ROTHAMSTED RESEARCH

Report for 1973 - Part1

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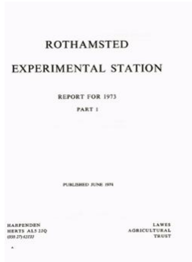
ROTHAMSTED
EXPERIMENTAL STATION
REPORT FOR 1973
PART 1

Nematology Department

F. G. W. Jones

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NEMATOLOGY DEPARTMENT

F. G. W. JONES

1973 in retrospect

During the year the work of the department was disrupted by yet another move, this time to permanent quarters in the new Bawden Building. Staff changes and secondments abroad also affected laboratory work. Fieldwork continued without hindrance, and the appointment of S. Moss in October 1972 enabled us in collaboration with ADAS, to begin the testing of granular nematicides on a range of soils. Work on cereal cyst-nematodes was strengthened by the appointment of B. R. Kerry in April 1973. Projects terminated include attempts to simulate by computer models the way in which male cyst-nematodes are attracted to their females and studies of the relationship between sex ratios and resistance to cyst-nematodes.

Identification, structure and function of nematode organs. Because the external and internal structures of nematodes lie near the limits of resolution of the light microscope, the department has turned increasingly to scanning and transmission electron microscopy. The Stereoscan microscope enables surface features to be seen clearly and greatly aids the identification and separation of species (p. 150). Unfortunately, specimens are viewed under vacuum which tends to shrink and distort them. Infiltration with epoxy resin offers a solution to this problem (p. 151). The transmission electron microscope has revealed that nematodes possess a hitherto undescribed valve mechanism (p. 151). Although electrophoresis of soluble proteins in polyacrylamide gels is sometimes a helpful tool in separating nematode species, proteins from host plants sometimes influence the protein band patterns displayed (p. 151). Our facilities for advanced ciné and other photography have been much improved (p. 151) and have greatly helped in understanding the mechanics of stylet action when piercing egg shells and cell walls.

Population studies. Several years' work on the population dynamics of the potato cyst-nematode, which appears to have no effective enemies (publ. 8.13, p. 341), shows that it behaves classically, i.e. in a manner predictable from simple mathematical models. The cereal cyst-nematode, however, which may have an effective enemy (p. 159) behaves unpredictably. It has long been known that some races of potato cyst-nematodes and of the cereal cyst-nematode are able to multiply on resistant cultivars whereas others are not. The department is participating in international schemes to type populations of both kinds of nematode and holds under licence many cultures from abroad. Work on typing, morphology and biology of these cultures continues (pp. 152, 158). Attempts to unravel the inheritance of ability to overcome major gene resistance have proceeded slowly and more evidence has accumulated in favour of the gene-for-gene hypothesis (p. 153). The ways in which the two closely related species of potato cyst-nematode compete is still little understood (p. 153). Information on these topics is valuable to plant breeders and is basic to the rational use of resistant varieties.

Tests with a second major gene for resistance (H_3) from *Solanum tuberosum* spp. *andigena* found by Dr. H. W. Howard, Plant Breeding Institute, confirms his findings that it is useful against the two British pathotypes (B and E) of *Heterodera pallida* (p. 154). Tests on a species of round cyst-nematode that occurs on the eastern seaboard of the USA suggests it is not a potential threat to potato crops (p. 155). To study this

https://doi.org/10.23637/ERADOC-1-130

and other related species A. R. Stone was seconded to Virginia Polytechnic Institute and State University for six months. For similar reasons and to search for specific enemies of round cyst-nematodes, K. Evans was seconded to the International Potato Center, Lima, Peru. Preliminary observations suggest that the commonest species in Peru may be *H. pallida* but more work is needed to confirm this and to determine the pathotypes.

Analysis of a long-term population experiment at Woburn is under way (p. 156). Results so far confirm that soil fumigants exert inadequate population control even on sandy soil where they perform best. Here *H. pallida* pathotype E is replacing *H. rostochiensis* pathotype A in plots where a variety resistant to pathotype A is grown continuously and, contrary to expectation, the rate of replacement is, if anything, enhanced by fumigation. The effects on nematode populations of growing resistant and susceptible varieties alternately appear to depend on which is planted first. Abroad, early lifting of early potatoes is a recommended method of preventing population increase and trap-cropping is also sometimes advocated. Both are fraught with difficulties (p. 157). An artificial hatching agent effective in the laboratory is ineffective in the field.

Populations of cereal cyst-nematode after resistant and susceptible oats were studied (p. 158). Attempts to study the relationship between this nematode and a condition in cereals known as 'scorch' in which plants seem to be deficient in copper were thwarted as the condition failed to develop (p. 158).

Bean straw is a potent source of inoculum of the oat and giant races of stem nematode. The latter damages beans most and persists for five years and possibly longer after an infested bean crop (p. 159). Heat treatment failed to dislodge infestations from seed but aldicarb diminished the number of stems attacked.

Nematicide trials. Attempts to eliminate both potato cyst-nematode and *Verticillium dahliae* which interact to damage potato crops severely, revealed that the fungicide benomyl is a potent and persistent nematostat, i.e. it prevents nematode larvae invading roots (p. 159). Most of our work on nematicides is against cyst-nematodes because these are more difficult to kill than other kinds and methods effective against them are likely to be more so against most non-cyst-forming species. In the main, potato cyst-nematodes (p. 160) are used as models because they are widespread and suitably infested sites on a range of soil types are easily obtained. However, this year some trials are on sites infested with beet (p. 162), pea (p. 162) and cereal cyst-nematodes (p. 163). One trial was against stem nematode with onions as the test crop (p. 164). Earlier work explored the potentialities of soil fumigants but this year we concentrated increasingly on granular nematicides applied in spring and began to explore the effects of different ways of incorporating them (p. 164). From all our field experiments since 1968 we conclude that cyst-nematodes can be controlled and that the most convenient and most useful nematicides are the oxime carbamates and some organophosphorus compounds, all of which can be applied as granules in spring immediately before planting.

Microscopy and photography

Surface morphology of root-lesion nematodes. To find new characters for the separation of the many closely allied species in this ubiquitous genus and to clear up obscurities not resolved by light microscopy, 12 species of *Pratylenchus* were examined under the scanning electron microscope. In face view there are six papillae closely adjoining and surrounding the oval mouth. The 'face' includes the fused lips and the first body annule, and may or may not be sub-divided. *P. brachyurus*, *P. coffeae*, *P. crenatus*, *P. loosi* and *P. zeae* have plain, undivided 'faces' whereas in *P. neglectus* and *P. thornei* the 'face' is divided into subdorsal and subventral segments separated by lateral segments.

https://doi.org/10.23637/ERADOC-1-130

P. andinus, *P. fallax*, *P. penetrans*, *P. pinguicaudatus* and *P. vulnus* have the 'face' similarly divided, but the segments are more angular. The scanning electron microscope also shows that features now used to separate species, e.g. number of head annules, crenation of the tail tip and the structure of the lateral field are more variable and less reliable than previously realised. (Corbett and Clark)

Preparation of nematodes for the scanning electron microscope. Preparation of nematodes for scanning electron microscopy is difficult. Water or other volatile substances must be absent before nematodes can be placed in the vacuum chamber for examination. Replacement of the water by a less volatile liquid is not entirely successful but when nematodes are slowly processed into acetone and infiltrated with an epoxy resin, shrinkage and distortion are avoided with larvae and males of *Heterodera* spp., and with juveniles and adults of *Pratylenchus* spp. and *Aphelenchoides* spp. After infiltration the resin is partly polymerised and any excess is washed away with acetone. Polymerisation of the resin within the nematode tissues is completed on the specimen stub of the microscope and gives hard, durable, clean-surfaced specimens which can be coated with metal for examination. (Stone and Clark)

Unusual valve structures in the intestines of nematodes. No obvious lumen can be seen in serial electron-microscope sections of the closed oesophago-intestinal valve of *Thornenema wickeni* or of the rectal valve of *Aphelenchoides blastophthorus*. Nevertheless the intestines of adult *T. wickeni* contain organic food materials (*Rothamsted Report for 1972*, Part 1, 156–7) which must have passed the oesophago-intestinal valve, and the rectal valve of *A. blastophthorus* opens widely during defaecation (*Rothamsted Report for 1972*, Part 1, 351, publ. 8.26). In sections of both valves, the opposing three-layered gut-cell membranes are closely adpressed and greatly convoluted in the region joining the microvillate intestinal wall to the cuticularised lining of the oesophagus (*T. wickeni*) or the rectum (*A. blastophthorus*). Although both valves close tightly, they open under pressure to allow the passage of a large volume of food or faeces. (Seymour and Shepherd)

Polyacrylamide gel electrophoresis. Attempts to establish whether the similarities and differences between electrophoretically developed protein patterns of the round cyst-nematodes are determined entirely by species, pathotype, or population, or whether they are affected by the proteins from the host plant on which they fed, suggest that some currently recognised species of nematodes share the same patterns when grown on the same host (e.g. *H. mexicana*, *H. solanacearum*, *H. tabacum* and *H. virginiae* cultured on tomato) but have slightly different patterns when grown on other hosts, e.g. potato and *S. dulcamara*. *H. rostochiensis* (pathotype A) is the same when grown on *S. dulcamara* or on tomato, but has a distinctly different pattern when grown on potato. Host plants, therefore, appear to influence protein patterns of some nematodes. Before electrophoresis can be used as a reliable taxonomic tool the host and other conditions must be defined. (Greet and Firth)

Facilities for advanced cinéphotography. Information on life processes in nematodes and other micro-organisms can be obtained by analysing ciné and still photomicrographic records but specimens must be shielded from vibrations which greatly impair the quality of the photographic image. The new photomicrographic column installed in the basement of the Bawden Building is designed to carry inverted and erect microscopes and for still- or ciné-photomicrography. The column weighs 5000 kg and has a basal inertia block of concrete, 1·25 m square and 1 m deep, sunk 5 cm below floor level. Integral with the

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block is the main column of concrete carrying two optical benches mounted vertically. Under one of these stands a heavy microscope table with legs passing through spaces in a floor panel. This arrangement allows the operator to film specimens without transmitting vibrations to them. The basal block can be isolated from the building by raising it some 3 mm on four mounts inflated with air at 7 kg/cm^2. When inflated the mounts automatically compensate for variations in load distribution and keep the optical benches vertical. The mounts have a low natural frequency (about 2 Hz) and provide efficient vibration damping over a wide range of frequencies and amplitudes.

A rapid system for selecting and copying individual frames from ciné film has been made with help from the Instrument Workshops. (Doncaster)

Mechanics of stylet action. All injurious plant-feeding nematodes possess mouth stylets which are organs used for piercing plant cells and extracting sap. They may also be used to pierce the egg shell during hatching and to cut a path through cells when nematodes are invading root or stem structures. Previous studies (p. 342, publication 8.21) concerned the frequency and direction of stylet movements during hatching and feeding. To simulate the distribution of stress in stylets a photoelastic method was used. Large-scale models of slices of stylet bases and tips were cut from perspex, a stress-birefringent material. Each model was placed between crossed polaroids and its image projected on a screen. Where the material is stressed, double refraction is induced and the two emerging light rays vibrate perpendicularly to each other, in the directions of the two principal stresses in the model (compressive and tensile). At all points in the model where the two principal stresses lie parallel to the optical axes of the polaroids, dark lines (isoclinics) appear on a bright image of the model. As the settings of the polaroid axes are known, the principal stress directions at points along each isoclinic can be drawn on the projected image or superimposed photographically. By rotating the crossed polaroids relative to the model, a set of isoclinics is obtained and from them stress trajectories are drawn. One set shows the directions of compressive stresses and the other the directions of tensile stresses.

In a model based on *Heterodera cruciferae*, the stylet was stressed by an axial thrust on the shaft to simulate resistance to piercing and the stress was balanced by artificial muscles made of linen tape which were glued to the knobs at the base of the stylet. From this model stress lines were mapped. It has been observed that stylets bend when nematodes explore surfaces and also during feeding. Changes in the stress pattern were mapped when bending forces were applied to the model. So long as induced stresses are within the elastic range of the material from which the model is made, the principal stress directions found for plastic models seem to portray accurately those in very different materials, e.g. steel girder, mammalian femur and probably do so for the substance of which nematode stylets are made. (Seymour)

Pathotypes and populations

Inheritance of ability to overcome resistance. Previously we suggested that ability to overcome resistance followed the principle established for microorganisms, fungi and some insects, i.e. that dominant genes for resistance in the host were usually matched by recessive genes in races able to overcome that resistance. This is the basis of the gene for gene hypothesis (Person, C. (1968) In: *The fungi*. Ed. C. S. Ainsworth & A. S. Sussman, London: Academic Press, Vol. III, 395–415). Unfortunately the evidence adduced earlier (Jones & Parrott, *Annals of Applied Biology* (1965), **56**, 27–36) was indecisive and has since been invalidated by the finding that there are two species of potato cyst-nematode that do not interbreed freely. However, within both species patho-

TABLE 1

Behaviour of the F_1 and F_2 progeny of bulk crosses between H. rostochiensis *British pathotype A and a population from Bolivia*

	Number of females produced on potatoes with gene H_1					
	F_1			F_2		
Mating ♀ ♂	Number observed	% observed	% expected	Number observed	% observed	% expected
A × A	4	1	0	6	1	0
A × Bolivia	23	8	0	111	22 } 25	25
Bolivia × A	20	7	0	143	28 } 25	25
Bolivia × Bolivia	298	100	100	504	100	100

types have been identified which do interbreed, so the hypothesis can be applied to them. Last year (*Rothamsted Report for 1972*, Part 1, 161) we reported on bulk crosses between pathotypes within *H. rostochiensis* which suggested that the individuals able to multiply on hybrid potatoes with the major gene H_1 for resistance were recessives. These tests have continued with the results shown in Table 1 which tend to confirm the suggestion more strongly than before. Tests have also begun on the interrelationships between British pathotypes B and E of *H. pallida* which can be distinguished by gene H_2 derived from *Solanum multidissectum*. Pathotype B is unable to reproduce on hybrid potato plants with this gene but pathotype E can do so. The behaviour of F_1 crosses on plants with gene H_2 also suggests that pathotype E contains recessive genes able to overcome this resistance but more tests are needed in F_1 and F_2. All crosses reproduced equally well on plants with gene H_1. It was hoped that these crosses would show whether the white colour of pathotype E females was recessive to the cream of pathotype B females but colour differences were too slight to be readily distinguished.

Further knowledge about the inheritance of ability to overcome resistance and about the interrelations of pathotypes would be helpful to plant breeders and in forecasting the effect of repeated cultivation of resistant varieties. A mathematical model already made (Jones, Parrott & Ross, *Annals of Applied Biology* (1967) **60**, 151–171) was used to predict events in populations where individuals interbreed freely. Predictions from the model suggest that selection of recessives able to overcome resistance would be slow. Unfortunately the principal pathotypes in the UK (pathotype A of *H. rostochiensis*, pathotype E of *H. pallida*) do not interbreed freely and plants with gene H_1 select mixed populations rapidly in favour of pathotype E (*Rothamsted Report for 1972*, Part 1, 161). (Parrott and Berry)

Competition between pathotypes. Little is known about the ways in which the two species of potato cyst-nematodes compete but females of both species attract each other's males (Green & Plumb, *Nematologica* (1970), **16**, 39–46). When *H. rostochiensis* females are mated with males of *H. pallida* few females produce eggs and these contain fewer eggs than when the females are mated with their own males (*Rothamsted Report for 1969*, Part 1, 185). To study competition between males, those of *H. rostochiensis* and *H. pallida* populations were placed together on females of *H. rostochiensis*. The number of females with eggs and the number of eggs per female were similar to those obtained when the females were mated with their own males (Table 2) but 10–20% of the females had at least some larvae with *H. pallida* type stylets. The percentage seemed to depend on the proportion of *H. rostochiensis* to *H. pallida* males and when the ratio was 1 : 3 the percentage was similar to that obtained when only *H. pallida* males were used. This suggests that *H. pallida* males compete successfully with *H. rostochiensis* males for those

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TABLE 2

Results of mating H. rostochiensis *females with different numbers of males of* H. rostochiensis *and* H. pallida

Number of males		% females with eggs	Number of eggs per female with eggs	% females with larvae having *H. pallida* type stylets
H. rostochiensis	*H. pallida*			
0	0	0	—	—
2	0	67	96	4*
6	2	60	97	10
2	6	64	93	19
0	6	25	70	21

* Long *H. rostochiensis* stylets are sometimes difficult to distinguish from short *H. pallida* stylets

H. rostochiensis females with which they are able to mate successfully. So, inability to produce large numbers of offspring probably arises after mating and fertilisation. (Parrott and Berry)

Tests of plants with resistance gene H_3. Gene H_3 (Howard, Cole & Fuller, *Euphytica* (1970), **19**, 210–216) which confers resistance to pathotypes B and E of *H. pallida* was tested against four E and three B populations (Table 3). The inoculum of hatched larvae for B populations was about half that of E populations, 1500 compared with 3000 larvae/pot. The results suggest that resistance is less complete than that conferred by gene H_1 to *H. rostochiensis* pathotype A and that B populations may contain more individuals able to overcome it. Although there were differences between the four hybrids used in the test, they were slight. (Course and Matthews)

TABLE 3

Number of females of H. pallida *on hybrid potatoes with resistance gene H_3 from* Solanum tuberosum *ssp.* andigena *compared with susceptible Arran Banner*

Populations	Arran Banner (3 replicates)	Hybrid with gene H_3 (8 replicates) % no. on Arran Banner
Pathotype E		
Jersey	256	5
Cadishead	316	9
Bridford	308	9
Frampton	339	5
Pathotype B		
Glarryford	84	18
Ballyloughan	89	15
Dunmining	63	11

Selection of Dutch pathotypes of potato cyst-nematodes on resistant potatoes. Some Dutch populations tested in 1970 (*Rothamsted Report for 1970*, Part 1, 152), which did not multiply as well on Maris Piper (with resistant gene H_1) or P55/7 (gene H_2) as on the susceptible potato Arran Banner, were raised on these varieties for a further two generations.

When raised on Maris Piper, population C3 (*Heterodera rostochiensis*, Dutch pathotype C) and a Bolivian population produced as many females on Maris Piper as on Arran Banner by the third generation (Table 4). Population A990 must have been a mixture of *H. rostochiensis* and *H. pallida* for the second generation reproduced 100% on Maris Piper compared with Arran Banner and contained only *H. pallida*. None of the other pathotype A populations produced enough larvae to test properly and may be

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TABLE 4

Percentage of females formed on Maris Piper (with gene H_1 for resistance) and P55/7 (with gene H_2) in successive generations

Arran Banner = 100

Population	Species	% number of females formed on resistant host Generation 1	2	3
		Maris Piper, gene H_1		
Bolivia	*H. rostochiensis*	65	50	100
*A1000	*H. rostochiensis*	3	2	?
A1004	*H. rostochiensis*	4	?	?
A1087	*H. rostochiensis*	1	1	?
C1	*H. rostochiensis*	2	?	21
C3	*H. rostochiensis*	24	27	100
C4	*H. rostochiensis*	21	16	37
A990	Species mixture	27	100	100
		P55/7 gene H_2		
A1087	*H. rostochiensis*	38	42	100
D1001	*H. pallida*	47	8	95
D1045	*H. pallida*	12	36	50
D1048	*H. pallida*	44	83	81
D1057	*H. pallida*	8	26	**—
D1063	*H. pallida*	11	30	—
D1068	*H. pallida*	43	50	—
D1077	*H. pallida*	6	13	65

* Prefix denotes Dutch pathotypes
** Not tested

similar to British pathotype A which do not increase their ability to overcome the resistance conferred by gene H_1 when repeatedly grown on Maris Piper. This ability did increase in populations C1 and C4 which may be similar to that found in Bolivia and C3.

When grown repeatedly on P55/7, population A1087 (*H. rostochiensis*) reached 100% reproduction on this variety by the third generation and the *H. pallida* populations, although not reaching 100%, progressively increased their reproduction on P55/7. (Parrott and Berry)

Multiplication of *H. solanacearum* on potatoes. Species of round cyst-nematode related to the potato cyst-nematodes are known from the eastern seaboard of the USA. These nematodes also attack solanaceous plants and one at least (*H. solanacearum*) is able to reproduce to a limited extent on potatoes in glasshouse tests (Stone, *Nematologica* (1973), **18**, 591–606); L. I. Miller, unpublished). Two field trials were made in the Virginia Piedmont area where the nematode reproduces on tobacco and solanaceous weeds. At one site, three varieties of potato susceptible to *H. rostochiensis* and *H. pallida* were planted and at the other, another variety with resistance derived from gene H_1. When plants were examined 80 days later no females were found on the roots and no active males were recovered from the rhizosphere. Whether larvae or males were present earlier is unknown but none was present at this time. Potato yields were not decreased but after the resistant potato variety was harvested, a nematode-susceptible tobacco variety grew poorly and had large numbers of all stages of *H. solanacearum* in its roots 61 days after planting. Evidently these two field populations of this nematode do not reproduce effectively on potatoes, but whether the progeny of the few females formed on potatoes in pot tests could be selected to enhance this ability is unknown. Selection of

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comparable females of *H. rostochiensis* pathotype A on resistant potatoes with gene H_1 has so far been unsuccessful. (Stone with Dr. L. I. Miller, Virginia Polytechnic Institute and State University, USA)

Some results of a long-term population experiment. In a field trial at Woburn on light sandy soil, on part of the old irrigation experiment, resistant and susceptible potatoes were grown continuously on some plots and alternately on others. Some plots were irrigated and some fumigated. The trial occupied two sites one of which (Series I) had previously grown potatoes every three years and the other (Series IV) had grown only grass or lucerne in the previous 15 years. Series I was moderately infested with *H. rostochiensis* pathotype A all over but Series IV had a slight and patchy infestation. Pathotype tests suggested that both sites probably had a trivial infestation of *H. pallida* pathotype E initially. On Series I, in plots that grew Maris Piper (with resistance gene H_1) continuously, nematode numbers declined at first but showed a tendency to increase after five or six years. On Series IV in similar plots numbers mostly remained small for four or five years. However, in a few plots *H. pallida* pathotype E began to multiply strongly and, after six or seven years, some plots are now heavily infested.

On Series IV, the small residual population of *H. rostochiensis* had little effect on the yield of susceptible potatoes, variety Pentland Dell, in the first year they were grown. By the second year, however, numbers had increased enough to halve the yield and, in subsequent years, nematode numbers and yields were similar to those on Series I, although in these and other plots the Series IV site produced yields somewhat greater than those from Series I, presumably because the soil structure and fertility had been improved by many years in grass and lucerne.

On plots that grew the resistant and susceptible potato variety alternately, the balance between *H. rostochiensis* pathotype A and *H. pallida* pathotype E depended on which variety was planted first. Where the alternation began with Maris Piper numbers of eggs/g soil did not decrease as might have been expected when this resistant variety was grown. From this behaviour it is inferred that *H. pallida* was increasing in both varieties. Where the alternation began with Pentland Dell, numbers fell sharply when Maris Piper was grown the next year. Subsequently numbers oscillated upwards. The difference was possibly because the large numbers of *H. rostochiensis*, generated in the first year when Pentland Dell was grown, competed strongly with *H. pallida* even in the roots of Maris Piper where *H. rostochiensis* females could not complete their development. It is possible that the many males of *H. rostochiensis* that would be produced also competed for *H. pallida* females (see p. 153).

TABLE 5

Influence of season, site and irrigation on potato yields in a long-term experiment at Woburn

Year	*Seasonal differences, % mean	Advantage of series IV over series I, t/ha	Effects of irrigation, t/ha: Series I	Series IV
1966	+17	+11·83	−6·02	−6·73
1967	−29	+11·48	+4·75	+3·24
1968	+9	+4·57	−0·60	+1·21
1969	+4	+3·49	+4·04	+5·93
1970	−14	+3·84	+5·52	+4·82
1971	+18	+0·98	+5·47	+6·50
†1972	−5	n.a.	+10·24	+6·80

* Seasonal differences measured by continuous resistant Maris Piper which suffered only slight nematode attack

† Pentland Crown grown in 1972 over the whole site of Series I

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The effects of season, site and irrigation on potato yields are summarised in Table 5. As the yields of continuous Maris Piper in Series IV suffered little from nematodes in the first six years, they measure the effects of season. In most years the effects of irrigation on yield were slight and irrigation had no effects on soil populations or the numbers of larvae invading roots, probably because these were determined before irrigation was applied. In some years there was an interaction between irrigation and fumigation. In those years the fumigation delayed senescence and the active plants probably benefited from additional water to the extent that their yields were improved by 5–7 t/ha whereas yields of unfumigated and heavily infested plants were unchanged.

With some of these effects removed, the influence of nematodes on the yields of the susceptible variety on unfumigated plots are being analysed. A difficulty in doing the same for fumigated plots arises because fumigation preserves eggs that are moribund. Attempts to estimate kill by counts of larvae invading roots were not successful but 'D-D' applied in the first three years appears to have killed 70–75% and dazomet in the succeeding years 80–85%. There is little doubt, however, that as can be predicted from population curves, these rates of kill have resulted in peak post harvest numbers. The suggestion that fumigation might delay the development of *H. pallida* in plots planted with Maris Piper (as implied in Dutch regulations for the control of potato cyst-nematode) is not borne out in practice. In fumigated continuous Maris Piper plots *H. pallida* tends, if anything, to be more abundant than in unfumigated. In fact the behaviour of *H. pallida* in fumigated plots of Maris Piper mirrors that of *H. rostochiensis* in fumigated plots of Pentland Dell. (Jones, Parrott and Berry)

Effects of trap-cropping and an artificial hatching agent. In Longmead, Woburn, in sandy clay soil, trap-cropping was attempted by planting many small potato tubers and lifting them after six weeks before larvae that hatched and invaded root systems could develop into adult females. This decreased the number of eggs in cysts to 34% of those present originally, whereas in bare fallow the number decreased to 72% only (Table 6).

TABLE 6

Effect of trap-cropping and of the artificial hatching agent picrolonic acid on the number of potato cyst-nematode eggs in soil

Treatment	Eggs/g soil after treatment	% number of eggs/g soil before treatment*	
Bare fallow	183	72	
Potatoes grown for 4 weeks	151	59	50
Potatoes grown for 6 weeks	86	34	
Potatoes grown for 8 weeks	†149	58	
Picrolonic acid 8·6 kg/ha	217	85	73
Picrolonic acid 17·2 kg/ha	175	69	
Picrolonic acid 34·4 kg/ha	164	64	
Potatoes grown for 4 weeks then picrolonic acid 17·2 kg/ha	109	43	

* Eggs/g soil before treatment: 255
† 8 weeks too long, possibly some new eggs produced

Lifting after four and eight weeks was less effective. After eight weeks some females had probably produced eggs and at four weeks hatch and invasion were probably incomplete. Picrolonic acid, an effective artificial hatching agent *in vitro* (Clarke and Shepherd, *Nature* (1966), **211**, 546) was ineffective in field soil at any of the three rates tried, either alone or when combined with trap-cropping. (Whitehead, Tite, Fraser and French)

https://doi.org/10.23637/ERADOC-1-130

Population changes in resistant and susceptible oats. On a site where wheat was grown in 1972, numbers of *H. avenae* eggs increased most in plots planted with spring-sown wheat and spring-sown winter wheat. In autumn-sown winter wheat plots the increase was smaller and the yields of oats grown on the plots in 1973 were larger in consequence. This is contrary to the view usually held that winter-sown cereals are more efficient hosts of *H. avenae* than spring sown ones. The residues of previous formalin treatments applied to the plots had little effect but the effects of resistant and susceptible oats grown in 1973 were marked (Table 7). Following autumn-sown winter wheat, the number of eggs

TABLE 7

Yield of oats and H. avenae *populations in 1973 following wheat crops in 1972*

	Oat varieties, 1973					
	Autumn-sown winter wheat (Autumn 1971)		Spring-sown winter wheat (Spring 1972)		Spring-sown spring wheat (Spring 1972)	
	Resistant	Susceptible	Resistant	Susceptible	Resistant	Susceptible
Pre-crop numbers, eggs/g, 1973	1·6	1·6	6·0	6·0	11·9	11·9
Post-crop, eggs/g, 1973	1·6	15·6	2·4	22·5	4·3	23·9
Grain, 85% DM kg/ha	2·24	2·14	1·74	1·77	1·67	1·67

remained the same after the resistant oat selection but increased ten-fold after susceptible Peniarth. Following spring-sown winter wheat, numbers decreased from 6·0 to 2·4 eggs/g under the resistant selection but increased four-fold after Peniarth. Following spring-sown spring wheat, numbers fell from 11·9 to 4·3 eggs/g under resistant oats, whereas they doubled under the susceptible variety. The rate of development of *H. avenae* was slower in roots of resistant oats and whereas 14% of larvae became fourth-stage females in susceptible oats less than 1% reached this stage in resistant. Also, twice as many larvae became fourth-stage males (25 against 11%). (Williams and Beane)

'Scorch', copper, nematicides and cereal cyst-nematodes. Following severe 'scorch' in 1972 (*Rothamsted Report for 1972*, Part 1, 170) the plots affected were again studied in 1973. The effects of Cu^{++} and of nematicides applied in 1971 and 1972 varied. Copper oxychloride was applied as a foliar spray to Kleiber spring wheat (sown on 15 March 1973) on 31 May at 1·12 and 2·24 kg/ha Cu^{++}. Severe browning of top leaves followed, especially at the highest rate but the plants soon recovered. Unfortunately, the large amount of nitrogen applied (740 kg/ha, 'Nitro-Chalk 25'), intended to increase the severity of 'scorch' in 1973, also encouraged a severe mildew attack. The beneficial effects of aldicarb in 1971 and 1972 could be seen clearly whereas the copper applied had no obvious effect. These observations were confirmed by the yields of grain. Only aldicarb applied cumulatively decreased post-harvest numbers of *H. avenae*. Numbers following formalin were increased. All other treatments (dazomet, residual and cumulative; aldicarb, residual; formalin, residual) were similar to untreated. Regrettably 'scorch' did not appear which emphasises again the difficulty of working on the cause of these symptoms. (Williams and Beane, with Bolton, Chemistry Department)

***H. avenae* pathotype investigations.** Populations of pathotype A and C (race 1 and 2) from England and Denmark were studied to see if they differ in respects other than their abilities to form females on Drost Barley. No differences in morphology or in protein band patterns were found, which suggests they belong to the same species. (Stone, Course, Williams and Beane)

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A fungus attacking females of the cereal cyst-nematode. Females of *H. avenae* from experimental plots of the Weed Research Organisation, Begbroke, Oxfordshire, contained spores of an unknown fungus. The site typifies many where, despite continuous cropping with cereals, numbers of *H. avenae* eggs rarely exceed 10–20/g soil. Infected females have unthickened and often disrupted cuticles and contain a mass of hyphae and spores. Recently affected females contain large branching hyphae which eventually produce many thick-walled resting spores. Attempts to produce conidia and to germinate resting spores have so far failed. No asexual spores have been obtained and without them identification is impossible but the fungus appears to belong to the genus *Entomophthora*, two species of which have previously been recorded from cysts of *H. schachtii*.

As larvae and young females, in or on roots, are free from the fungus, infection appears to occur shortly after females rupture the root cortex—during May and June. The fungus has also been found in *H. avenae* at Bridgets' Experimental Husbandry Farm and at Rothamsted but not so far at Woburn. In samples, the proportion of females infested ranges from 0 to 63%, with a mean rate of 10% but it is not known how many of the females ultimately become infested in a given field. If, as seems possible, this is the unknown enemy that controls *H. avenae* populations where cereals are grown frequently (*Rothamsted Report for 1967*, 143), it is the only known example of control of a cyst-nematode by a naturally occurring pathogen. A fungus attacking females before they produce many eggs is more likely to prevent population increase than nematode-trapping fungi that kill larvae before they enter roots. These usually remove individuals surplus to the carrying capacity of the roots, so diminishing competition for feeding sites but not greatly influencing egg production. (Kerry)

Stem nematode on field beans. Field plots were inoculated in the autumn with field bean straw (3·1 or 6·2 t/ha) infested with either the oat race or giant race of *Ditylenchus dipsaci*. The two application rates, the smaller of which is equivalent to an average straw yield, had little effect on the number of stems subsequently infested (81% for both rates of oat race, 100% for both rates of giant race, most untreated plots remained uninfested). The smaller rate of inoculation with the oat race did not affect grain yield but the larger rate decreased yield by 25%, with 3% of the seed being infested. The smaller rate of inoculation by the giant race decreased yield by 50% and 63% of the seeds were infested. The larger rate decreased yield by 58% and 67% of the seed was infested. The trial confirms that the giant race is more injurious and more likely to produce infested seed than the oat race.

At Rothamsted in 1973, 83% of bean plants were infested in plots that grew beans infested with the oat race in 1972, and 20% were infested with the giant race in plots that were infested in 1970. Observations over eight years indicate that stem nematodes readily survive in soil under non-host crops for up to five and possibly for seven years. (Hooper and Walker)

Infested bean seed is an important means of dispersing and re-establishing populations of both races of stem nematode but attempts to eradicate them from infested seed by hot air treatment were unsuccessful. Nematodes survived in seeds treated for four days at 60°C, or for 1 h at 80°C. Both treatments reduced seed germination, Aldicarb decreased the number of stems of var. Maris Bead infested by a seed-borne source of the giant race of *D. dipsaci* (see p. 246). (Hooper and Walker, with Cockbain, Plant Pathology Department)

Trials with nematicides

***Heterodera rostochiensis* and *Verticillium dahliae* interactions.** In the third successive potato crop after applying chemicals to the soil in 1971, the variety Pentland Dell

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planted in plots that had been treated with benomyl or aldicarb plus benomyl, yielded 12·7 and 16·7 t/ha whereas untreated crops yielded only 2·2, aldicarb-treated 3·3, dazomet-treated 1·8 and methyl bromide-treated 1·2 t/ha. On the plots that received benomyl growth was best and plants lived longest, also fewer *Heterodera rostochiensis* larvae invaded the roots and the numbers of eggs remaining in the soil after harvest were significantly fewer. Evidently residues of benomyl persist longest and its main breakdown product was found in soil samples taken in August 1973, 29 months after application (see also p. 147). (Corbett, with Hide, Plant Pathology Department, and Austin, Chemical Liasison Unit)

Another experiment on heavily infested land suggests that benomyl, or its breakdown product MBC, does not inhibit hatching of eggs, but prevents larvae from invading potato roots as long as it is present in the soil. This contrasts with methyl bromide which kills eggs within cysts, prevents them hatching and preserves them until after harvest when they are indistinguishable from those that are viable. The same problem (i.e. that of distinguishing viable from dead or moribund larvae within eggs, arises when other soil fumigants are applied (see p. 157). (Corbett, with Miss Jane Burnell-Higgs, Bath University)

Potato cyst-nematodes

On tomato. At Morecambe, Lancs., in a heated glasshouse on a peaty sandy loam, *H. pallida* pathotype E was controlled on tomatoes by treating the soil in autumn with methyl bromide, dazomet with 'Di-Trapex CP' (20% methylisothiocyanate; 65% dichloropropene; 15% chloropicrin), dazomet with 'Telone' (dichloropropene mixture) and in spring with 'Du Pont 1410' (*S*-methyl-1-(dimethylcarbamoyl)-*N*-[(methylcarbamoyl)oxy]thioformimidate). Plots treated with methyl bromide, dazomet or 'Di-Trapex CP' were covered with polythene sheeting to prevent the gases escaping rapidly into the air. After methyl bromide the tomato plants grew vigorously but fruited late. After 'Du Pont 1410' alone the plants grew less well and yielded less fruit than in fumigated soil. Dazomet alone did not control the nematode, whether the soil was covered with polythene sheeting or not, and the dust formulation was no more effective than prill. In an adjacent, unheated glasshouse in similar soil, yields were less than in the heated glasshouse and all treatments controlled potato cyst-nematodes. Here dazomet was less effective when the soil was 'sealed' with water than with polythene.

TABLE 8

Effect of 'Du Pont 1410', benomyl and 'Dowco 275' on yield of potatoes var. Pentland Crown in sandy loam heavily infested with potato cyst-nematode

Treatment	Amount a.i. (kg/ha)	Yield of tubers over 3·8 cm diam. (t/ha)
Untreated	0	7·1
'Du Pont 1410'	3·0	25·6***
	6·0	27·6***
	12·0	27·1***
benomyl	5·6	12·2
	11·2	8·5
	22·4	12·7
'Dowco 275'	2·9	13·4*
	5·8	16·9**
	11·6	18·8***

*, **, *** Significantly more than untreated at 5%, 1%, 0·1% probability, respectively

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On potato. On Great Hill, Woburn Experimental Farm, in sandy loam heavily infested with *H. rostochiensis* pathotype A the yield of susceptible Pentland Crown potatoes was greatly increased by 'Du-Pont 1410' or 'Dowco 275' (*O,O*-diethyl *O*-(6-fluoro-2-pyridyl) phosphorothioate) but not by benomyl (Table 8).

The effect of 63 pesticides on potato cyst-nematode (*H. rostochiensis* pathotype A) was assessed by growing tomato plants (var. Moneymaker) in pots of infested, sandy loam and scoring the roots for females some six or seven weeks later, when they were abundant on the roots of plants grown in untreated soil. Of 28 organophosphorus compounds incorporated in air-dried soil at 10 ppm, six entirely prevented the development of females on the roots (phoxim, 'Dursban', for which the name chlorpyrifos is being adopted, cyanthoate, 'CGA 12223', pirimiphos-methyl and azinphos-ethyl) and two prevented the formation of all but a few (coumaphos and fonophos). Most of the effective compounds were diethyl phosphorothioates or diethyl phosphates and most of the ineffective ones were dimethyl phosphorothioates or dimethyl phosphates. Of 22 isothiocyanates tested, allyl, ethyl, carbethoxy- and five aryl isothiocyanates were effective at 100 ppm of air-dried soil, but most were phytotoxic. At 10 ppm the nematodes were controlled by 2-ethylpyrid ylisothiocyanate. Two oximecarbamates (methomyl and 'Du Pont 1410') were effective at 10 ppm and two more were not ('Talcord', for which the name thiocarboxime is being adopted, and 'Du Pont 1642'). No females were observed on the roots of tomato plants grown in pots of soil treated at 10 ppm with benomyl or thiabendazole.

An experiment to control *H. rostochiensis* pathotype A, by a combination of nematicides, crop rotation and a resistant potato variety (Maris Piper) was started in 1972 on sandy loam in Stackyard Field, Woburn Experimental Farm. The rotations are (a) resistant potatoes, sugar beet, barley, susceptible potatoes and (b) susceptible potatoes, sugar beet, barley, susceptible potatoes. As in 1972 nematode numbers were controlled in 1973 by Maris Piper potatoes, 'Du Pont 1410', and large amounts of dazomet incorporated in the topsoil, half before and half after ploughing and by a combined treatment of dazomet and 'Telone' applied after ploughing in October 1972 (Table 9). In this experiment and in others there are difficulties in calculating increase rates especially after fumigants which tend to preserve moribund eggs. The increase rates for these treatments are therefore smaller than is shown in Table 9.

TABLE 9

Yield of two potato varieties and increase of potato cyst-nematode in soil treated with different amounts of three nematicides

		Maris Piper		Pentland Crown	
Treatment	Amount a.i. (kg/ha)	Tubers over 3·8 cm diam. (t/ha)	Increase	Tubers over 3·8 cm diam. (t/ha)	Increase
Untreated	0	22·9	×0·6	19·2	×6·9
dazomet (2)	224	35·1***	×1·0	42·6***	×1·2
dazomet (2)	336	40·6***	×1·2	42·4***	×1·4
dazomet (2)	448	41·5***	×1·0	40·5***	×1·5
dazomet (2)	672	43·2***	×1·2	46·7***	×1·2
'Telone' (1)	448	38·5***	×1·5	36·6***	×2·2
dazomet (1) and 'Telone' (1)	224 224	36·7***	×1·0	38·8***	×0·8
'Du Pont 1410' (S.)	5·6	30·4*	×0·4	32·5***	×0·6
'Du Pont 1410' (S.) and 'Telone' (1)	5·6 224	40·9***	×0·5	37·2***	×0·4
		Mean 36·6		37·4	

(1) applied after ploughing; (2) half before, half after ploughing; (S.) incorporated in topsoil in spring just before potatoes planted.

*, *** Significantly more than untreated at 5%, 0·1% probability, respectively.

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Beet cyst-nematode. At Mepal, Isle of Ely, good crops of sugar beet were grown in peaty clay, heavily infested with beet cyst-nematode (*H. schachtii*) in which aldicarb, 'Du Pont 1410' or 'Dowco 275' had been incorporated just before the beet was sown. The best treatment was aldicarb, which left the soil less infested with nematodes after harvest than before sowing (Table 10). Population control was evidently good enough to prevent

TABLE 10

Yield of sugar beet and increase of beet cyst-nematode in soil treated with different amounts of three nematicides

Treatment	Amount a.i. (kg/ha)	Sugar (t/ha)	Increase of beet cyst-nematode
Untreated	0	3·4	×1·0
aldicarb	2·7	7·1***	×1·0
	5·3	7·7***	×0·8
	10·7	7·5***	×0·5
'Du Pont 1410'	3·0	6·2***	×1·3
	5·9	7·0***	×1·8
	11·9	7·0***	×1·5
'Dowco 275'	2·9	3·3	×0·7
	5·8	3·8	×2·1
	11·6	6·2***	×1·3

*** Significantly greater than untreated at 0·1% probability.

large increases by the second (autumn) generation of the nematode, but whether such a generation occurred in the dry autumn of 1973 is unknown.

Pea cyst-nematode. In 1972 we showed that pea cyst-nematode (*H. goettingiana*) could be controlled by incorporating small amounts of non-phytotoxic nematicides in the seedbed before sowing. Two further experiments were made in 1973, one on severely infested clay loam near Spalding, Lincs., the other on moderately infested sandy clay near Ipswich, Suffolk. On the clay loam soil the yield of peas was greatly increased by all treatments and the soil was left less infested by the nematode after harvest than before

TABLE 11

Yields of fresh peas and increase of pea cyst-nematode in two soils treated with different amounts of three nematicides

		Clay loam, Spalding		Sandy clay, Ipswich	
Treatment	Amount a.i. (kg/ha)	Fresh peas (t/ha)	Increase	Fresh peas (t/ha)	Increase
Untreated	0	3·2	×0·9	4·0	×2·0
aldicarb	2·8	9·6***	×0·5	4·3	×1·4
	5·6	11·3***	×0·7	6·1**	×1·0
	11·2	11·1***	×0·5	6·6**	×1·0
'Du Pont 1410'	2·8	6·4***	×0·9	4·0	×1·0
	5·6	8·3***	×0·7	6·1**	×1·5
	11·2	11·9***	×0·5	5·8*	×0·5
'Dowco 275'	2·8	6·2***	×0·6	3·7	×1·7
	5·6	8·1***	×0·5	4·0	×0·8
	11·2	9·0***	×0·4	4·2	×0·7

*, **, *** Significantly more than untreated at 5%, 1%, 0·1% probability, respectively.

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sowing (Table 11). On the sandy clay soil aldicarb and 'Du Pont 1410' increased the yield of peas and controlled the nematode. In this experiment herbicide applied to control couch grass stunted the pea plants and reduced the yield of peas. (Whitehead, Tite, Finch, Fraser, French and Wright)

Cereal cyst-nematode. In mid-March, on a chalk downland site at the Animal Diseases Research Institute, Compton, Berks., plots were treated with aldicarb, 'Du Pont 1410' and 'Dowco 275' and sown with spring barley immediately afterwards. Early and mid season growth differences between treatments were large. Yields (Table 12) were disappointing despite liberal applications of farmyard manure in 1968 and 1971, partly because of severe lodging from summer storms.

TABLE 12

Spring barley yields and H. avenae *population changes, Compton, Berks., 1973*

	Amount a.i. (kg/ha)	*H. avenae* (eggs/g) Before planting	After harvest	Grain 85% DM (t/ha)
Untreated	0	24	18	2·32
aldicarb	2·0	22	6	3·44
	5·6	23	6	2·55
	10·2	20	2	3·37
'Du Pont 1410'	2·4	21	6	2·76
	4·8	23	5	2·89
	9·6	20	3	3·15
'Dowco 275'	2·4	20	7	2·42
	4·8	20	5	2·64
	9·6	20	3	2·95

Plots treated with nematicides, especially aldicarb, yielded appreciably better than untreated ones. The largest yields were 50% more than untreated coupled with substantially decreased *H. avenae* populations after harvest. Egg numbers in untreated plots decreased slightly from 24 eggs/g to 18/g. This agrees with the finding of members of the Agricultural Development and Advisory Service that on downland sites, populations of 20 eggs/g or more are seldom maintained. (Whitehead, Williams and Beane)

TABLE 13

Yields of resistant (R) and susceptible (S) spring oats. Comparison between plots with and without H. avenae *before treatment and with or without aldicarb*

	No aldicarb 10·9 eggs/g Grain (t/ha)	Post-crop (eggs/g)	aldicarb 9·2 eggs/g before treatment Grain (t/ha)	Post-crop (eggs/g)
Nelson (R)	3·63	2·5	6·23	1·1
Mostyn (S)	4·28	10·8	6·33	1·3
W 16840 (R)	4·52	0·5	6·97	0·3

	No *H. avenae* Yield	Post-crop (eggs/g)	No *H. avenae* Yield	Post-crop (eggs/g)
Nelson (R)	6·76	0·0	7·08	0·0
Mostyn (S)	6·78	0·0	6·27	0·0
W 16840 (R)	7·62	0·0	7·41	0·0

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When the Cereals Disease Reference Plots (Series II) were terminated in 1972, the plots were split and sown with the susceptible oat variety Mostyn and two resistant ones, Nelson and a Weibull's selection ex. Rothwell Plant Breeders (No. W. 16840). Half the area under each variety was treated with aldicarb immediately before planting on 14 March 1973. Eggs of *H. avenae* were numerous in four of the 12 plots only and few or undetectable in the remainder.

The relative performance of the three oat varieties is summarised in Table 13. When *H. avenae* was controlled by aldicarb, Nelson slightly outyielded Mostyn, otherwise it yielded less. Although Nelson is resistant in the sense that *H. avenae* does not multiply in it, it is evidently sensitive to larvae invading its roots. W. 16840 yielded best with or without aldicarb although its yield was depressed when large numbers of *H. avenae* invaded its roots. The yield loss seems solely due to *H. avenae*, which is effectively controlled by aldicarb, as the yields in the plots without *H. avenae* and in those treated with aldicarb are similar. Yields in untreated plots with *H. avenae* were 60% smaller. Both resistant varieties effectively decreased the numbers of *H. avenae* after harvest while Mostyn did no more than maintain them. (Williams and Beane)

Stem nematode. In Great Field, Rothamsted, in clay soil, aldicarb applied in the seed furrow at sowing time protected onions (var. Robusta) from injury by the oat race of stem nematodes (*Ditylenchus dipsaci*). Treated rows yielded more than 48 t/ha of healthy onions compared with untreated rows which yielded only about 2 t/ha. This was on land which had grown a crop of beans (*Vicia faba* L.) in 1971, which had been badly infested with stem nematode, followed in 1972 by winter wheat. (Whitehead, Tite and Finch)

Effect of nematicide distribution on potato cyst-nematode control. Granules of 'Du Pont 1410', uniformly distributed throughout the soil at planting at a rate equivalent to 1·68 kg/ha incorporated to a depth of 15 cm in the field, reduced root invasion of pot-grown potato plants by 97%. When the uniformity of the granule distribution was decreased artificially by packing treated and untreated soil into regular patterns, more larvae invaded the roots. Surface treatment decreased invasion by only 45%. Results with the nematicide 'Nemacur', for which the name fenamiphos is being adopted, were less decisive and the best treatment, thorough mixing, reduced invasion by no more than 60%.

Except for the surface treatment which gave poor control, all other distributions of 'Du Pont 1410' granules controlled the nematode almost equally as well as did uniform admixture. The poorer distributions of 'Nemacur' granules were less effective but they were only a little worse than treatments with 'Du Pont 1410'. These differences are attributed to the more polar nature of 'Du Pont 1410' which allows it to redistribute itself more rapidly in the soil by diffusion and leaching than does 'Nemacur'. (Bromilow, with Tucker, Bath University)

Incorporation of nematicide granules in soil by rotavation. The distribution of non-fumigant nematicides formulated as granules was studied in a fen peat soil at the Arthur Rickwood Experimental Husbandry Farm. Granules containing known amounts of 'Dowco 275' were spread uniformly on the soil surface and incorporated by one or two passes with a tractor-mounted rotavator set at different depths. Subsequently the concentrations of the chemical in sections of cores were determined by gas–liquid chromatography. Shallow rotavation distributed the granules reasonably well to a depth of 10 cm and deep rotavation to a depth of 20–25 cm. A second pass of the rotavator had little effect on depth or uniformity of incorporation.

After planting potatoes and ridging to a height of about 25 cm the granules in the shallow rotavated plots were distributed to 15 and 5 cm below the ridges and furrows respectively, and there was about eight times as much chemical in cores from the centres of ridges as from the furrows. In the deep rotavated plots, there was only one and a half times as much material in the ridges as in the furrows and the granules were distributed to 30 cm below the ridge and 15 cm below the furrow.

The soil at this site was lightly infested (19 eggs/g soil) and the King Edward potatoes planted grew well and yielded a heavy crop even on untreated plots, but the effects of treatments on nematode increase differed greatly (Table 14). Aldicarb placed in the seed

TABLE 14

Effect of three nematicides applied to the soil in different ways at planting time on increase of potato cyst-nematode in peaty loam soil

Treatment	Amount a.i. (kg/ha)	Method of incorporation	Times rotavated	Nematode increase
Untreated	0	Rotavated 10 cm deep	Once	×52
Untreated	0	Rotavated 10 cm deep	Twice	×69
aldicarb	3·3	Rotavated 25 cm deep	Once	×6
aldicarb	3·3	Rotavated 25 cm deep	Twice	×6
aldicarb	6·5	Rotavated 25 cm deep	Once	×2
aldicarb	6·5	Rotavated 25 cm deep	Twice	×1
aldicarb	3·4	In seed furrow	—	×79
aldicarb	5·6	In seed furrow	—	×57
'Du Pont 1410'	5·9	Rotavated 10 cm deep	Once	×3
'Du Pont 1410'	5·9	Rotavated 10 cm deep	Twice	×2
'Du Pont 1410'	5·9	Rotavated 25 cm deep	Once	×13
'Du Pont 1410'	5·9	Rotavated 25 cm deep	Twice	×8
'Dowco 275'	5·8	Rotavated 10 cm deep	Once	×25
'Dowco 275'	5·8	Rotavated 10 cm deep	Twice	×19
'Dowco 275'	5·8	Rotavated 25 cm deep	Once	×39
'Dowco 275'	5·8	Rotavated 25 cm deep	Twice	×49

furrows had no effect on the number of nematodes left in the soil after the crop had been harvested, but aldicarb incorporated deeply before planting restricted or prevented increase. Shallow rotavation, which concentrated 'Du Pont 1410' or 'Dowco 275' in the top 10 cm of soil controlled the nematode better to 20 cm depth than deep rotavation. Nematode control was not improved by rotavating the soil twice.

These results show that the efficiency of granular nematicides applied to the soil at planting time is greatly affected by the way in which they are applied and incorporated and that chemical analysis is an accurate guide to the degree of nematode control to be expected. (Whitehead, Tite, Fraser and French, with Bromilow and Lord, Chemical Liaison Unit and Mr J. Smith, Arthur Rickwood Experimental Husbandry Farm)

Other work

Work on the characterisation of cyst-nematode hatching factors and on the energy sources of quiescent larvae continued. (Clarke and Hennessy)

Hexatylus viviparus reproduced readily on hyphae of the fungus *Botrytis cinerea*. Reproduction is parthenogenetic as cultures can be established from single juveniles: males did not occur. At 22°C eggs hatched in two days and the generation time was about eight days. The optimum temperature for the reproduction of *Ditylenchus destructor*, a bisexual species, on the same fungus was 25°C. At this temperature eggs hatched in five to seven days and the generation time was 19–20 days. Neither nematode reproduced below 10°C or above 30°C. (Hooper and Walker)

The earliest symptoms of the root rot that damages field beans at Rothamsted were

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reproduced by inoculating beans with *Pratylenchus pinguicaudatus* in sterile culture. (Corbett and Webb)

Staff and visiting workers

Dr. A. Gomez-Barcina, Vice-Director of the Estacion Experimental 'La Mayora', Malaga, Spain, and Professor J. P. Hollis, Louisiana State University, Baton Rouge, Louisiana, USA, worked in the Department during the year. Among others, brief visits were paid by Professor T. Masamune, Sapporo, Japan, Dr. U. Wyss, Hannover, Germany and Dr. K. Wright, University of Toronto, Canada, at present on sabbatical leave at Leeds University. A. R. Stone went to the Virginia Polytechnic Institute and State University, Blacksburg, Virginia, USA, for six months on a NATO grant and K. Evans went to the International Potato Centre, Lima, Peru, also for six months on funds provided by the Centre. In September F. G. W. Jones, A. R. Stone and D. C. M. Corbett attended the 2nd International Congress of Plant Pathology held in Minneapolis, Minnesota, USA. F. G. W. Jones also visited the Department of Plant Pathology, University of Missouri, Columbia, and D. C. M. Corbett visited several other centres of nematological research in the United States and Canada. June Edwards, Katherine Pike, Annelise Kempton and J. Burton left and Laura Burgess, Jean Firth, D. Crump and B. R. Kerry joined the staff during the year. Jane Burnell-Higgs, Judith Connor, J. Warrack, and G. J. King worked in the Department as Sandwich students. In June the Department was host to a Workshop on the identification of *Longidorus*, *Paralongidorus* and *Xiphinema* (see p. 341, publication 8.11) sponsored by the Nematology Group of the Association of Applied Biologists. It was organised by D. C. M. Corbett and D. J. Hooper and was attended by 40 participants.

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