Report for 1968 - Part 1

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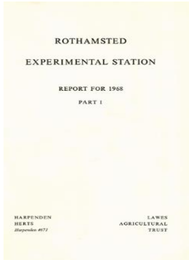
ROTHAMSTED

EXPERIMENTAL STATION

REPORT FOR 1968

PART 1

HARPENDEN HERTS

LAWES AGRICULTURAL TRUST

Nematology Department

F. G. W. Jones

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NEMATOLOGY DEPARTMENT

F. G. W. JONES

Although many species of nematodes (eelworms) have been identified in soil, many more doubtless await discovery. Most species that attack plants are small, about a millimetre long, but a few are larger, up to a centimetre long. They are important parasites of field and plantation crops in most countries and are more difficult to kill than most insect pests. Although they move through soil only slowly, a few inches a year, they are dispersed easily and widely in plants and soil, and quarantine measures intended to prevent harmful species entering areas thought not to have them, interfere with trade and are never wholly successful.

In addition to identifying and describing new species, the department studies the life cycles and behaviour of economically important ones, to find ways of avoiding the losses they cause.

Cyst-nematodes

Fine structure. Observation with the light microscope of the structure of young unfertilised females fixed in acrolein and embedded in glycol methacrylate are being supplemented by electron microscopy of sections cut from individuals fixed in glutaraldehyde, with or without formalin, followed by osmium tetroxide and embedded in araldite.

The only organised structures seen so far are the hypodermis and reproductive tract. Cells of the uterus wall, which has a secretory function, contain characteristic whorls of granular endoplasmic reticulum. The intestinal tissue is apparently a syncytium containing several types of granules, each easily recognisable by its fine structure. Other granules are associated with the reproductive tract throughout most of its length but lie outside its cell boundaries. The cuticle of young females consists of several layers, which are not easily equated with the three zones usually postulated for nematode cuticle. The structural organisation of the layers differs between species but in all is consistent with the large amounts of collagen present. (Shepherd and Dart, Soil Microbiology Department)

Composition of cyst walls. The main component of the cyst walls of *Heterodera schachtii* and *H. rostochiensis* was a collagen-like protein (70% and 72% respectively). Hydrolysates of cyst walls of *H. schachtii* contain more glutamic acid and less alanine and proline than those of *H. rostochiensis*. Cyst walls of *H. schachtii* also contain more ash. Most of the inorganic material in *H. schachtii* cysts is probably bound by ionic forces, because extraction with EDTA decreased the amount to 1%. Nevertheless, the ash content remained at 17% when the cyst walls were dialysed against water and decreased only to 10% when dialysed against dilute (0·01 N) hydrochloric acid. The inorganic material included 1·7% calcium, 1·5% phosphorus, and 1·0% carbonate.

The cyst wall of young females and the larval cuticle probably have related composition and the differences between the cyst walls of *H.*

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schachtii and *H. rostochiensis* (ash 17% and 5%, calcium ions 1·7% and 0·05% respectively) parallels the ease with which eggs of the species are hatched by inorganic ions; more than twenty kinds were moderately or very active hatching agents for *H. schachtii* but only ten for *H. rostochiensis*. Also, calcium ions hatched *H. schachtii* eggs but not *H. rostochiensis* eggs. (Clarke)

Hatching factor for the potato cyst-nematode. In collaboration with Professor A. W. Johnson, at Nottingham University, the extraction of the factor was improved and simplified. The procedure developed has four main steps; extraction of 4–5 week old potato roots, two successive separations by column chromatography, and fractionation by thin layer chromatography. The yields of products at the successive stages were about 2, 1, 0·07 and 0·005% by weight of the potato roots and the final product contained about 20% of the initial hatching factor (based on hatching tests).

This product could be further fractionised by thin layer chromatography. Even with conditions carefully controlled, the active material was broadly spread over about 0·3 RF units, with the zone of maximum hatch covering 0·2 units. This zone contained at least ten compounds. Five did not stimulate hatching; one that did was converted to a volatile trimethylsilyl derivative for insertion in the mass spectrometer. A system recently found spreads the compounds more widely and this is being used in attempts to get a purer sample of the hatching factor. One impurity, extractable in ether, was palmitic acid. (Clarke)

Attraction of males to females. Adding 0·05% solutions of some chemicals that are common in soil to sand had only slight effects on the movement of males, whose behaviour was greatly influenced only by the sex attractant of the females. (Evans)

Before related species can mate, the males of one must be attracted by the females of the other.

Table 1 shows the degree to which males were attracted to the sedentary females of nine species of cyst-nematodes, on a scale from 0, no attraction

TABLE 1

Relative attraction of males to females of different species of Heterodera

	Males								
	Group 1				Group 2			Group 3	
Females	*rostochiensis*	*tabacum*	*mcn**	*avenae*	*goettingiana*	*cruciferae*	*carotae*	*glycines*	*schachtii*
Group 1									
rostochiensis	5	5	5	4	2	2	1	1	1
tabacum	5	5	5	2	3	0	1	1	3
*mcn**	5	5	4	3	5	1	1	2	1
avenae	4	5	4	3	2	1	1	2	1
Group 2									
goettingiana	4	5		4	5	4	5	4	2
cruciferae	5	3	2	1	5	5	5	5	4
carotae	1	0		1	2	4	5	5	4
Group 3									
glycines	1	1		0	0	0	1	5	5
schachtii	2	2	2	0	3	1	2	5	3
trifolii	0	1		1	1	1	1	4	0†

Note: *H. trifolii* does not produce males. * Mexican cyst nematode. † Rated 3 or 4 in other tests.

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(random movement of males), to five, the strongest attraction. The ratings for attraction to females of the same species run diagonally across the table and, excluding *H. trifolii* which is parthenogenetic and lacks males, they average 4·4. Ratings between species suggest they fall into three groups, in each of which the species are mutually attractive. The first includes *H. rostochiensis*, *H. tabacum*, an undescribed species from Mexico, and *H. avenae*, the second *H. goettingiana*, *H. cruciferae* and *H. carotae*, and the third *H. glycines*, *H. schachtii* and *H. trifolii*. Females of *H. goettingiana* and *H. cruciferae* seemed more attractive to males of some of the *H. rostochiensis* group than females of the group were to males of *H. goettingiana* and *H. cruciferae*. To explain the three groups and the anomalies between them, the secretion of at least five major attractant substances must be postulated.

Tests were made with three populations of *H. rostochiensis*, one predominantly pathotype A and the other two predominantly pathotype E. Males of all pathotypes were attracted by females of all pathotypes to the extent shown in Table 1 as 4 or 5.

However, as Table 2 shows there were significant differences, and females of the Woburn and Colyton populations attracted males of their own populations more than those of the other population. By contrast females of the St. Leonards population attracted males of the Woburn population, a different pathotype, more than females of the Colyton population thought to be the same pathotype. These differences between closely related pathotypes suggest there may be individual population odours, possibly caused by different minor attractants and synergists secreted by the females. The small differences show only in carefully controlled tests, but in field soils, where males can exercise a choice, they might lead to non-random mating and to some reproductive isolation between pathotypes.

TABLE 2

Attractiveness of females to males of different populations of H. rostochiensis *measured on a logarithmic scale*

		Males			
		Woburn A*	Colyton E*	St. Leonards E*	
Females	Woburn A*	2·18	1·84	1·82	
	Colyton E*	1·82	2·13	2·18	LSD ±0·23
	St. Leonards E*	2·29	1·95	2·09	

* Predominant pathotype.

H. rostochiensis, which probably originated on the Andes plateau of South America, is now widespread in Europe but less so in Central and Northern America. Related round cyst-nematodes that exist in Mexico and North America have some common host plants in the Solanaceae. *H. rostochiensis* and *H. tabacum*, a North American species, mate and produce progeny when single males and females are brought together on

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agar plates. Different pathotypes of *H. rostochiensis* also mate, but less successfully than males and females of the same pathotype (*Rothamsted Report for 1967*, p. 147). Attempts were made to hybridise four species of round cyst-nematode with three pathotypes of *H. rostochiensis*. Two newly hatched, second stage larvae, one of each species or pathotype, were placed in a drop of water on the roots of a seedling of a common host growing in steam sterilised loam free from round cysts. None of the species or pathotypes is known to be parthenogenetic, so the presence of fertilised eggs within females indicated that the larvae added had developed into opposite sexes and mated. Table 3 shows that females were produced

TABLE 3

Matings between species of round cyst-nematodes and pathotypes of H. rostochiensis. *Percentages of tests giving females with and without eggs*

	Pathotypes of *H. rostochiensis*								
	A		B		E		Means		% tests
Species of *Heterodera*	With eggs	Without eggs	With eggs	Without eggs	With eggs	Without eggs	With eggs	Without eggs	producing females
tabacum	15	6 (89)*	15	15 (26)	17	4 (23)	15	7 (138)	22
virginiae	16	13 (88)	16	19 (31)	14	14 (28)	15	14 (147)	29
Osborne's cyst nematode	12	13 (83)	15	30 (27)	19	12 (26)	14	16 (136)	30
Mexican cyst nematode	15	10 (82)	17	29 (24)	30	4 (27)	18	12 (133)	30
Means	14	10 (342)	16	23 (108)	20	9 (104)	16	12 (554)	
% tests producing females	24		39		29				28

* Number of tests in parentheses.

in from 24 to 39% of the tests and apparently fertile eggs in 12–30%. Thus these species can mate with pathotypes of *H. rostochiensis*, but whether the progeny can survive, develop and reproduce has yet to be established. Mating between species and pathotypes indicates close relationships, in keeping with their morphological and biological similarities. If the progeny from the matings are viable and fertile, the differences observed between them are sub-specific. The genetic relations these experiments seek to unravel are of interest, not only because of the light they may shed on the taxonomy of this group, but also because they may indicate how new pathotypes arise able to multiply on the resistant varieties of potato and tomato now being bred. (Green and Dr. L. I. Miller, Virginia Polytechnic Institute, U.S.A.)

The root-knot nematodes (*Meloidogyne* spp.) are placed in the same family as the cyst-nematodes (*Heterodera* spp.) but whereas most cyst-nematodes are obligate bisexual species, most species of *Meloidogyne* are parthenogenetic although they produce males. Tests were made to see whether the females of *Meloidogyne* produce substances that activate and attract their males, as do females of *Heterodera* species. Females of *Meloidogyne arenaria* were first placed in agar blocks 1 cm diameter to allow any attractant to diffuse through the block. After 24 hours, the block was cut into 3 mm discs each bearing one female and placed singly in the centres of Petri dishes containing agar. A reference circle 1·8 cm diameter concentric with the disc was drawn dividing the Petri dish into three zones, central, inner and outer. After 3 hours, to allow any attractant to form a gradient, five active males were placed at points on the reference circle, and 30 and 60 minutes later their positions were noted. The numbers

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of males in the three zones were proportional to the areas, i.e. their distribution was random, strikingly different from that of cyst-nematodes in similar experiments. Not only was there no indication that *Meloidogyne* females produced an attractant, but the males were not stimulated to move as are those of *Heterodera* species. (Santos)

To improve success in matings between single males and females of *H. rostochiensis*, tests repeated 60 or more times were done in agar, fine sand, coarse sand and peat. Table 4 gives the percentage of females

TABLE 4

Fertilisation of females in various environments

Medium		On medium	In medium	Attached to roots	Detached from roots	Petri dish	Cavity slide
0·8% Ionagar	% Fertilised	14	29	33	10	20	23
	Eggs/female	95	128	140	83	130	93
Sand or peat	% Fertilised		21	25	17		
	Eggs/female		119	157	82		

fertilised (i.e. that produced eggs) and the mean number of eggs per female. Differences between peat and sand were small, so the results were combined. More females were fertilised, and more eggs produced when females were in agar than on an agar surface. Also attachment to roots aided fertilisation and egg production, probably because the females were not damaged by handling, and continued to feed. Females in agar did as well as in sand or peat and males could be observed in agar. A day after males were added, 68% were in contact with females on or in agar in Petri dishes (surface area 4·9 sq cm) but only 28% of those on or in agar in cavity slides (0·75 sq cm). The agar in the cavity slides may have been too little to dilute the attractant and establish a gradient, or the concentration may have been such as to cause sensory fatigue or males may have found and mated with females sooner in cavity slides and then moved away. Whatever the cause, although about the same percentage of females were fertilised in Petri dishes and cavity slides, those in Petri dishes produced more eggs.

Another experiment showed white or yellow virgin females to be more attractive to males than fertilised females or virgin females that had turned brown and were presumably dead. White or yellow virgins remained attractive for more than a month. (Greet)

The effects of chemosterilants and radiation. Some of the chemicals used as alternatives to gamma-irradiation to sterilise insect pests were tested on *H. rostochiensis*. Cysts were soaked in solutions of the chemicals and potato plants inoculated with the larvae that emerged from them and from untreated cysts. The treatments had no significant effect on the numbers of cysts produced on the inoculated plants or the numbers of eggs in these cysts, but the larvae in some eggs derived from treated cysts were not properly formed. Both 6-mercapto-purine and alpha-aceto-gamma-hydroxy butyramide significantly increased the numbers of un-embryonated eggs per cyst, and they also harmed plants less than the other chemicals tried. Nevertheless, it seems improbable that any of the chemosterilants developed for insects will be useful against nematodes.

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Various stages of *H. rostochiensis* were exposed to doses of gamma radiation up to 64000 rads. Hatching from cysts was stimulated by 8000 rads but depressed by larger doses. Irradiation had little or no effect on the mobility of larvae but affected their ability to develop in inoculated plants; fewer cysts and fewer eggs per cyst were produced as the radiation dose increased, until there were none after a dose of 32000 rads. Larvae from irradiated cysts competed poorly with unirradiated ones in infecting plants inoculated with mixtures.

Irradiation seemed not to affect mating ability of adults. Irradiated males found and mated with females, and more than 32000 rads were needed to decrease their fertility. By contrast, females exposed to only 8000 rads produced fewer eggs than unirradiated females. (Evans)

Nematodes and *Verticillium* wilt of potatoes. Further experiments with potatoes in pots confirmed that *H. rostochiensis* increased the severity of wilt caused by *Verticillium dahliae* in potatoes. Infestation with the fungus did not affect the number of cysts produced. CCC, shown elsewhere to affect *V. dahliae* in tomatoes and at Rothamsted to decrease numbers of *H. rostochiensis*, was applied when more than half the plants had emerged: it decreased significantly the incidence of *V. dahliae* and the number of cysts of *H. rostochiensis* at the end of the experiment.

When potato root systems were divided and halves inoculated with either *H. rostochiensis* or *V. dahliae*, or both, wilt developed only in plants inoculated with both together. At Woburn, fumigating soil containing both organisms with methyl bromide increased potato yields by about 8 tons/acre (see p. 149). (Corbett and Hide, Plant Pathology Department)

Control of potato cyst-nematode. In Butt Furlong, Woburn, where the sandy soil (about 10% clay) is infested with potato cyst-nematode, 'D-D' injected 9 in. deep into pre-formed ridges 7 weeks before planting potatoes, greatly decreased the invasion of the roots by larvae and increased the yield (Table 5) by up to 6·1 tons/acre. This was where 32 gal/acre were used on land given 6·7 gal/acre for potatoes in 1967. Despite the success of the 'D-D' applied in 1967 in increasing yield, at harvest there were more cyst-nematodes on 'D-D'-treated than on untreated plots. In spite of this plots given 16 gal/acre 'D-D' yielded almost as well in 1968 as in 1967.

In Long Mead, Woburn, where the soil is a loam with 39% clay, 'D-D' injected either during the autumn of 1967, or into pre-formed ridges in March 1968 seven weeks before planting, killed few larvae but increased yield. Dazomet rotavated into the top 6 in. 7 weeks before planting, and 'Temik' rotavated into the top 6 in. immediately before planting, killed more larvae and greatly decreased the invasion of roots. As little as 23 lb/acre of 'Temik' granules (10% active ingredient) increased tuber yield by 3·6 tons/acre: with 92 lb/acre, which increased yield by 6·6 tons/acre and killed more than 99% of the larvae in the ridges, the ware tubers contained 0·15 ppm 'Temik'.

'D-D', dazomet and 'Temik' were tested in peaty soil (25–30% organic matter) at the Arthur Rickwood Experimental Husbandry Farm, Mepal,

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TABLE 5

Nematicides and potato cyst-nematod

Ware tons/acre; (larval invasion % untreated plots)

Treatment	Rate gal (lb/acre)	Butt	Furlong	Long Mead	
Untreated		5·3		6·0	(100)
Autumn, 1967					
'D-D'	16 (190 lb)			7·7*	(85)
	32 (380 lb)			9·1‡	(53)
	64 (760 lb)			9·3‡	(35)
Spring, 1968					
'D-D'	4 (47·5 lb)	4·8	(100)		
	8 (95 lb)	7·0	(67)	6·6	(100)
	16 (190 lb)	9·6†	(13)	8·5†	(68)
	32 (380 lb)	11·4‡	(12)	10·5‡	(77)
Dazomet					
	(100 lb)			10·6‡	(25)
	(200 lb)			13·6‡	(6)
	(400 lb)			13·8‡	(3)
'Temik'					
	(23 lb)			9·6‡	(7)
	(46 lb)			10·9‡	(9)
	(92 lb)			12·6‡	(0·3)

*, † or ‡ significantly different from the untreated at 5%, 1% or 0·1% levels of probability.

Cambridgeshire. On a lightly infested site, 'D-D' injected 6 in. deep in rows 12 in. apart during November immediately followed by rotavation of the top 4 or 5 in. of soil decreased the invasion of roots and increased yields (Table 6, Experiment A). Plots similarly injected with 'D-D' but harrowed immediately afterwards also had fewer larvae in potato roots but the yield was not increased. The reason for this is not clear. At 46 and 92 lb/acre, 'Temik' applied at planting time killed more larvae than 'D-D' did, but gave only a slightly greater yield. Maris Piper, a variety resistant to pathotype A, the pathotype on the farm, yielded more than King Edward and its yield was not increased by 'D-D' or 'Temik'.

On an adjacent site containing more cysts, 'D-D' applied to pre-formed ridges 7 weeks before planting decreased the invasion of roots and significantly increased the yield at 32 gal/acre. (Table 6, experiment B.) Dazomet powder (prill) rotavated 6 in. deep 7 weeks before planting killed many larvae but also damaged the potato plants. 'Temik' applied at planting also killed nematodes, and at 92 lb/acre its effect was probably greater than the figures in Table 6 suggest, because the infestation was patchy and effects were therefore inconsistent.

These and previous results show that losses from the potato cyst-nematode can be diminished by treating the ridges with nematicide during spring. 'D-D' does this on sandy soils but not on loams or peats whereas dazomet does it on all three but needs to be applied to peats during autumn because it damages the plants when applied during spring. 'Temik' which is the most effective nematicide, can be applied immediately before planting and does not damage potato plants. It has the added

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TABLE 6

Nematicides and potato cyst-nematodes on peaty soil

Ware tons/acre (larval invasion % untreated plots)

Treatment	*Potato variety*		*Dosage* (gal, lb/acre)			*Means* (Vertical com-parisons only)
	Experiment A (lightly infested site)					
'D-D' in December		*Untreated*	*29 gal*	*58 gal*	*87 gal*	
harrowed	King Edward	8·5	8·5 (34)	8·5 (13)	8·1 (18)	8·4
rotavated	King Edward	8·0	9·2 (54)	9·5* (20)	10·1† (12)	9·2
'Temik' at planting			*23 lb*	*46 lb*	*92 lb*	
	King Edward	9·0	9·5 (20)	9·9 (3)	9·8 (0·3)	9·6*
	Maris Piper	11·5	12·1	11·4	12·0	11·8‡
	Experiment B (heavily infested site)					
	King Edward	*Untreated*	*8 gal*	*16 gal*	*32 gal*	*Mean*
'D-D' to ridges 7 weeks before planting		4·2	2·4 (73)	6·0 (18)	6·5* (12)	4·8
			100 lb	*200 lb*	*400 lb*	
Dazomet 7 weeks before planting		4·2	5·8 (14)	5·9 (1)	5·2 (0·1)	5·3
			23 lb	*46 lb*	*92 lb*	
'Temik' at planting		6·5	8·7* (15)	8·6* (0·6)	8·5* (0·1)	8·1†

*, † or ‡ significantly different from the untreated at 5%, 1% or 0·1% levels of probability.

advantage of killing aphids on the growing plants, but the disadvantage that it is hazardous to apply and leaves small residues in the tubers. (Whitehead and Tite)

An experiment was begun in 1966 at Woburn to see how irrigation, fumigation and growing an eelworm-resistant variety affects potato yields and the numbers of *H. rostochiensis* in the soil. One aim was to see the effects of combining fumigation with growing a resistant variety, and another an attempt to grow potatoes continuously on land where it is usually dangerous to grow them more than once in 4–5 years. One half of the experiment, now in its third year, was on land that had grown only lucerne or grass during the last 15 years and contained fewer than 1 egg/g soil. The other was on land that had grown potatoes on average once every three years and contained from 1 to 42 eggs/g (average 7·5).

Table 7 shows potato yields and numbers of eggs in soil after harvest. Irrigation had little influence on the number of nematodes. In 1966 it decreased yields by 2–3 tons/acre, in 1967 it increased them by 1½ tons and in 1968 had little effect. In 1966 the yields of Pentland Dell, an eelworm-susceptible variety, and of Maris Piper, resistant, were good on the lightly infested site. On the heavily infested site, Pentland Dell yielded poorly whereas Maris Piper yielded reasonably well. In 1967 and 1968, Pentland Dell grown for the second and third time on the same unfumigated plots yielded very little, especially on the heavily infested site. Alternating it with the resistant variety Maris Piper improved its yield more on the lightly infested than on the heavily infested site. Alternating Maris Piper with

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TABLE 7

Influence of irrigation, fumigation and susceptible and resistant potato varieties grown continuously and alternately on yield of tubers and numbers of H. rostochiensis

		Without irrigation				With irrigation			
		Pentland Dell*		Maris Piper†		Pentland Dell		Maris Piper	
		O	F‡	O	F	O	F	O	F
		Lightly infested site							
		Tons ware/acre							
1966		15·4	16·3	18·3	19·0	10·7	14·7	14·4	17·5
1967	Same	5·1	10·1	10·7	11·9	4·8	12·8	9·2	13·4
	Alternating	9·5	12·5	7·6	11·1	9·9	17·2	8·7	13·9
1968	Same	0·9	5·3	14·2	15·7	1·5	5·1	14·4	16·0
	Alternating	9·6	12·6	12·6	15·2	10·1	13·9	12·9	14·4
		Eggs/g soil, after harvest							
1965		1	1	1	1	2	1	1	2
1966		42	11	4	4	34	27	3	3
1967	Same	35	46	1	1	41	50	4	1
	Alternating	7	12	3	3	4	8	5	3
1968	Same	79	197	6	4	100	156	3	8
	Alternating	68	39	21	24	88	53	18	18
		Heavily infested site							
		Tons ware/acre							
1966		7·1	13·1	11·7	15·8	4·4	11·4	9·4	13·4
1967	Same	0·5	2·6	4·3	10·1	0·7	4·6	5·5	12·5
	Alternating	2·9	6·8	4·3	10·2	3·4	10·4	4·7	14·3
1968	Same	1·4	7·4	11·8	14·4	1·8	5·7	11·4	13·3
	Alternating	3·0	11·5	9·7	13·9	4·1	11·2	9·7	13·2
		Eggs/g soil, after harvest							
1965		15	7	7	7	5	8	7	6
1966		87	120	13	11	78	153	10	12
1967	Same	58	120	2	3	41	97	5	4
	Alternating	24	33	70	21	29	24	26	36
1968	Same	68	168	6	3	68	130	4	5
	Alternating	88	91	28	35	123	100	47	46

* Eelworm—susceptible.
† Eelworm—resistant.
‡ Fumigated with 400 lbs 'D-D'/acre in autumn.

Pentland Dell depressed its yield slightly. Fumigation with 400 lb 'D-D'/acre increased yields, especially of Pentland Dell on the heavily infested site. The kill of eggs was difficult to estimate but ranged from 70 to 90%. The numbers of eggs after harvest in fumigated plots depends on both the kill achieved and the rate survivors reproduce. Because few larvae invade roots, roots grow better than in unfumigated soil, and survivors multiply greatly in the susceptible variety. Consequently in 1967 and 1968 eggs were most numerous in plots planted with Pentland Dell and fumigated each year. The roots of Maris Piper are also bigger after fumigation, but larvae that invade them do not reproduce, so effects of growing Maris Piper and of the nematicide should be additive and, with both, egg populations could reasonably be expected to decrease rapidly. In fact they did not, but increased slightly on the lightly infested and decreased slightly on the heavily infested site. Counts of sparse populations are inaccurate but it seems improbable these changes are entirely within experimental error. If

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they are not, they are disturbing, for they suggest that the field population (mainly pathotype A) contains some individuals that reproduce on Maris Piper. If it does, this should become clearer as the experiment continues, and will show a difference from another field at Woburn, where a variety with the same genetic resistance as Maris Piper has been grown each year for 9 years without greatly increasing pathotypes that multiply upon it.

The yields of Maris Piper grown each year on fumigated and unfumigated plots have been maintained. An additional problem arose in 1968 from taint in tubers from plots fumigated with 'D-D'. Smaller amounts of 'D-D' applied during spring have not tainted tubers, but dazomet will be used instead of 'D-D' for the 1969 crop. (Jones and Parrott)

Cereal cyst-nematode. Plots that in 1967 carried varieties of barley differing in susceptibility to the cereal cyst-nematode were sown with Maris Badger, a susceptible variety, to see whether previous cropping affected the numbers of larvae in roots, the growth of tops, grain yield or numbers of eggs in the soil at harvest (Table 8).

TABLE 8

Numbers of nematodes, and yields of a susceptible variety (Maris Badger), *in 1968 after resistant and susceptible barleys in 1967*

	Resistant 1967				Susceptible 1967			
	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean
Initial eggs/g soil 1968	8·1	5·8	4·5	6·1	9·9	16·9	17·2	14·7
Larvae/g root	186·0	167·0	215·0	189·0	264·0	321·0	309·0	298·0
Top weight g (20 plants)	76·9	111·5	135·6	108·0	64·4	104·3	136·9	101·9
Grain cwt/acre, 15% moisture	21·1	28·9	35·1	28·3	18·7	26·7	33·9	26·4
Final eggs/g soil 1968	4·3	4·8	4·9	4·7	7·9	13·3	16·9	12·7

N_1 = 0·4 cwt N/acre N_2 = 0·8 cwt N/acre N_3 = 1·2 cwt N/acre

Average grain yields were significantly more, and larvae in the roots significantly fewer, after the resistant variety, than after the susceptible. The population of cysts in the soil at harvest of the Maris Badger was also influenced by the previous cropping (4·7 eggs/g after the resistant and 12·7 g after the susceptible one). Increasing nitrogen significantly increased plant growth and yield but had no effect on numbers of nematodes. Yet again *H. avenae* failed to increase in this Woburn soil after cropping with a susceptible host. As resistant barleys decrease numbers of *H. avenae* (pathotype C) significantly at Woburn and increase the yield of a susceptible crop grown immediately afterwards, when they become available they should be able to help cereal growers whose land is infested with this pathotype.

Another experiment tested the effect of trap cropping and 'D-D' on numbers of *H. avenae* and the yield of spring wheat and barley. The site was sown with oats in 1966, some of which was left to mature, whereas some was rotavated in May to lessen infestation with *H. avenae*, and some rotavated plots were also treated with 'D-D' at 400 lb/acre. The site was sown with barley and spring wheat in 1967 and 1968.

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Barley yields in 1968 were significantly affected only by nitrogen but mean yields were greater from treatment C and B than from treatment A (Table 9). Plots in treatment C given most nitrogen lodged badly and their yields were depressed. Numbers of larvae in the roots, and of eggs at harvest, were influenced significantly (P = 0·001) by the treatments

TABLE 9

The effects of different numbers of H. avenae *on spring wheat and spring barley 1968*

	A Oats to harvest 1966			B Oats rotavated 1966			C Oats rotavated, +DD 1966		
Barley	N_1	N_2	N_3	N_1	N_2	N_3	N_1	N_2	N_3
Initial eggs/g 1968	5·9	6·8	5·1	1·2	2·1	1·3	1·0	2·1	1·3
Larvae/g root	163·0	196·4	177·5	60·9	54·6	117·8	23·5	21·4	23·9
Top wts g (20 plants)	131·0	194·4	227·8	161·6	214·0	223·3	148·0	196·6	248·3
Grain cwt/acre 15% moisture	25·7	34·0	36·7	26·6	36·8	37·7	32·3	34·8	34·0
Final eggs/g 1968	5·9	7·3	5·4	1·9	1·5	3·9	1·8	0·6	1·3
N_1 = 0·4 cwt/acre			N_2 = 0·8 cwt/acre			N_3 = 1·2 cwt/acre			
Wheat									
Initial eggs/g 1968	4·3	5·0	7·3	1·0	2·1	2·3	0·4	0·0	1·0
Larvae/g root	159·6	116·4	141·6	52·9	52·4	40·0	29·9	16·6	13·9
Top wts g (20 plants)	90·6	152·1	195·5	131·6	151·0	217·6	124·3	196·6	236·3
Grain cwt/acre 15% moisture	22·3	35·1	41·0	26·7	36·9	41·7	28·2	40·4	41·2
Final eggs/g 1968	5·4	5·2	5·2	2·5	2·1	2·9	1·3	0·8	1·2
N_1 = 0·6 cwt N/acre			N_2 = 1·2 cwt N/acre			N_3 = 1·8 cwt N/acre			

applied in 1966. Weights of tops were significantly affected only by N, which had no effect on final egg populations.

Wheat grain yields also were not significantly affected by the previous treatments but treatment means were again in the order C B A. Increasing nitrogen significantly increased yields. Rotavation made invading larvae significantly fewer (P = 0·01) and with 'D-D' there were fewer still (P = 0·001). Weights of tops were significantly affected only by N. Treatments B and C significantly decreased the final numbers of eggs/g soil (P = 0·001), which were unaffected by nitrogen.

H. avenae did not increase during the year 1968 in plots carrying either barley or wheat. Although nematodes in 1968 were significantly fewer where control measures were applied in 1966, even without these treatments populations were too small to depress growth of wheat and barley significantly.

At Rothamsted also, despite the monoculture with wheat, *H. avenae* fails to increase in Broadbalk to numbers that depress yield significantly. (Williams)

Cereal root-knot nematode

Population changes of cereal root-knot nematode (*Meloidogyne naasi*) in soil and in barley were studied in a field near Reading. Soil samples were

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collected monthly and the larvae extracted from sub-samples by the tray method (*a*) after 24 hours and (*b*) after incubating for a week at 20° C. (Table 10.) From March to November (except for the April and May samples) there were about 150 larvae/100 ml soil and little difference

TABLE 10

Effect of soil temperatures and incubation on larvae of Meloidogyne naasi *extracted*

Sampling date	Mean soil temperature during the previous 2 weeks 15 cm deep* °C	Mean number of larvae recovered from 100 ml soil: 24 hours after sampling 0–8 cm	24 hours after sampling 8–20 cm	after a week at 20° C 0–8 cm	after a week at 20° C 8–20 cm
11 March	2·4	120	127	96	302
8 April	6·0	551	1304	4496	7821
6 May	10·5	1758	2537	2683	2050
4 June	13·0	200	181	223	207
1 July	16·2	93	77	427	210
30 July	16·4	84	60	133	78
26 Aug.	15·7	161	119	187	169
23 Sept.	14·1	192	208	229	186
21 Oct.	12·3	194	384	2181	7521
18 Nov.	5·4	221	207	2243	3103

* Mean of temperatures 0–8 and 8–20 cm deep; differences were slight.

between samples taken 0–8 and 8–20 cm deep. In April, after many overwintering eggs had hatched, there were 551 and 1304 larvae/100 ml, and in May 1758 and 2537 at these two depths, but June numbers were again fewer at about 200/100 ml. The soil temperature in April during the two weeks before eggs hatched averaged 6° C (43° F) whereas in May after hatching it was 10·5° C (51° F). Most subsamples incubated at 20° C for a week yielded the same number of larvae as those not incubated, but incubated samples taken in April yielded many more (4496 and 7821 larvae/100 ml at 0–8 and 8–20 cm deep respectively) because rising soil temperature in the field stimulated eggs which all hatched within a week at 20° C. In May there were fewer, about 2250/100 ml at both depths, whether the subsamples were incubated or not, for by then many larvae had entered barley roots. Incubation increased the numbers of larvae extracted again in October, because the soil then contained many new egg masses produced by females in the barley roots. The deeper samples contained more (7521 compared with 2181/100 ml) because there were more roots 8–20 cm deep as the land had not been ploughed.

Barley sown early in March germinated about 2½ weeks later. The roots were free from larvae at the end of the first week in April but were invaded at the middle of the month, when there were about 20 in each root tip and up to 50 larvae/mm of root. By the end of the first week in May larvae had established feeding sites, giant cells were developing and the roots were galled. Adult females were first observed in mid-June and by mid-July all were mature. Egg laying began early in July. But although soil temperatures exceeded 15° C (59° F) in July and August and ranged from 13 to 15° C in September, few eggs hatched in the field. Cold may be needed before the eggs hatch. These observations confirm that in cereals *M. naasi* has one generation only in a year and that the eggs overwinter.

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Couch grass, *Agropyron repens*, is an alternative host that vegetates the year round. In November its roots bore many galls and many females with egg sacs but no developing stages, so again there was no evidence of a second generation although the soil was warm enough for eggs to hatch and develop. When estimating numbers of larvae in soil, it is important to collect samples when larvae are free or eggs are ready to hatch, i.e. not between October and April. Whether hatch can be induced at other times by chilling remains to be tested. (Franklin)

Root-lesion nematodes

Root-lesion nematodes (*Pratylenchus* spp) are common migratory root endoparasites in British soils. *P. thornei* parasitises wheat on Broadbalk, *P. minyus* (formerly *P. neglectus*) is common at Rothamsted and more numerous at Woburn, and *P. fallax* parasitises barley and other crops in the East Midlands.

In September 1967, in an attempt to eliminate *P. thornei*, a 10 ft strip was fumigated across the Broadbalk plots in a discard area that has grown only winter wheat since 1843. The fumigant was methyl bromide applied at 2 lb/100 sq ft under a gas-tight sheet. Winter wheat was sown in December and, by April 1968, the fumigated strip was greener than the corresponding unfumigated strip. In May patches that were taller and greener coincided with points where the fumigant was released. In June, just before the ears emerged, these patches turned yellow and the tips of leaves died. Affected plants contained extra bromine (see page 141). Effects of fumigation on yields were inconsistent but on average fumigated plots yielded a little more; they also contained fewer nematodes (Table 11).

The effect of *P. fallax* on barley was tested at Papplewick, Notts., where three nematicides and a herbicide were applied, and of *P. minyus* at Woburn, where the three nematicides were applied (Table 12).

TABLE 11

Effect of fumigating strips of Broadbalk with methyl bromide

	FYM only	No manure	Complete minerals No N	Complete minerals N_1	Complete minerals N_2	Complete minerals N_3	N_2 only	Mean all plots
			Yield, cwt grain/acre					
Fumigated	18·6	16·4	16·2	24·2	27·9	20·8	9·9	20·9
Unfumigated	23·8	11·8	12·1	21·1	28·0	23·9	12·7	20·0
			Pratylenchus/100 ml soil, geometric means					
September 1967, before fumigating	76	135	447	316	269	269	151	191
January 1968, after planting								
Fumigated	246	0	20	0	5	10	0	5
Unfumigated	316	120	209	159	186	251	5	96
			All nematodes/100 ml soil, geometric means					
September 1967, before fumigating	2140	1150	1950	1910	1410	2190	1230	1660
January 1968, after planting								
Fumigated	3240	40	65	100	150	19	10	140
Unfumigated	2400	1000	1020	576	950	460	260	690

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TABLE 12

Effect of nematodes on P. fallax *and barley*

Treatment	Un-treated	Amino-triazole	'D-D'	'Temik'	Chloro-picrin	S.E.
	Papplewick, Notts.					
Barley, cwt/acre	32·4	30·6	35·2	35·2	37·4	1·58
Log *Pratylenchus*/g root	2·80	2·96	2·01	2·22	2·19	0·12
Log *Pratylenchus*/litre soil	3·21	3·09	2·52	2·74	2·64	0·08
Log all nematodes/litre soil	4·37	4·26	4·38	4·12	4·61	0·05
	Butt Close, Woburn					
Barley, cwt/acre	25·4	—	23·4	22·1	30·3	0·78
Log *Pratylenchus*/g root	0·82	—	0·60	—$\bar{1}$·60	0·43	0·21
Log *Pratylenchus*/litre soil	3·17	—	2·66	2·04	2·56	0·24
Log all nematodes/litre soil	4·28	—	3·79	3·62	4·11	0·09

At both places only chloropicrin significantly increased the yield of barley grain. At Papplewick, 'D-D', 'Temik' and chloropicrin significantly decreased the numbers of *Pratylenchus* in roots and soil. The plots treated with 'D-D' contained fewest *Pratylenchus* and those treated with 'Temik' fewest nematodes of all kinds. At Woburn only 'Temik' decreased *Pratylenchus* significantly in roots and soil but damaged the barley and decreased yield significantly. At both places, the main effect of 'D-D' and chloropicrin was by mineralising soil nitrogen. Treated plots given the largest amount of nitrogen fertiliser (1·2 cwt N/acre) lodged badly. At Papplewick, chloropicrin increased yields more than that expected from the mineralisation of nitrogen, presumably by killing pathogens, including *P. fallax*.

CCC (Chlorocholine chloride), a growth substance that shortens stems of cereals, also influences plant endoparasitic nematodes (*Rothamsted Report for 1966*, p. 160). It was applied at planting, when seedlings emerged, and 3 and 5 weeks after planting wheat and barley grown in pots of soil infested with *P. minyus* as well as on all four occasions (Table 13). Untreated pots with barley contained more nematodes than those treated with CCC at planting, and these were fewest when it was applied on all four occasions. Also, with wheat nematodes were fewest when CCC was applied on all four occasions. Applied when seedlings emerged, numbers of *P. minyus* were fewer than in untreated pots, but at 3–5 weeks after planting it had little effect, so when applied to shorten straw and prevent lodging in

TABLE 13

Effect of CCC on Pratylenchus minyus *in the roots of cereals in pots*

	Untreated	CCC applied at planting	CCC applied on emergence	CCC applied 3 weeks after planting	CCC applied 5 weeks after planting	CCC applied on all four occasions	S.E.
Log *Pratylenchus*/g root							
Wheat	2·51	2·13	1·73	2·36	2·19	1·16	0·20
Barley	2·12	1·65	1·82	2·43	2·12	1·10	
Log *Pratylenchus*/litre soil							
Wheat	2·97	1·78	0·43	2·23	1·84	1·47	0·43
Barley	2·90	1·10	2·00	2·14	2·65	1·36	

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field crops, it is improbable that it could check infestation of roots or soil.

To find whether *P. fallax* injured cereal roots and avoid the complications that arise from bacteria and fungi in field soils, tests were done with sterile root cultures. When sterile roots were inoculated with sterile nematodes in nutrient agar, the nematodes were attracted to wheat and barley root-tips and to the root hair zone immediately behind them. They also gathered around the points where lateral rootlets of wheat emerge and within 24 hours were attempting to penetrate cells. The first brown discoloured areas were seen within 12 days and after 2 months the central conducting strand of the roots was brown and dying, as were areas in the cortex. Some roots had begun to disintegrate and, in addition to being discoloured, some had rough surfaces and were slightly swollen.

The nematodes were less attracted to the roots of sugar beet than to those of wheat and barley. The most attractive areas were the junctions between laterals and the main root, and within 24 hours many had penetrated at these points. After 3 days the nematodes had stimulated the production of more lateral roots and, after 12 days, parts of the central conducting strand were discoloured and dying. Discolorations appeared wherever the nematodes had fed and some young lateral roots had rough surfaces and were club-shaped. Many nematodes fed inside and outside the roots at root-tips and at the junctions of lateral and main roots, which were penetrated preferentially. After 2 months, roots had large diffuse brown areas in the cortex and dark brown and dying conducting tissue. Laterals were short and stubby. Again, there were many worms and eggs within the roots and free in the agar. After 2 months in the roots of cereals the nematodes had multiplied almost ten times and were evidently injurious. Reproduction barely maintained the initial inoculum level in the sugar-beet roots, which were severely damaged. (Corbett and Webb)

Root ectoparasitic nematodes

A needle nematode (*Longidorus elongatus*), previously known to attack sugar beet only on coarse sandy soils derived from greensand and from Bunter sandstone, was found attacking crops on light fen peat soil in Stoke Ferry and Feltwell Fens, Norfolk. Either in the field or in pots, *L. elongatus* attacked sugar beet, red beet, carrots, kale, cabbage, Brussels sprout, turnip, radish, cress, dwarf bean, tomato, celery, onion, oats, wheat, American tall fescue and cocksfoot grass; it produced characteristic galls on the roots of all these plants. (Whitehead)

To study changes in the numbers and kinds of root ectoparasitic nematodes in the Ley Arable experiment at Woburn, soil samples were taken at intervals and the nematodes extracted. The commonest were *Tylenchorhynchus dubius*, *Paratylenchus microdorus* and *Trichodorus primitivus* but *Tyl. maximus*, *Tyl. icarus*, *Para. bukowinensis*, *Tri. cylindricus*, *Longidorus leptocephalus*, *L. caespiticola* and *Hemicycliophora typica* also occurred, in addition to many *Pratylenchus minyus*, a migratory root endoparasite (see page 164). In 1967 all species decreased to a minimum in mid-summer and increased again to a maximum in November. In 1968 the summer minimum was less pronounced. Numbers were greatest with leys, sainfoin, rye and barley and smallest with sugar beet, potatoes and

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TABLE 14

Longidorus *spp/litre in plots of the Ley Arable Experiment (Woburn)*

1967 1968	Ley All plots	Hay Barley	Crops grown Sainfoin	Carrots	Dunged	Undunged
			Longidorus/litre soil			
1967	500	450	10	45	278	225
1968	123	140	33	63	98	76

TABLE 15

Nematode population (October 1967–October 1968) under crops grown continuously in microplots

Numbers per litre of soil

	Clover		Potato		Brussels sprout		Peas		Oats		Carrots		Sugar beet		Means	
	Sand	Chalk	Sand	Chalk	Sand	Chalk	Sand	Chalk	Sand	Chalk	Sand	Chalk	Sand	Chalk	Sand	Chalk
Tylenchorhynchus	1606	656	44	0	4931	338	1050	31	1994	656	394	213	63	125	1269	288
Trichodorus	275	6	200	0	669	0	213	0	81	0	75	6	106	0	231	2
Paratylenchus	6475	506	25	13	138	231	56	25	44	106	569	31	625	2619	1132	504
Pratylenchus	381	125	63	125	650	675	44	19	1825	1181	25	63	194	100	454	363
All kinds	21163	9306	4825	4256	13688	6419	7456	3481	13550	10294	8519	4213	8525	6313	11103	6326

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carrots. There were very many *Paratylenchus* in all crops (maximum in any plot, 30750 per litre) and also many *Tylenchorhynchus dubius*. *Tyl. icarus* and *Tyl. maximus* were mostly in leys. *Trichodorus primitivus* and *Pratylenchus minyus* also occurred in most crops. A few *Hemicycliophora typica*, a root-tip feeder, occurred in leys, sanfoin, potatoes and sugar beet. Because of their great length *Longidorus* spp were extracted by sieving and were most abundant after grass and least after carrots and sainfoin (Table 14). Barley supported fewer than grass but more than sainfoin or carrots.

To observe the influence of crops grown continuously rather than in rotation, some microplots of Woburn sandy soil at Rothamsted were studied and compared with similar plots holding a chalky soil from Winchester. (See also *Rothamsted Report for 1967*, p. 142). *Tylenchorhynchus*, *Paratylenchus*, *Helicotylenchus*, *Tylenchus* and *Aphelenchus* occurred in both soils although not always the same species. *Trichodorus*, *Longidorus* and *Criconemoides* occurred in the Woburn soil but not in the finer textured chalk soil. *Tylenchorhynchus dubius* in the Woburn soil was in larger numbers than *Tyl. brevidens* and the reverse in the chalk soil. The sandy soil contained almost twice as many nematodes of all kinds as the chalk soil (Table 15). The dominant genus was *Paratylenchus*. Clover supported more nematodes than any other crop although there were more *Trichodorus* with Brussels sprout and more *Pratylenchus* with oats. (Mojica)

After our work showing that small amounts of 'D-D' injected beneath predetermined rows greatly increased yields of sugar beet on sandy soil infested with root ectoparasitic nematodes (chiefly *Trichodorus* spp. and *Longidorus attenuatus*), Ripper Farms Ltd., Docking, Norfolk, treated 115 acres at 1 ml 'D-D'/ft (6·4 gal/acre) 2–3 weeks before sowing. Seedlings grew evenly and comparisons with areas left untreated showed obvious benefits. On 11 June seedlings from untreated rows weighed only 0·4 g and had 1000 *Trichodorus* (chiefly *T. cylindricus*) per litre of soil close to their roots, whereas seedlings in treated rows weighed 6·0 g and the soil had only 150 *Trichodorus*/litre. The plants in treated rows were larger and greener and the roots yielded 49 cwt sugar/acre, 18 cwt/acre more than roots from untreated areas.

In a field at Docking where beet is usually stunted but only lightly infested with *L. attenuatus*, four experiments were done to determine the effects of applying 'D-D' to the soil in autumn by a specially adapted reversible plough, or by knife tines on a tractor-drawn toolbar in autumn and in spring. 'D-D' injected by a three-furrow reversible plough on 26

TABLE 16

Effect of 'D-D' injected into plough furrows in autumn on yield

'D-D' ml/sq ft	'D-D' gal/acre	Sugar cwt/acre
0	0	23·3
½	4·8	23·5
1	9·6	31·9*
2	19·2	35·0†

*, † or ‡ significantly different from the untreated at 5%, 1% or 0·1% levels of probability.

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October 1967 killed a large number of nematodes only at 19 gal/acre, but it significantly increased sugar yield at 9·6 and 19·2 gal/acre (Table 16).

In four other experiments on the same field 'D-D' or 'Telone' (dichloropropenes) were injected beneath predetermined beet rows. 'D-D' injected at 6·5 or 13 gal/acre by the reversible three-furrow plough in September greatly increased the yield of sugar (Table 17). In an adjacent experiment

TABLE 17

Effect on sugar yield of 'D-D' and 'Telone' injected beneath rows before sowing

Sugar cwt/acre

Injected Autumn 1967—'D-D' only

		Reversible plough, 8 in. deep in rows 12 in. apart				Knife tines, rows 18 in. apart. Depth of injection			
	gal/acre	Un-rolled	Rolled once	Rolled twice	Means	3 in.	6 in.	9 in.	Means
	0	29·2	28·3	29·3	28·9	35·4	38·0	29·7	34·4
	3·25	31·7	38·0	26·5	32·1	40·4	36·3	36·8	37·8
	6·5	35·7	41·5*	38·6	38·6*	35·0	38·9	33·7	35·9
	13·0	37·9	40·9*	43·7*	40·8*	41·5	37·7	44·5*	41·2*
Means of treated plots only		35·1	40·1	36·3		39·0	37·6	38·3	

Injected Spring 1968

		'D-D'				'Telone'			
Depth of injection		3 in.	6 in.	9 in.	Means	3 in.	6 in.	9 in.	Means
Untreated		39·1	40·7	40·7	40·2	40·3	41·3	37·6	39·4
Treated	2	42·4	42·6	41·8	42·3	42·6	43·7	43·9	43·4
	4	45·6*	46·6	47·6*	46·6*	44·3	48·2	45·0	45·8
	8	46·8*	49·0*	48·8*	48·2*	48·2*	49·3*	51·9†	49·8†
Means of treated plots only		44·9	46·1	46·1		45·0	47·1	46·9	

*, † or ‡ significantly different from the untreated at 5%, 1% or 0·1% levels of probability.

13 gal/acre injected by knife tines on 23 September 1967 also significantly increased sugar yield. As little as 4 gal 'D-D'/acre injected by tines in March significantly increased the sugar yield of beet drilled in the rows three weeks later. Eight gal/acre 'Telone' applied similarly was also beneficial. Differences between depths of injection were small, 6 or 9 in. were better than 3 in. Most of the *L. attenuatus* were killed by 4–8 gal/acre 'D-D' injected beneath the predetermined rows but few *Pratylenchus* spp. and *Tylenchorhynchus* spp. Thus, small amounts of 'D-D' injected beneath predetermined sugar-beet rows can increase sugar yield even in lightly infested land, and the injection can be done in spring when soil and weather are often more suitable than in autumn. (Whitehead and Tite)

Conjoint and other work

T. D. Williams collaborated with D. Hornby (Plant Pathology Department) on the interaction between the 'take-all' fungus and the cereal

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cyst-nematode. C. C. Doncaster collaborated with P. S. Nutman (Soil Microbiology Department) in studying the infection of clover root hairs by nodule bacteria, using time-lapse cinematography. He also made a film, 'Behaviour of *Heterodera* species through the life cycle', 16 mm colour and monochrome; it has a commentary and explanatory diagrams, runs for 35 minutes and can be hired or bought from the British Film Institute.

Staff and visiting workers

A. G. Whitehead visited Dominica and other Islands of the Windward group, at the request of the Commonwealth Development Corporation, and with Dr. J. E. Edmunds of the Windward Islands Banana Research Scheme, laid down field trials to try and control the burrowing and other nematodes of bananas. At the request of the Barbados Ministry of Agriculture, he also visited Barbados. D. C. M. Corbett spent a month in Bolivia surveying plant diseases for the Ministry of Overseas Development. A. G. Whitehead, D. J. Hooper and F. G. W. Jones took part in the Caribbean Symposium on 'Nematodes of Tropical Crops' sponsored by the Commonwealth Development Corporation and the Food & Agriculture Organisation, Rome. Afterwards, D. J. Hooper and F. G. W. Jones visited centres of nematological research in the U.S.A. and Canada. F. G. W. Jones organised a series of symposia in the First International Congress of Plant Pathology held in London in July in which most members of the Department participated. Several members of the Department assisted with courses at Imperial College Field Station and at the School of Agriculture, Cambridge.

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