35	1.26	1.02	0.110								1.39	0.95	1.29	0.110
Aug.	1.91	1.72	1.84	0.147								1.93	1.41	2.13	0.147
Sept.	1.44	1.43	2.00	0.091								1.79	1.42	1.65	0.091
Numbers/litre soil transformed to log(x + 1)															
May	3.16	3.10	2.79	0.140								3.00	2.96	3.07	0.140
June	3.44	3.55	3.15	0.086								3.36	3.23	3.54	0.086
July	3.94	4.13	3.72	0.078								4.11	3.72	3.97	0.078
Aug.	3.61	3.84	3.74	0.073								3.84	3.61	3.75	0.073
Sept.	3.50	3.80	3.66	0.077								3.73	3.54	3.69	0.077
Oct.	3.58	3.79	3.69	0.059								3.76	3.50	3.80	0.059
Nov.	3.76	3.62	3.51	0.067								4.02	3.45	3.42	0.067
Numbers/g root transformed to log(x + 0.1)															
Dec. 1966	1.00	0.44	F	0.70	0.10	0.82	0.403	0.20	0.58	0.27	0.313				
Jan. 1967	1.18	0.44	F	1.30	1.34	1.74	0.395	0.88	1.22	1.50	0.306				
Feb.	1.22	1.10	F	1.87	1.67	0.86	0.520	1.25	1.14	1.64	0.402				
Mar.	1.92	1.25	F	1.81	1.67	2.17	0.257	1.53	1.87	1.89	0.199				
April	1.81	1.29	F	1.86	1.84	1.82	0.178	1.74	1.71	1.73	0.138				
May	1.69	0.99	F	1.77	1.84	1.79	0.146	1.57	1.68	1.59	0.113				
June	1.16	0.67	F	1.23	1.03	1.36	0.167	1.22	1.12	0.92	0.129				
July	1.45	0.86	F	1.24	1.23	1.35	0.092	1.25	1.20	1.22	0.071				
Aug.	1.88	1.18	F	1.81	1.82	1.72	0.076	1.63	1.76	1.66	0.059				
Sept.	1.68	1.11	F	1.90	1.56	1.98	0.144	1.79	1.71	1.44	0.112				
Numbers/litre soil transformed to log(x + 1)															
Dec. 1966	3.11	2.59	3.34	3.04	3.32	3.15	0.288	2.92	3.17	3.19	0.204				
Jan. 1967	3.48	2.90	3.47	3.39	3.60	3.51	0.140	3.56	3.18	3.44	0.099				
Feb.	3.41	2.78	3.47	3.56	3.47	3.53	0.092	3.54	3.16	3.41	0.065				
Mar.	3.24	2.87	3.32	3.15	3.16	3.38	0.118	3.39	2.90	3.26	0.083				
April	3.26	2.86	3.63	3.33	3.26	3.61	0.097	3.50	3.10	3.37	0.069				
May	3.25	2.77	3.48	2.98	3.27	3.29	0.156	3.17	3.02	3.33	0.110				
June	3.41	3.04	3.37	3.26	3.41	3.34	0.100	3.46	3.14	3.32	0.071				
July	3.42	3.14	2.86	3.48	3.43	3.66	0.151	3.26	3.31	3.43	0.107				
Aug.	3.39	3.38	2.93	3.56	3.65	3.66	0.095	3.66	3.25	3.38	0.067				
Sept.	3.45	3.37	2.94	3.80	3.70	3.93	0.131	3.68	3.35	3.56	0.092				

found in roots. However, in both 1966 and 1967 *Pratylenchus* in the soil were consistently fewest in plot 3. Numbers in plots 2B and 7 were similar, with 2B having slightly more in most months.

The numbers of *Paratylenchus microdorus* fluctuated approximately as the *Pratylenchus* population (Table 8.5, Fig. 8.1): there were consistently

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TABLE 8-5
Log numbers of ectoparasitic nematodes/litre soil
1966 Crop

Month	Sections			S.E.	Plots			S.E.
	IA	II	III		2B	3	7	
<i>Paratylenchus microdorus</i>								
May	2.76	1.96	2.04	0.576	1.59	2.77	2.39	0.576
June	3.01	2.32	2.78	0.067	3.10	2.54	2.47	0.067
July	3.31	3.68	3.37	0.258	3.61	3.30	3.46	0.258
Aug.	3.06	3.24	3.47	0.107	3.49	3.00	3.28	0.107
Sept.	3.19	3.42	3.29	0.121	3.35	3.08	3.46	0.121
Oct.	3.25	3.33	3.25	0.082	3.26	3.17	3.41	0.082
Nov.	3.25	3.13	3.19	0.109	3.44	3.06	3.07	0.109
<i>Tylenchorhynchus</i> spp.								
May	1.70	2.55	1.68	0.812	1.85	2.40	1.68	0.812
June	2.83	1.68	2.26	0.474	2.61	1.62	2.55	0.474
July	3.08	2.84	2.63	0.323	2.93	2.79	2.84	0.323
Aug.	2.46	2.77	2.84	0.301	3.02	2.52	2.53	0.301
Sept.	2.22	2.49	2.66	0.192	2.58	2.15	2.65	0.192
Oct.	2.56	2.69	2.76	0.178	2.95	2.24	2.83	0.178
Nov.	2.80	2.69	2.63	0.111	3.10	2.47	2.55	0.111
<i>Helicotylenchus</i> spp.								
May	3.36	3.26	2.78	0.213	3.27	3.29	2.83	0.213
June	3.52	3.10	2.98	0.154	3.38	3.27	2.95	0.154
July	2.74	2.91	2.82	0.165	2.85	2.87	2.76	0.165
Aug.	2.93	2.97	2.93	0.087	3.08	2.95	2.80	0.087
Sept.	2.69	2.93	2.70	0.119	3.09	2.45	2.77	0.119
Oct.	2.64	2.85	2.87	0.144	2.98	2.74	2.64	0.144
Nov.	2.91	1.87	2.30	0.534	3.13	2.24	1.70	0.534

more in plot 2B than either 3 or 7, but in contrast to *Pratylenchus* there was no consistent difference between the populations in plots 3 and 7.

There were more *Tylenchorhynchus* in plot 2B than in 3 or 7 with little difference between numbers in 3 and 7. *Helicotylenchus* were most numerous in plot 2B and fewest in 3 but numbers in plot 7 fluctuated widely and exceeded those in 2B in some months but not in others. 'Other' nematodes were most numerous in plot 2B with numbers in 3 and 7 about the same.

Total Parasites were most numerous in plot 2B and fewest in 3, with 7 intermediate. Other Tylenchs were most numerous in plot 2B with numbers in 3 and 7 about the same: All Nematodes showed a similar distribution.

Crop fallow cycle. Migratory nematodes were estimated in the crop-fallow cycle in 1961, 1966 and 1967. In February and May 1961, surface soil was taken from plots 2B, 3, 7 and 10 in sections IA (continuous wheat), IB (fallow), II (fourth-year wheat) and III (first-year wheat). Random samples from the plots were mixed and 12.5 ml/plot extracted on 'Scottie' brand tissues in small sieves in water in petri dishes. The results are given in Table 8.3. (The standard error in this and all succeeding tables was derived from the interaction of plots and sections.) *Pratylenchus* spp., *Paratylenchus microdorus*, *Helicotylenchus* spp. and Aphelenchs were fewest in section III (first-year wheat) on both sampling dates and were fewer in May than in February except in section IB where there were slightly more. *Tylenchorhynchus* spp. were also fewer in May than February

BROADBALK: NEMATODES

TABLE 8-5 (Continued)
Log numbers of ectoparasitic nematodes/litre soil

	1967 Crop							Plots			
	IA	IB	II	III	IV	VA	S.E.	2B	3	7	S.E.
<i>Paratylenchus microdorus</i>											
Dec. 1966	2.85	2.42	2.76	2.21	2.77	2.75	0.303	2.49	2.73	2.67	0.214
Jan. 1967	2.69	2.54	2.85	2.66	3.17	2.84	0.251	2.99	2.75	2.65	0.177
Feb.	3.09	2.59	3.05	3.08	3.38	3.09	0.109	3.29	2.93	2.92	0.077
Mar.	2.98	2.67	2.93	3.06	3.20	3.07	0.107	3.17	2.85	2.93	0.076
April	3.06	2.35	3.27	2.82	3.13	3.13	0.146	3.18	2.87	2.83	0.103
May	3.26	3.03	3.13	2.91	3.26	3.24	0.161	3.15	3.13	3.13	0.114
June	3.03	3.13	3.05	2.96	3.38	3.02	0.160	3.36	3.01	2.90	0.113
July	3.50	3.48	2.63	3.12	3.18	3.11	0.188	3.20	3.01	3.30	0.133
Aug.	3.25	3.51	2.74	3.32	3.45	3.38	0.133	3.56	3.08	3.19	0.094
Sept.	3.49	3.66	2.83	3.62	3.74	3.81	0.138	3.69	3.38	3.50	0.098
<i>Tylenchorhynchus</i> spp.											
Dec. 1966	0.67	1.91	1.91	2.41	2.21	1.67	0.521	1.85	2.02	1.52	0.369
Jan. 1967	2.30	1.14	2.55	2.14	2.32	2.41	0.328	2.20	1.98	2.25	0.232
Feb.	2.40	2.22	1.62	2.16	2.67	2.52	0.378	2.56	2.15	2.10	0.267
Mar.	2.06	1.14	2.41	1.44	1.63	2.42	0.484	2.40	1.37	1.78	0.343
April	2.35	0.73	1.86	2.46	2.26	2.53	0.486	2.55	1.61	1.95	0.344
May	2.72	2.20	2.38	2.22	1.54	1.71	0.529	2.41	1.94	2.04	0.374
June	2.64	1.57	1.57	2.37	2.62	1.49	0.530	2.50	2.04	1.59	0.375
July	2.69	2.33	2.10	2.45	2.27	2.17	0.170	2.43	2.30	2.28	0.120
Aug.	2.62	2.65	2.26	2.91	2.92	3.05	0.221	3.17	2.34	2.70	0.156
Sept.	2.19	1.57	1.65	3.06	2.53	2.96	0.421	2.81	2.51	1.66	0.298
<i>Helicotylenchus</i> spp.											
Dec. 1966	2.49	2.58	2.66	1.39	2.55	2.01	0.609	2.27	2.73	1.83	0.431
Jan. 1967	3.03	2.60	2.96	2.78	2.93	2.97	0.178	3.12	2.65	2.86	0.126
Feb.	2.94	2.81	3.02	3.03	2.88	2.89	0.165	3.17	2.67	2.95	0.117
Mar.	2.89	2.86	2.79	2.87	2.90	3.14	0.154	3.14	2.76	2.83	0.109
April	2.90	3.09	2.98	2.76	2.83	2.98	0.146	3.05	2.70	3.02	0.103
May	3.10	2.81	3.19	2.78	2.92	2.92	0.236	2.98	2.80	3.08	0.167
June	3.18	3.00	2.83	2.86	2.93	2.96	0.177	3.19	2.67	3.01	0.125
July	3.14	2.98	2.47	3.05	2.96	3.17	0.141	3.00	2.73	3.16	0.100
Aug.	3.26	2.94	2.63	2.96	2.92	2.97	0.180	3.10	2.84	2.89	0.128
Sept.	3.32	3.33	2.84	3.30	3.42	3.69	0.141	3.52	3.02	3.41	0.100

except in the fallow land and did not differ much between sections. *Tylenchus* and *Ditylenchus* were fewest in section III at both sampling dates, and populations diminished between both sampling dates except in the fallow: Aphelenchs and 'Other' nematodes decreased in all sections between sampling dates and were fewest in section III. All stylet-bearing nematodes (Total Parasites and Other Tylenchs) were fewest in section III and decreased between sampling dates except in the fallow, and the entire nematode population decreased between sampling dates in all sections. The populations did not differ consistently between plots except that, as in 1960, plot 2B had fewer Aphelenchs than other plots.

In 1966 plots 2B, 3 and 7 in sections IA (continuous wheat), II (fourth-year wheat) and III (first-year wheat) were sampled and in the 1967 crop the same plots in sections IA, IB (first-year), II (fallow), III (second-year), IV (third-year) and VA (fourth-year) were sampled. Twenty 1-inch soil auger samples approximately 8 in. deep were taken at random in each plot at the beginning of each month. The soil was thoroughly mixed and sieved and 250 cc of it extracted in open trays for 24 hours (Whitehead &

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TABLE 8-6
Log numbers of nematodes/litre soil
1966 Crop

Month	Sections				Plots			S.E.
	IA	II	III	S.E.	2B	3	7	
<i>Tylenchus/Ditylenchus</i> spp.								
May	3.59	3.27	2.89	0.182	3.38	3.43	2.94	0.182
June	3.79	3.76	3.53	0.089	3.89	3.60	3.59	0.089
July	4.03	3.85	3.59	0.109	3.93	3.71	3.83	0.109
Aug.	3.43	3.62	3.56	0.108	3.70	3.41	3.51	0.108
Sept.	3.48	3.78	3.69	0.129	3.77	3.58	3.60	0.129
Oct.	3.58	3.72	3.62	0.056	3.71	3.57	3.64	0.056
Nov.	3.72	3.59	3.46	0.074	3.92	3.41	3.43	0.074
<i>Aphelenchus</i>								
May	2.36	2.67	2.88	0.088	2.70	2.65	2.55	0.088
June	2.65	1.74	2.44	0.495	1.65	2.45	2.74	0.495
July	3.54	3.24	3.38	0.040	3.47	3.21	3.48	0.040
Aug.	3.06	3.07	3.20	0.257	3.18	3.01	3.14	0.257
Sept.	3.41	3.37	3.56	0.206	3.16	3.51	3.66	0.206
Oct.	2.89	2.85	3.53	0.209	3.05	2.91	3.31	0.209
Nov.	2.83	2.85	3.09	0.300	3.32	2.82	2.64	0.300
<i>Other nematodes</i> (mainly non spear-bearing forms)								
May	3.85	3.90	3.57	0.149	3.95	3.88	3.49	0.149
June	3.97	4.05	3.85	0.057	4.01	3.87	4.00	0.057
July	4.46	4.25	4.11	0.047	4.44	4.04	4.33	0.047
Aug.	4.01	4.03	4.21	0.140	4.27	3.95	4.02	0.140
Sept.	3.94	4.13	4.35	0.182	4.22	4.07	4.13	0.182
Oct.	3.94	3.89	4.10	0.061	4.07	3.86	4.00	0.061
Nov.	3.92	3.69	4.03	0.115	4.23	3.77	3.64	0.115

Hemming, 1965). Root samples were extracted for 48 hours after blending for a short period in a Waring blender (Stemerding, 1963).

In the 1967 crop, *Pratylenchus* spp. were found in the roots of emerging plants within a month of planting (Table 8.4, Fig. 8.2). In spite of cold, numbers of *Pratylenchus* increased steadily in the roots through the winter to reach a peak in March. Numbers in roots declined thereafter to few in June and then increased to a second peak in August, repeating the trend observed in 1966. In 1967 *Pratylenchus* were fewest in the roots of first-year plants after fallow all through the year except in December and February. There was no difference in numbers of *Pratylenchus* in roots between any of the other wheat crops in the cycle.

Numbers of *Pratylenchus* in the soil varied according to the year of the crop in the cycle. In both years *Pratylenchus* in the soil in the first year after fallow were fewer than in all other crops until August, when they exceeded or equalled numbers under continuous wheat. In first-year wheat, numbers started to increase in May and continued to do so until August. In 1966 there was a peak in numbers in all sections sampled in July. This was not seen in 1967—possibly because June and July were dry months. Mean numbers of *Pratylenchus* in section II (fourth year, 1966; fallow, 1967) increased steadily in May and June 1966 to a peak in July, decreasing in August, and thereafter remaining steady until the fallow was established by ploughing the stubble in October. Numbers then declined rapidly until December, when there was a slight increase, possibly caused by nematodes escaping from decaying roots: samples of stubble taken from

BROADBALK: NEMATODES

TABLE 8·6 (Continued)
Log numbers of nematodes/litre soil

Month	1967 Crop							Plots			
	IA	IB	II	III	IV	VA	S.E.	2B	3	7	S.E.
<i>Tylenchus/Ditylenchus</i> spp.											
Dec. 1966	3·39	3·09	3·38	3·23	3·17	3·44	0·129	3·31	3·39	3·16	0·091
Jan. 1967	3·33	2·92	3·53	3·36	3·39	3·50	0·135	3·64	3·23	3·15	0·095
Feb.	3·43	3·17	3·42	3·49	3·42	3·59	0·103	3·76	3·31	3·19	0·073
Mar.	3·46	3·06	3·36	3·41	3·30	3·43	0·127	3·66	3·23	3·12	0·090
April	3·69	3·61	3·78	3·67	3·51	3·88	0·080	3·96	3·61	3·51	0·057
May	3·66	3·44	3·72	3·53	3·56	3·69	0·129	3·74	3·61	3·45	0·092
June	3·67	3·50	3·52	3·50	3·65	3·66	0·099	3·78	3·50	3·47	0·070
July	3·52	3·56	3·48	3·57	3·60	3·69	0·113	3·65	3·45	3·62	0·080
Aug.	3·29	3·37	3·27	3·37	3·36	3·51	0·129	3·65	3·31	3·13	0·092
Sept.	3·87	3·87	3·52	3·73	3·84	3·99	0·107	3·96	3·73	3·71	0·075
<i>Aphelenchs</i>											
Dec. 1966	2·84	2·72	2·79	2·60	2·99	2·62	0·286	2·74	2·75	2·79	0·202
Jan. 1967	3·16	2·54	3·12	3·12	3·43	3·41	0·227	3·43	3·01	2·95	0·160
Feb.	2·82	2·78	2·76	3·15	3·07	2·71	0·136	3·04	2·79	2·81	0·096
Mar.	2·95	2·62	2·54	2·94	2·82	2·88	0·155	3·07	2·63	2·67	0·110
April	2·84	3·00	2·43	3·02	2·59	3·02	0·223	3·12	2·63	2·70	0·158
May	2·62	1·49	2·16	2·51	2·53	2·66	0·333	2·04	2·43	2·52	0·235
June	3·12	2·87	2·77	1·91	3·14	2·34	0·399	2·95	2·30	2·82	0·282
July	2·66	2·71	2·32	2·83	2·64	2·52	0·240	2·82	2·49	2·53	0·169
Aug.	2·55	2·91	1·49	2·94	2·81	2·83	0·327	2·86	2·21	2·70	0·231
Sept.	2·71	2·54	2·37	2·93	2·93	2·96	0·242	2·78	2·71	2·73	0·171
<i>Other nematodes</i> (mainly non spear-bearing forms)											
Dec. 1966	3·75	3·10	3·44	3·76	3·39	3·52	0·135	3·58	3·45	3·45	0·095
Jan. 1967	3·60	3·42	3·55	3·55	3·67	3·74	0·129	3·98	3·34	3·44	0·091
Feb.	3·63	3·40	3·47	3·83	3·71	3·71	0·136	4·00	3·48	3·40	0·096
Mar.	3·66	3·43	3·29	3·60	3·50	3·66	0·145	3·91	3·37	3·29	0·102
April	3·55	3·77	3·75	4·02	3·62	4·09	0·155	4·07	3·69	3·64	0·109
May	3·78	3·52	3·60	3·58	3·66	3·80	0·156	3·78	3·60	3·58	0·110
June	4·05	3·77	3·39	3·85	4·00	3·79	0·122	3·97	3·63	3·83	0·086
July	3·85	3·77	3·60	3·82	3·87	3·90	0·105	3·91	3·64	3·86	0·074
Aug.	3·88	3·73	3·37	3·83	3·71	3·72	0·103	4·06	3·53	3·53	0·073
Sept.	3·98	4·04	3·49	4·06	4·24	4·17	0·147	4·12	3·94	3·93	0·104

the soil surface in December still had eight *Pratylenchus/g* in the roots. Numbers then remained fairly steady until March when there was a sudden increase, possibly because eggs in the soil and decaying stubble hatched; they then declined again, very rapidly in June before summer ploughing of the fallow, to give a small residual population at the end of the fallow. The major benefit of the fallow in lessening nematode populations seems to occur in June.

Numbers of *Paratylenchus microdorus* fluctuated approximately as the *Pratylenchus* population (Table 8·5, Fig. 8·2). However, the difference between the numbers in the first year and those in other years was smaller than with *Pratylenchus*. Numbers increased faster than those of *Pratylenchus* with a steep rise in April. The population in the fallow also increased in March, followed, as with *Pratylenchus*, by a steady fall culminating in a steep one in June.

Populations of *Tylenchorhynchus* fluctuated widely throughout the period; observations made in 1966 and 1967 showed no consistent pattern (Table 8·5, Fig. 8·2).

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TABLE 8·7
Log numbers of groups of nematodes/litre of soil
1966 Crop

Month	Sections				Plots			
	IA	II	III	S.E.	2B	3	7	S.E.
<i>Total parasites</i>								
May	3·68	3·63	3·25	0·161	3·57	3·59	3·40	0·161
June	3·94	3·74	3·51	0·111	3·83	3·65	3·71	0·111
July	4·15	4·31	3·99	0·074	4·28	3·98	4·19	0·074
Aug.	3·85	4·02	4·01	0·050	4·11	3·81	3·95	0·050
Sept.	3·75	4·03	3·89	0·070	3·98	3·73	3·95	0·070
Oct.	3·82	4·00	3·92	0·049	3·98	3·76	4·01	0·049
Nov.	3·96	3·82	3·75	0·048	4·21	3·66	3·66	0·048
<i>Other Tylenchs, incl. Aphelenchs</i>								
May	3·63	3·38	3·19	0·157	3·54	3·53	3·12	0·157
June	3·82	3·78	3·57	0·085	3·90	3·63	3·65	0·085
July	4·15	3·95	3·80	0·086	4·06	3·85	3·99	0·086
Aug.	3·59	3·74	3·73	0·140	3·81	3·58	3·66	0·140
Sept.	3·75	3·94	3·98	0·144	3·88	3·86	3·94	0·144
Oct.	3·69	3·78	3·89	0·067	3·82	3·72	3·82	0·067
Nov.	3·78	3·69	3·63	0·101	4·03	3·55	3·51	0·101
<i>All nematodes</i>								
May	4·24	4·18	3·86	0·146	4·23	4·20	3·85	0·146
June	4·41	4·37	4·17	0·067	4·41	4·22	4·31	0·067
July	4·77	4·68	4·47	0·061	4·77	4·46	4·68	0·061
Aug.	4·36	4·47	4·52	0·095	4·60	4·33	4·42	0·095
Sept.	4·34	4·56	4·63	0·113	4·55	4·43	4·55	0·113
Oct.	4·32	4·40	4·48	0·054	4·46	4·29	4·45	0·054
Nov.	4·38	4·23	4·33	0·050	4·67	4·17	4·10	0·050

Numbers of *Helicotylenchus* spp. fluctuated widely during the period sampled (Table 8·5, Fig. 8·2). Numbers fell after ploughing in October 1966 in section II (fourth-year, 1966; fallow, 1967) and section III (first-year, 1966; second-year, 1967) but not in section IA (continuous wheat). In section II numbers increased again in November, whereas they fell further in section III, to rise in December. Thereafter numbers in the different years of the crop fallow cycle did not differ from one another until July, when the fallow had fewest, populations having declined from the beginning of May. Numbers of *Helicotylenchus* increased in August and were most in all sections except the fallow at the beginning of September.

The groups of nematodes not known to feed on plant roots (Table 8·6) also tended to be fewer at first in the first year after fallow. In May 1966 *Tylenchus/Ditylenchus* were fewer in section III than in the others, but by August were the same as in IA and II. Numbers of *Aphelenchs* fluctuated inconsistently, but 'Other' nematodes remained fewest in section III until August when most were present. In the 1967 crop, these were again fewest in first year after fallow (section IB). Populations increased faster than those of the different parasitic genera, so that by April populations of *Tylenchus/Ditylenchus*, *Aphelenchs* and 'Others' in section IB had equalled or exceeded those in other sections. Under fallow (section II), 'Other' nematodes decreased greatly in April and May. *Tylenchus/Ditylenchus* decreased from April to August, when they were fewest. *Aphelench* numbers fluctuated during this period, but decreased greatly in July. There-

BROADBALK: NEMATODES

TABLE 8·7 (Continued)
Log numbers of groups of nematodes/litre of soil

Month	1967 Crop							Plots			
	IA	IB	II	III	IV	VA	S.E.	2B	3	7	S.E.
<i>Total parasites</i>											
Dec. 1966	3·40	3·07	3·55	3·35	3·54	3·39	0·272	3·25	3·50	3·40	0·192
Jan. 1967	3·70	3·23	3·73	3·60	3·85	3·74	0·137	3·82	3·47	3·64	0·097
Feb.	3·74	3·28	3·76	3·82	3·85	3·78	0·084	3·90	3·52	3·70	0·060
Mar.	3·59	3·34	3·64	3·55	3·63	3·75	0·089	3·80	3·38	3·57	0·063
April	3·67	3·38	3·91	3·57	3·63	3·87	0·073	3·85	3·48	3·68	0·051
May	3·75	3·42	3·81	3·41	3·70	3·71	0·156	3·65	3·54	3·71	0·110
June	3·76	3·57	3·65	3·59	3·85	3·68	0·080	3·89	3·52	3·64	0·057
July	3·90	3·78	3·23	3·79	3·76	3·89	0·123	3·68	3·63	3·85	0·087
Aug.	3·84	3·87	3·36	3·89	3·96	3·98	0·090	4·06	3·63	3·76	0·064
Sept.	3·93	3·98	3·40	4·15	4·14	4·34	0·101	4·17	3·81	4·00	0·071
<i>Other Tylenchs, incl. Aphelenchs</i>											
Dec. 1966	3·52	3·25	3·50	3·39	3·40	3·51	0·147	3·44	3·51	3·33	0·104
Jan. 1967	3·56	3·09	3·69	3·56	3·71	3·76	0·155	3·87	3·44	3·38	0·110
Feb.	3·54	3·33	3·51	3·66	3·59	3·67	0·083	3·85	3·44	3·36	0·059
Mar.	3·60	3·20	3·43	3·54	3·44	3·54	0·114	3·77	3·33	3·27	0·080
April	3·75	3·71	3·81	3·76	3·57	3·94	0·081	4·03	3·68	3·57	0·057
May	3·70	3·47	3·73	3·58	3·60	3·72	0·125	3·76	3·64	3·50	0·089
June	3·78	3·60	3·59	3·55	3·78	3·68	0·095	3·86	3·57	3·58	0·067
July	3·60	3·62	3·52	3·65	3·66	3·73	0·108	3·72	3·50	3·67	0·076
Aug.	3·36	3·52	3·30	3·51	3·47	3·60	0·134	3·73	3·38	3·28	0·095
Sept.	3·91	3·89	3·57	3·80	3·90	4·03	0·100	3·99	3·78	3·77	0·071
<i>All nematodes</i>											
Dec. 1966	4·10	3·66	4·00	4·02	3·96	3·99	0·155	3·96	3·99	3·91	0·110
Jan. 1967	4·12	3·79	4·15	4·06	4·24	4·24	0·127	4·39	3·91	4·00	0·090
Feb.	4·15	3·84	4·10	4·28	4·23	4·21	0·090	4·42	3·98	4·00	0·064
Mar.	4·11	3·83	3·98	4·08	4·06	4·15	0·112	4·33	3·87	3·91	0·079
April	4·16	4·15	4·32	4·33	4·12	4·48	0·090	4·50	4·15	4·14	0·063
May	4·23	3·97	4·22	4·04	4·15	4·25	0·132	4·24	4·09	4·10	0·093
June	4·38	4·16	4·05	4·18	4·40	4·21	0·088	4·40	4·07	4·21	0·063
July	4·29	4·23	3·98	4·26	4·26	4·35	0·090	4·29	4·10	4·30	0·064
Aug.	4·24	4·22	3·84	4·27	4·26	4·29	0·091	4·46	4·04	4·06	0·064
Sept.	4·46	4·48	3·99	4·56	4·63	4·70	0·094	4·60	4·37	4·44	0·066

after the populations of all three groups were smaller in fallow than in any other section.

Grouping the nematodes into Parasites, Other Tylenchs (mainly spear-bearing non-parasites) and All Nematodes (Table 8·7) gives much the same pattern. In 1966 under first crop after fallow they are fewest until August, when the numbers exceed those in section IA (continuous wheat). In 1967, Other Tylenchs and All Nematodes were as numerous in April under the first crop after fallow (IB) as in other sections: by May Total Parasites were as numerous in IB as in other sections. In the fallow, All Nematodes and Other Tylenchs declined steadily from the beginning of April to fewest in August, increasing slightly in September. Populations of parasites declined slowly in April and May, and rapidly in June, to increase slightly in July.

Depth samples. The migratory nematodes in soil sampled down to a depth of just over 2 ft were studied in 1961 and 1966 and deep samples in 1968 (Tables 8·8 and 8·9. The standard error was derived from the interaction of sections with depth.) In March and May 1961 samples were taken from

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the land at the side of sections I, II, III and IV to depths of just over 2 ft. A 12.5 ml sample from each depth was extracted through 'Scottie' brand tissue on small sieves in water in Petri dishes. Results are in Table 8.8. *Pratylenchus* spp. were the most numerous plant parasites and there were many throughout the profile sampled; they equalled or exceeded in number

TABLE 8.8
Log numbers of nematodes/litre soil at various depths, 1961

Month	Depth (in.)					S.E.	Sections				S.E.
	0-4	4-8	8-12	12-24	24+		I	II	III	IV	
<i>Pratylenchus</i>											
Mar.	3.79	3.73	3.53	3.47	3.29	0.093	3.56	3.35	3.86	3.47	0.083
May	3.11	3.08	3.18	3.07	3.28	0.080	3.02	3.36	3.37	2.83	0.072
<i>Paratylenchus</i>											
Mar.	3.50	3.26	1.68	0.00	0.04	0.275	1.94	1.33	1.69	1.82	0.246
May	2.63	2.57	0.55	0.48	0.06	0.417	1.17	1.24	1.54	1.08	0.373
<i>Tylenchorhynchus</i>											
Mar.	2.61	2.42	2.06	1.15	0.09	0.348	1.44	1.51	1.77	1.93	0.311
May	1.98	1.58	2.10	0.95	2.13	0.421	2.00	1.73	1.67	1.60	0.377
<i>Helicotylenchus</i>											
Mar.	3.07	3.03	3.38	2.55	2.01	0.174	2.94	2.56	2.92	2.80	0.156
May	2.31	1.82	2.26	1.97	1.54	0.395	2.14	2.56	2.14	1.07	0.353
<i>Tylenchus/Ditylenchus</i>											
Mar.	3.63	3.56	2.33	0.00	0.03	0.063	1.88	1.90	1.86	2.01	0.056
May	3.29	3.28	1.15	2.21	0.86	0.394	2.06	2.75	1.85	1.97	0.352
<i>Aphelenchus</i>											
Mar.	3.00	3.26	2.03	0.55	1.33	0.373	1.47	2.41	2.35	1.90	0.333
May	2.69	2.81	1.51	0.48	0.94	0.428	1.96	1.47	1.61	1.69	0.383
<i>Others</i>											
Mar.	4.04	4.22	3.41	2.61	2.57	0.112	3.38	3.42	3.10	3.57	0.100
May	3.61	3.75	3.00	2.59	2.32	0.107	3.13	3.06	2.96	3.06	0.096
<i>Total parasites</i>											
Mar.	4.06	3.99	3.81	3.56	3.32	0.093	3.83	3.52	3.98	3.67	0.083
May	3.41	3.39	3.29	3.19	3.30	0.103	3.29	3.50	3.46	3.00	0.092
<i>Other Tylenchs, incl. Aphelenchus</i>											
Mar.	3.80	3.78	2.53	0.55	1.35	0.337	1.94	2.53	2.80	2.33	0.301
May	3.39	3.43	2.18	2.22	2.00	0.145	2.58	2.82	2.52	2.65	0.130
<i>All nematodes</i>											
Mar.	4.51	4.57	4.02	3.66	3.47	0.101	4.02	3.95	4.12	4.09	0.091
May	3.98	4.05	3.50	3.41	3.43	0.094	3.63	3.80	3.75	3.52	0.084
<i>Pratylenchus as % of total nematodes</i>											
Mar.	22.2	18.5	35.2	65.4	69.8	4.65	41.8	35.6	58.1	33.4	4.16
May	17.4	11.4	47.9	49.9	74.9	7.18	33.0	43.2	52.8	32.2	6.42

all other nematodes below a depth of 12 in., and as a percentage of total nematodes were fewest in samples 4 to 8 in. deep. In total in the complete profile, they were most abundant next to section III. *Paratylenchus microdorus* was almost restricted to the top 12 in. The depth distribution of *Tylenchorhynchus* spp. varied; in March they were most numerous at the surface and in May at the greatest depth sampled. *Helicotylenchus*

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TABLE 8-9
Log numbers of nematodes/litre soil to a depth of 25 in.

Month	1966					S.E.	Sections			S.E.
	0-5	5-10	Depth (in.)		20-25		IA	II	III	
<i>Pratylenchus</i> spp.										
May	3.04	2.55	2.75	2.60	1.95	0.473	1.82	2.93	2.99	0.367
June	2.99	2.97	3.13	2.70	2.71	0.233	2.89	2.82	2.99	0.181
July	4.14	3.77	3.67	3.37	3.07	0.164	3.38	3.73	3.69	0.127
Aug.	3.75	3.72	3.93	3.57	3.03	0.229	3.49	3.58	3.74	0.177
Sept.	3.13	3.67	3.53	3.39	3.25	0.242	2.99	3.47	3.73	0.188
Oct.*	3.73	3.50	—	—	—	0.151	3.88	3.43	3.55	0.185
<i>Paratylenchus microdorus</i>										
May	2.64	2.53	0.57	0.77	0.77	0.563	1.51	1.96	0.90	0.436
June	2.47	2.21	0.67	0.00	0.14	0.476	1.49	1.25	1.14	0.369
July	3.54	2.18	1.69	2.28	1.37	0.766	1.88	2.29	2.48	0.593
Aug.	3.29	1.88	2.19	0.80	1.38	0.621	1.62	2.67	1.43	0.481
Sept.	2.35	3.00	1.60	1.30	1.34	0.428	0.59	2.63	2.54	0.331
Oct.*	3.36	2.95	—	—	—	0.140	3.01	3.14	3.32	0.171
<i>Tylenchorhynchus</i> spp.										
May	2.07	1.40	0.57	0.67	0.00	0.389	1.74	0.34	0.74	0.302
June	1.14	1.49	0.83	1.34	0.57	0.655	1.45	1.43	0.34	0.507
July	2.63	2.52	2.16	0.73	1.91	0.344	1.72	2.29	1.95	0.266
Aug.	2.32	1.67	1.44	0.57	1.80	0.644	1.70	1.74	1.24	0.499
Sept.	1.54	2.33	1.91	0.57	0.57	0.572	1.23	1.55	1.37	0.443
Oct.*	1.55	0.57	—	—	—	0.409	1.00	0.00	2.18	0.501
<i>Helicotylenchus</i> spp.										
May	2.97	2.70	0.00	1.14	0.67	0.428	1.59	1.78	1.11	0.332
June	1.89	1.59	2.01	0.77	0.57	0.781	1.51	1.20	1.39	0.605
July	1.65	1.44	1.55	2.20	1.71	0.684	1.64	1.86	1.62	0.530
Aug.	2.68	1.67	0.67	0.67	1.21	0.637	1.25	2.08	0.80	0.493
Sept.	0.67	2.69	2.12	1.49	0.90	0.445	0.93	2.50	1.30	0.345
Oct.*	2.52	1.40	—	—	—	0.451	2.73	1.20	1.94	0.553
<i>Tylenchus/Ditylenchus</i> spp.										
May	3.23	3.27	1.14	1.86	1.86	0.679	2.56	2.63	1.63	0.526
June	3.24	3.52	2.49	2.20	1.34	0.374	2.93	2.48	2.27	0.290
July	3.48	3.48	2.78	2.86	2.87	0.139	3.16	3.26	2.86	0.108
Aug.	3.48	3.24	2.65	2.43	1.30	0.452	2.53	2.68	2.66	0.350
Sept.	2.99	3.29	2.32	2.16	2.39	0.186	2.46	2.74	2.70	0.144
Oct.*	3.33	3.18	—	—	—	0.096	3.33	3.22	3.21	0.118
<i>Aphelenchus</i>										
May	2.06	2.45	0.85	1.47	2.16	0.510	1.91	2.30	1.18	0.395
June	2.50	2.46	2.65	2.37	0.89	0.454	2.31	2.66	1.55	0.351
July	3.33	2.98	2.53	2.68	1.49	0.400	2.34	2.83	2.64	0.310
Aug.	3.45	2.69	2.76	2.09	2.48	0.273	2.52	2.85	2.71	0.212
Sept.	2.83	2.53	2.12	1.82	1.49	0.433	1.38	2.40	2.69	0.336
Oct.*	3.13	3.31	—	—	—	0.157	3.12	3.25	3.29	0.192
<i>Others</i>										
May	3.30	3.34	2.35	1.73	2.78	0.431	3.08	2.78	2.23	0.334
June	3.65	3.99	3.09	3.19	1.68	0.408	3.42	3.34	2.59	0.316
July	4.10	4.24	3.60	3.36	3.00	0.126	3.61	3.90	3.46	0.098
Aug.	4.19	3.77	3.78	2.94	2.89	0.423	3.34	3.83	3.37	0.328
Sept.	3.49	3.61	3.12	2.95	2.88	0.159	2.86	3.28	3.49	0.123
Oct.*	3.67	3.79	—	—	—	0.169	3.68	3.50	4.02	0.208

* To 10 in. only.

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spp. were present throughout the profile and at both sampling dates were most numerous between 8 and 12 in. The *Tylenchus/Ditylenchus* group were present 12 in. deep in March, but in May also occurred down to 24 in. Aphelenchs were very few below 12 in. All other nematodes were most numerous 4-8 in. deep, but many also occurred below 2 ft. Plant nematodes as a group were concentrated near the surface in March and were less numerous but more evenly distributed throughout the profile in May. All groups of nematodes were fewer in May than in March.

In 1966 soil samples were taken in the cropped headland discard of plot 7 in section IA, II and III to depths of 25 in. in May, June, July, August and September. In October samples were taken to 10 in. only. Two samples were taken at each site with a 2 in. Jarrett auger and thoroughly mixed. 250 ml of soil from each was then extracted through 'Scottie' tissues on large open trays (Whitehead & Hemming, 1965). The results (Table 8·9) are broadly comparable with those obtained from the land at the side of the main plots in 1960: *Pratylenchus* spp. were more numerous than any other nematode except in June at 15-20 in., and formed a third or more of the total nematodes deeper than 10 in. *Pratylenchus* as a percentage of all nematodes were fewest at 5-10 in. in May, June, July and October and at 0-5 in. in August and September (Table 8·10), but highest numbers at 0-5 in. and 5-10 in. depths were reached in July, between 10 and 20 in.

TABLE 8·10

Log numbers of groups of nematodes/litre soil to a depth of 25 in., 1966

Month	Depth (in.)					S.E.	Sections			
	0-5	5-10	10-15	15-20	20-25		IA	II	III	S.E.
<i>Total parasites</i>										
May	3·48	2·92	2·91	2·81	1·99	0·483	2·20	3·11	3·16	0·374
June	3·24	3·18	3·20	2·80	2·79	0·215	3·09	2·95	3·08	0·166
July	4·27	3·90	3·73	3·45	3·15	0·145	3·46	3·83	3·80	0·112
Aug.	3·95	3·78	3·95	3·59	3·08	0·216	3·56	3·65	3·80	0·168
Sept.	3·30	3·82	3·58	3·43	3·29	0·270	3·03	3·62	3·81	0·209
Oct.*	3·93	3·66	—	—	—	0·148	3·97	3·63	3·78	0·181
<i>Other Tylenchs, incl. Aphelenchs</i>										
May	3·29	3·25	1·44	1·97	2·55	0·631	2·59	2·92	1·99	0·489
June	3·38	3·59	2·95	2·72	1·51	0·355	3·09	3·08	2·33	0·275
July	3·72	3·60	3·10	3·08	2·95	0·091	3·31	3·44	3·13	0·071
Aug.	3·77	3·37	3·02	2·61	2·50	0·312	3·00	3·14	3·01	0·242
Sept.	3·22	3·36	2·55	2·58	2·53	0·195	2·55	2·95	3·05	0·151
Oct.*	3·56	3·56	—	—	—	0·070	3·56	3·54	3·58	0·085
<i>All nematodes</i>										
May	3·88	3·67	3·12	3·26	3·29	0·179	3·42	3·48	3·43	0·139
June	3·94	4·20	3·60	3·44	3·04	0·243	3·75	3·66	3·52	0·188
July	4·57	4·51	4·05	3·84	3·55	0·111	3·98	4·28	4·04	0·086
Aug.	4·51	4·23	4·27	3·74	3·42	0·273	3·91	4·12	4·07	0·211
Sept.	3·92	4·13	3·75	3·63	3·50	0·170	3·42	3·89	4·05	0·132
Oct.*	4·28	4·21	—	—	—	0·056	4·30	4·07	4·37	0·069
<i>Pratylenchus as % of all nematodes</i>										
May	15·7	4·5	55·2	40·2	32·7	14·56	3·6	31·1	54·4	11·28
June	11·1	7·9	36·8	18·3	54·3	9·36	18·0	17·5	41·5	7·25
July	37·7	20·7	43·0	37·0	34·2	4·78	26·1	32·1	45·4	3·70
Aug.	19·5	38·4	51·0	70·0	39·7	12·13	43·3	29·1	58·8	9·39
Sept.	19·0	34·4	61·1	60·3	57·4	6·92	48·3	40·0	51·0	5·36
Oct.*	29·9	23·4	—	—	—	6·10	38·1	23·3	18·5	7·47

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in August and from 20 to 25 in. in September (Table 8·9). *Paratylenchus microdorus*, *Tylenchorhynchus* spp. and *Helicotylenchus* spp. occurred throughout the profile but in May and June there were few of them below 10 in. In the other months more were present at depth, but most were in the top 15 in. Most nematodes were most numerous in the top 10 in. (Table 8·10), and though the relative numbers of *Pratylenchus* increased with depth, it was a proportionate increase and most were in the top 10 in. There was no consistent difference between numbers in the three sections sampled.

The first deep samples were taken in February 1968 to a depth of 6 ft in the uncropped pathway between plots 3 and 5 and 8 and 9 in the headland separating sections III and IV. The small amount of partially dried soil from the two cores was extracted on open trays (Whitehead & Hemming, 1965) and contained the nematodes shown in Table 8·11. *Pratylenchus*

TABLE 8·11
Log numbers of nematodes/litre soil

Deep samples, February 1968

	Depth (in.)						
	0-3	9-15	21-27	33-39	45-51	57-63	69-72
<i>Pratylenchus</i>	2·30	2·89	2·90	2·35	2·10	2·44	0·00
All nematodes	3·48	2·93	2·98	2·35	2·10	2·58	0·00

Deep samples, September 1968

	Depth (in.)								
	0-9	9-18	18-27	27-36	36-45	45-54	54-63	63-72	S.E.
<i>Pratylenchus</i>	3·08	3·51	3·06	2·67	2·10	1·60	0·50	0·53	0·277
<i>Paratylenchus</i>	2·44	1·34	0·00	0·00	0·33	0·00	0·11	0·11	0·359
<i>Tylenchorhynchus</i>	2·03	2·05	2·41	0·90	0·00	0·00	0·02	0·02	0·206
<i>Helicotylenchus</i>	2·81	2·55	1·98	1·27	1·35	0·29	-0·10	0·34	0·381
<i>Tylenchus/Ditylenchus</i>	3·14	2·49	1·42	1·67	1·62	0·57	0·39	0·45	0·297
Aphelenchs	2·20	0·00	0·29	1·27	0·00	0·29	-0·07	-0·07	0·203
Other nematodes	3·37	2·78	1·92	1·94	1·39	1·19	0·42	0·76	0·419
Total parasites	3·45	3·60	3·26	2·83	2·46	1·88	0·47	0·56	0·252
Other Tylenchida	3·26	2·49	1·70	2·09	1·62	0·85	0·35	0·41	0·272
All nematodes	3·90	3·77	3·34	3·03	2·78	2·33	1·13	0·91	0·314
<i>Pratylenchus</i> % of all nematodes	20·6	56·8	54·4	47·3	43·4	50·1	42·8	25·4	7·42

thornei and *P. minyus* were found near the surface with *P. thornei* occurring as deep as 5 ft: few other nematodes were found at this depth.

More samples were taken in September 1968 from plots 2B, 3 and 7 in the cropped headland separating sections IA and IB. Table 8·11 shows the results from this sampling, with standard errors derived from the interaction of plots and depths. *Pratylenchus* spp. which were most abundant at 9-18 in., occurred down to 6 ft, though few were present below 54 in. They comprised more than 40% of all nematodes between 9 and 63 in. deep. *Paratylenchus* were almost restricted to the top 18 in., *Tylenchorhynchus* were most abundant between 18 and 27 in., with very few below 36 in. *Helicotylenchus* were very few below 45 in. *Tylenchus* and *Ditylenchus* were present throughout the profile, but became fewer with increasing depth. Aphelenchs occurred at the surface and between 27 and 36 in. deep, with few or none at other depths. Populations of 'Other' nematodes decreased rapidly below 9 in., but some occurred at all depths sampled.

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Broadbalk drains

Broadbalk is drained along the centre line of each plot by tile drains 2 ft. deep, which run for short periods after heavy rain. In December 1966 nematodes were caught at the drain outfalls of plots 3, 7 and 8 on 300 mesh sieves. The drains from plots 7 and 8 were running at approximately the same rate, but that from plot 3 was running much faster; plot 2A and 2B drains were not running. The nematodes were not counted, but those caught included *Pratylenchus thornei*, *P. minyus* (very few), *Helicotylenchus vulgaris*, *Paratylenchus microdorus*, *Tylenchorhynchus* sp. probably *T. macrurus*, *Trophurus imperialis*, larvae of *Heterodera avenae*, *Tylenchus* spp., and some Rhabditids, Plectids and Mononchs.

Discussion

The evidence from these surveys shows that the most numerous nematodes in Broadbalk soil that are parasitic on plants are species of *Pratylenchus*. They invade roots of young wheat seedlings and increase rapidly there throughout the winter, a period when nematodes have been considered to be inactive. Nematode populations do not differ consistently with plot treatments, except that species parasitic on plants are often fewer than elsewhere in the unmanured plot, where the plants do not grow well and presumably have small root systems. The recent surveys (1966-67) show more nematodes in the FYM plots than in others, which was not shown in the earlier surveys: it is uncertain whether the differences between the surveys reflect long-term population changes or altered sampling and extraction techniques.

Populations of all nematodes decrease under the fallow and increase under the first wheat crop at rates that differ with different species. Many nematodes occur in the soil and subsoil to a depth of 6 ft, but below 10 or 12 in. *Pratylenchus* spp., mainly *P. thornei*, are the most numerous.

The information is too little to assess what effect the feeding by the nematodes has on crop yield, but it is improbable they contribute much to the difference in yield between different plots.

Acknowledgement

We thank J. H. A. Dunwoody for the statistical analyses.

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