Report for 1964

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Nematology Department

F. G. W. Jones

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NEMATOLOGY DEPARTMENT

F. G. W. JONES

J. E. Peachey left to join the Commonwealth Bureau of Helminthology, St. Albans, Dr. G. O. Poinar returned to the United States of America and A. Coomans, D. A. Cooke, D. L. Trudgill and T. D. Williams joined the Department as temporary workers. Audrey M. Shepherd spent four months in the U.S.A. visiting centres of nematological research. In January and February F. G. W. Jones, J. B. Goodey and Dr. D. W. Raski (California) ran a course on plant nematodes at the Indian Agricultural Research Institute, New Delhi. M. B. Lima attended the International Symposium on *Xiphinema* at the Institut für Hackfruchtkrankheiten und Nematodenforschung in Münster, West Germany, and several members of the department helped with the nematology course at Imperial College Field Station.

The department studies soil and plant nematodes, especially those that seriously injure crops either directly by their feeding or indirectly because they infect the plants with viruses. Part of the work is concerned with identification and description of new species, part with the unravelling of life cycles, host ranges and plant injury, part with experiments on feeding, movement, mating and host finding, and part with control by chemicals applied to plants or soil.

Systematics

A neotype of *Aphelenchus avenae* from the type locality, Broadmoor, was described. The nematode can be grown in culture on mushroom mycelium and other fungi. It is a pest of mushrooms and is suspected also of harming higher plants, but for this there is little evidence. Examination of type specimens of the related genus *Metaphelenchus* showed that, as in *Aphelenchus*, the oesophagus overlaps the intestine to a variable extent. *Metaphelenchus* is therefore regarded as a synonym of *Aphelenchus*. A new species of *Longidorus*, close to *L. goodeyi*, was found in two places in England and is being described. Two populations of *Nordia* (*Longidorella*), a genus not previously reported from Britain, are also being studied. Males and females of *Pandurinema* were obtained from an East Anglian soil; the genus was known only from East Pakistan and is based on a single male. (Goodey and Hooper)

A new species of *Anatonchus* from Italy was found in which the posterior ovary is a long uterine sac ending in a fine duct leading to an oval structure, probably the remains of a degenerate ovary. (Coomans and Lima)

Much time was spent on the genus *Xiphinema*, which contains vectors of important soil-borne viruses. The study of the *X. americanum* group based on 80 populations from all over the world is nearly complete. The three species, *X. americanum*, *X. opisthohysterum*and *X. bre vicolle*, are considered valid, and the identity of *X. americanum* (*sensu stricto*) has been clarified.

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The descriptions of Cobb, Thorne and Tarjan do not entirely agree. Cobb's notes suggest that he had two species and that described by Tarjan from a neotype is best regarded as *X. americanum*. *X. opisthohysterum* is common in the Mediterranean area and also occurs in England and Australia. Some populations of *X. opisthohysterum* differ from others in the length of the stylet and the form of the tail; some populations contain individuals of both kinds, and a few individuals combine the longer stylet with the unusual tail. For these reasons subspecies cannot be distinguished, and the peculiar distribution of characters may arise because males are rare and reproduction is parthenogenetic. *X. diversicaudatum*, *X. index* and *X. vuittenezi* from different sources were studied and, despite their similarities, are valid species. A species similar to or identical with *X. coxi* was collected in Norfolk. (Lima)

Bionomics

A new edition of the late T. Goodey's *The nematode parasites of plants catalogued under their hosts* was prepared, incorporating the first edition of 1956, the supplement of 1959 and all new records from 1959 to 1963. The catalogue is the standard reference list for world records of nematode attack on plants. (Goodey, Franklin and Hooper)

To provide a basis for comparing "natural" nematode populations with those of agricultural land and to gain information on the ecology of species of undisturbed habitats, *Xiphinema diversicaudatum* was studied in Geescroft Wilderness and species of the spiral nematodes *Helicotylenchus* and *Rotylenchus* in part of Broadbalk Wilderness. Both are areas formerly under cultivation but left uncultivated for many years.

X. diversicaudatum in Geescroft Wilderness is distributed vertically to about one metre's depth, although approximately 90% are within the A horizon of the soil (0–31 cm). Within the range 24–30 cm the population decreases sharply, and below 30 cm a fairly constant small population is maintained. The sharp decrease in numbers is associated with the changing structure of the soil where the A horizon merges into the B. *X. diversicaudatum* is confined to spaces between the structural units of the soil, because the pores within aggregates of clay and silt are too small for it to enter. With increasing depth, the clay fraction increases and the structural units become large, more angular and more compact. Spaces between them are consequently more dispersed and movement of nematodes down the profile becomes restricted. Within the A horizon the population is least dense at the surface and increases gradually to a maximum around 24 cm. Where colonies of dog's mercury (*Mercurialis perennis*) occur, its roots spread out radially from the bases of the stems to a depth of 6–12 cm or more, and the nematodes associated with the roots are densest around 8 cm. This pattern of distribution is influenced by climatic factors. Large-scale migration up and down never occurs, but some nematodes move downward under the influence of percolating water when the soil is wetter than field capacity and the large pores are full of water. Reproduction is in the root zone and tends to maintain the original distribution. Apparent

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downward shifts in the population in the summer were caused by nematodes dying as the soil dried out from above.

Probably because *M. perennis* provides a denser root system than other hosts, such as elm, wild rose and blackberry, the population was densest around it and fluctuated more than elsewhere, giving two maxima in December and April, but for temperatures below 0° C at 6 cm in January and February there would probably be one maximum in spring. During November to April temperatures ranged from 0° to 7° C and the tension of moisture rarely fell below 5 cm/Hg (about field capacity): on several occasions during this time the population shifted downwards. From May to September, when temperatures ranged from 10° to 17° C and the soil gradually became drier, the population decreased, and by August was only one-third its maximum. The relative humidity of the soil atmosphere must have dropped to 99–98%, as indicated by the wilting of herbaceous plants, and the nematodes survived mainly as larvae, which made up 85% of the population. Throughout the year the proportions of males and females remained more or less equal. Without host plants, more adults survived than larvae, and more of both stages survived at 5° C than at 10°, 15°, 20° or 25° C. After 48 weeks at 5° C 50% of the adults but only 27% of the larvae were still alive. At the higher temperatures only about 20% adults and 5% larvae were alive after 24 weeks.

Arabis mosaic virus is likely to be transmitted most often by *X. diversicaudatum* during autumn and spring, when the soil is cool and moist and favours population increase. Although tensions of 3–4 cm/Hg might be too moist for smaller nematodes, *X. diversicaudatum* necessarily lives in large pores that retain moisture only at small tensions. *X. diversicaudatum* is unlikely to be decreased much by fallowing, because it survives at depths where cold and dryness may not become lethal. Apart from its role as a virus vector, *Xiphinema* is sometimes directly injurious, e.g., to roses in glasshouses. (Larbey)

Broadbalk Wilderness consists of grazed grassland, ungrazed grassland kept free from bushes and regenerated woodland. Of the 81 species of nematode extracted from the soil of the woodland and ungrazed grass, 53 occurred in both. The abundance of nematodes that feed on plants or bacteria also differed in the two areas. In the ungrazed grassland the distribution of the seven species of spiral nematodes found was indirectly influenced by trees near the boundary. *Rotylenchus pumilus* and *Helicotylenchus vulgaris* were widespread away from the trees; *H. canadensis*, *H. broadbalkiensis* and *H. ?dihystera* occurred near or within the shade of the trees. In the woodland *H. paxilli*, *H. varicaudatus* and *H. vulgaris* had their own centres of maximum density and were usually few where the species overlapped. Horizontal distribution was not entirely dependent on vegetation. In the ungrazed grassland the seasonal fluctuations in populations of *H. pumilus* and *H. vulgaris* suggested two peaks, one in late winter–early spring, the other in late summer–early autumn. The first was caused by larvae, for adults did not increase until May. In the woodland and ungrazed grassland nematodes were most abundant in the upper layers of the soil, whereas in Broadbalk wheatfield there were few in the top 0–2 cm and most between 6 and 8 cm. In the ungrazed grassland *R.*

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pumilus remained most abundant in the 0–2 cm layer throughout the year, whereas *H. vulgaris* was most abundant at 4–8 cm during August and between 8 and 10 cm during winter. The vertical distribution patterns of *H. vulgaris* and *R. pumilus* were not related to soil moisture or root content, and vertical migration was not observed, which suggests that each species is most plentiful at a depth where conditions are best for reproduction. (Yuen)

Nematodes and "Docking Disorders" of Sugar Beet

Many crops of sugar beet on alkaline sandy soils in Eastern England grew slowly in 1964. In some fields (type *a*) the stunted plants had short tap roots and long thick laterals, in others (type *b*) the tap roots were normal in shape, but small with short tufted laterals, which bore small galls behind the dead or dying root tips. The galls did not contain endoparasitic nematodes and could have been caused by the feeding of ectoparasitic nematodes. Early in the season, in seven out of nine type *b* fields, the needle nematode, *Longidorus attenuatus*, and in one field *L. elongatus*, was more abundant around the roots of stunted than around normal plants: in type *a* fields *Longidorus* spp. were rare. Other species of ectoparasitic nematode were common in both kinds of field. *Tylenchus* was equally abundant around normal and stunted plants and *Tylenchorhynchus* was more abundant around normal plants. Endoparasitic *Pratylenchus* spp. were recovered in equal numbers from around the roots of normal and stunted plants.

In a type *b* field in Norfolk at harvest 1963, *L. attenuatus* was about equally abundant in the four 6-in. layers down to 24 in. In two others there were few in the top 6 in. and many between 6 and 24 in. In one field the population of *L. attenuatus* in the top 6 in. was 1/litre soil in December, 11/litre in mid-March and 30/litre in the rows of sugar beet at the end of June. This suggests that the nematode moves downwards in the soil during winter, upwards during spring and assembles in the beet rows after sowing, but too little is known of the life cycle to be sure. (Whitehead and Cooke)

Sugar beet usually follows barley on the soils prone to "Docking disorders", and if *L. attenuatus* is one of the causal organisms its spring numbers are determined in many fields by the preceding barley crop and its weeds. In tests where various plants were grown in pots the nematode did not increase under any, but most survived under white clover, more survived under barley than under peas or sugar beet, and fewest under chickweed. The greatest concentration of this species recorded in field soil was 710/litre in a core of 4 in. diameter taken 4–8 in. deep. An average concentration of 100/litre, if aggregated about normally spaced sugar-beet plants, represents 5,000 per plant. Experiments are needed to measure aggregation around seedlings and to find what population densities injure seedlings and singled plants. (Green)

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A Nematode Parasite of an Insect

The penetration of the sphaerulariid nematode parasite, *Tripius sciarae*, into its fly host, *Bradysia paupera*, was studied and filmed. The infective stage of the nematode is the adult female still ensheathed in the last larval skin and it takes from 10 minutes to 2 hours to penetrate the cuticle of fly larvae. After exploring the host cuticle the nematode becomes attached by an adhesive mass formed from the front part of its ensheathing larval cuticle that has been partly dissolved by a secretion from the pharyngeal glands. When attached, the nematode thrusts its mouth stylet around the area where it will penetrate and then confines the thrusting to an area about 1 μ across. At this stage the pharyngeal gland ducts are almost empty, whereas before forming the adhesive mass they are much distended. After the stylet has penetrated and the hole is large enough, the nematode thrusts the fore part of its body through the cuticle and enters its host. The entrance hole is sealed, partly by cuticular elasticity and partly by the adhesive mass with the nematode's ensheathing cuticle attached. Although the nematode continues thrusting its spear for a while when inside its host, it cannot feed, because pharynx and intestine are not connected. After a few days the nematode's uterus prolapses through the vulva, eggs are laid, escape into the haemocoel of the insect host, hatch and develop into fourth-stage larvae. The host continues to develop, and although parasitised females are usually sterile, they go through the motions of egg laying, but instead of eggs deposit groups of nematodes containing males and pre-infective females. The nematodes copulate through the ensheathing last larval skin, the males die and the females are ready to begin the infective cycle again.

The host fly, *Bradysia paupera*, feeds on soil fungi and is of little economic importance, but sometimes damages mushroom compost. Parasitism of this type by nematodes, about which little is known, may be an important part of natural control. (Poinar and Doncaster)

Stem and Bulb Nematodes

Hot-water treatment of bulbs is the only effective way of controlling the bulb race of *Ditylenchus dipsaci* in narcissus. Experiments started at the Ministry of Agriculture's Plant Pathology Laboratory showed that more *D. dipsaci* died when stored at 25° and 30° C after hot-water treatment at 46° C for 2 hours than when stored at 15° or 20° C. Slow heating to 46° C and slow cooling after treatment did not alter the number killed. Storage at 25° C or above before the hot-water treatment acclimatised the nematodes to heat, and more survived the treatment than when stored in the cold. Storage at 35° C was itself harmful to nematodes.

Co-operative work with A. L. Winfield (National Agricultural Advisory Service, Kirton) showed that nematodes become acclimatised to heat when bulbs are placed in warm stores to lessen flower injury from hot-water treatment. Less than a fifth of the nematodes survived hot-water treatment after storage at 20° C for 4 days but more than four fifths survived after storage at 34° C for 4 days. Infested bulbs stored in unheated buildings at

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temperatures around 20° C before treatment produced no "spikkel" symptoms of nematode attack, whereas a third of those stored at 34° C bore "spikkels". (Green)

D. dipsaci exists in biological races that differ in their ability to reproduce on different crops and weeds, although plants can be invaded and harmed by races that do not multiply on them. As more than one race may occur in a field, knowledge of the behaviour of the races is important economically. Races obtained from lucerne, red clover, white clover, oat, narcissus and tulip were tested on lucerne, red and white clover, narcissus, tulip and hyacinth grown in pots. All six races invaded all six plants, and some reproduced on other plants in addition to the type host. For example, the oat race also reproduced on hyacinth and tulip, the narcissus race on tulip, and the tulip race on narcissus and hyacinth. Ability of the nematode to reproduce was not correlated with injury to the host. Some plants that either were not invaded or invaded only temporarily were severely injured.

Onion is a host of several races, and crosses between races were made by inoculating onion seedlings with single pre-adult females of one race and introducing five males of another. The F_1 progeny from these crosses reproduced on onion, and are being compared on a range of hosts with their parents.

Weekly sampling of a plot of infested oats showed how the proportions of different stages of *D. dipsaci* changed during the year. Before sowing, the soil contained fourth stage (pre-adult) larvae and a few adults. Within a month of the oats germinating, half the population was second- and third-stage larvae which must have arisen from eggs laid by newly formed adults. During the growing season the population structure was relatively stable, with second-, third-, fourth-stage larvae and adult nematodes in the proportions 28, 22, 34 and 16% respectively. As the oat plants matured and dried, the proportions of the resistant fourth stage increased. By September adults were only 4% of the population, there were no eggs or second-stage larvae, 18% were third-stage and 78% fourth-stage larvae.

Considerable success was achieved in raising clonal populations of *Aphelenchoides ritzemabosi* and *D. dipsaci* from individual females placed on plant callus tissue. Indeed, at 18° C *A. ritzemabosi*, while increasing only five times on lucerne seedlings, increased 100 times on callus tissue of lucerne or red clover. When cultured on callus of different plants, namely, lucerne, red clover, potato, pea, apple, rose and turnip, it multiplied most on rose callus, which grew most rapidly. It did not reproduce on turnip callus, the only one derived from root tissue.

In an experiment to compare rates of reproduction of different races of *D. dipsaci* on callus in a medium containing different amounts of 2, 4-D, all six races tried reproduced rapidly on lucerne and red clover callus, but the lucerne race multiplied best on lucerne callus and the red clover race best on red clover callus. Increasing the amount of 2,4-D above 2 ppm decreased the growth of callus and slowed the multiplication of the nematodes.

When red clover seedlings were placed on basic medium plus coconut milk, 2,4-D or an extract of nematodes of the red clover race, much callus

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formed with 2,4-D, there was a little hypertrophy with the nematode extract and no callus with the basic medium or medium plus coconut milk. *A. ritzemabosi* does not normally reproduce on red clover plants, but it multiplied rapidly onthe red clover callus produced by 2,4-D, it also multiplied, although less rapidly, on seedlings in medium plus nematode extract, but did not multiply in the other media. This suggests that the red clover nematodes contained a substance that acted on the seedlings in a manner similar to 2,4-D. (Webster)

Root-knot Nematodes

Root-knot nematodes (*Meloidogyne* spp.) are important pests of cultivated plants in tropical, subtropical, warm temperate and glasshouse soils. The host ranges of different *Meloidogyne* spp. differ, so a suitable rotation of resistant and susceptible crops might control them. As the choice of crops is determined by the species of *Meloidogyne* in the soil, correct identification of these is important, but some of the most widespread species have been inadequately described. Hence the genus was studied closely to improve the bases for identification. The posterior cuticular patterns of the females (the usual criterion for identification) retain their morphological characters throughout periods of culture on host plants, but several species have similar patterns, and in some the pattern is variable. Measurements of the males and females are of little value, but some measurements of larvae, e.g. total length, greatest breadth, tail length, breadth at anus and length of stylet, can be used to separate them into groups. The groups, other than that in which the rectum is normally inflated, can be further subdivided by the shape of the head, the number and disposition of the head annules, the shape and annulation of the tail, markings of the lateral field and the position of the cephalids and hemizonid (when visible). Useful supplementary characters are shape of the females and the thickening of the female body cuticle, the length of the stylet, the shape of the stylet knobs and the position of the excretory pore, in terms of body annules behind the head. Males can be identified by the shape and length of the head, the disposition of the head cap and head annules, the positions of the anterior and posterior cephalids, the appearance of the stylet, the markings of the lateral field, the form of the spicules and gubernaculum and the position of the phasmids. Illustrated descriptions of most *Meloidogyne* spp., including four new ones, have been prepared for publication. (Whitehead)

A new species of root-knot nematode found in Wales and the West of England from Lancashire to Cornwall was described and named *M. naasi* n. sp. It occurs mainly on spring barley and is often associated with poor plants in patchy crops. Winter wheat, sugar beet, several fodder grasses and some common weeds are also attacked. The galls are usually small, even when several nematodes are developing in them. They are club-shaped when terminal, but when intercalary they may make the root bend in a horse-shoe or loose spiral. The females and their egg masses are usually completely embedded in the gall, and the only external evidence of their presence is the swelling and distortion of the root. (Franklin)

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The only record of a false root-knot nematode, *Nacobbus serendipiticus*, in the United Kingdom was from a glasshouse in 1957. This and the fact that galls form late in the season suggest it is an alien species requiring warmer temperatures than are usual in the United Kingdom. However, it does overwinter successfully outdoors either as egg or larva, and may therefore be native. Eggs hatch readily in water and infective larvae measure 334 by 14 μ. After entering a host root they enlarge and become coiled in the form of a letter C. They continue to grow, increasing to 600–700 by 30 μ as the gonads begin to develop. After a parasitic phase the larvae probably leave the roots and undergo one or two moults in the soil, then the females, and perhaps the males, re-enter roots to complete the life cycle which, in a cold house, takes 7–9 weeks. There is some evidence that small galls are formed by larvae, but mature females cause the typical galls associated with *Nacobbus* attack. (Franklin and Clark)

Cyst-nematodes

Cereal cyst-nematode, *Heterodera avenae*. An experiment at Woburn to find how formalin, nabam and other treatments affected the occurrence of "scorch" in spring wheat, gave plots with different populations of *Heterodera avenae* and provided an opportunity to study its effect on yield. On 1 June samples of tops and roots of the plants were weighed; also nematodes in and around roots and the "knots" on the roots were counted. Correlations were calculated between these results and the yields of grain and straw at harvest.

There were large negative correlations between numbers of nematodes and the various attributes of yield (plant weights in the samples, yields of grain and straw), suggesting that the nematodes had depressed growth and yield. The number of "knots" was positively correlated with the number of nematodes and usually gave an even greater negative correlation with attributes of yield. Plant weights in June were very closely correlated with yields of grain and straw. The practical implications are: (1) that root "knots" alone, which are much easier to count than nematodes, can be used to measure nematode attack, and (2) that the weight of tops in samples gives a good indication of final yield. Hence, the incidence of the pest and the losses it causes can be assessed by counting "knots" on roots and weighing the tops of plants in early June.

A feature of the results was that root and top weights in samples were not correlated. By inducing "knots" and stimulating proliferation of rootlets, the nematodes apparently increased root weights while decreasing plant top weights. (Williams)

The potato cyst-nematode, *H. rostochiensis*. The ability of 43 populations of potato cyst-nematode to multiply on hybrid potatoes containing genes for resistance derived from *Solanum tuberosum* ssp. *andigena* (gene H_1) or *S. multidissectum* (gene H_2), or from both (H_1H_2), was tested and compared with their ability to reproduce on the susceptible variety, Arran Banner, which lacks both genes (h_1h_2). The results suggest that the

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populations contained at least four races or pathotypes. Using a notation similar to that used for races of the potato blight fungus gives the four pathotypes numbered as in Table 1. Populations fall into five groups distinguished by the proportions in which they contained different pathotypes (Table 2).

TABLE 1

Pathotypes distinguished by resistance derived from S. andigena *and* S. multidissectum

Pathotypes	Arran Banner h_1h_2	ex *andigena* H_1h_2	ex *multidissectum* h_1H_2	ex *andigena* × *multidissectum* H_1H_2
0	+	—	—	—
1	+	+	—	—
2	+	—	+	—
1, 2	+	+	+	+

+ indicates ability to reproduce.

TABLE 2

Mean percentage of different pathotypes in the populations tested

Population group	No. of populations	Pathotypes 0	1	2	1, 2
A	5	<1	92	4	3
B	10	<1	75	<1	25
C	9	<1	78	14	7
D	5	27	17	50	6
E	14	35	8	57	<1

The evidence for pathotype 1,2 is positive, being based on the occurrence of cysts on plants of type H_1H_2, but evidence for pathotype O is negative and therefore less satisfactory. The proportion of type O individuals given is the difference between the number of cysts formed on h_1h_2 plants and the sum of those on H_1h_2, h_1H_2 and H_1H_2; this assumes that the numbers of females potentially able to develop is constant, and whether they do develop is determined only by the genes in question.

These results confirm that the varieties bred from *S. andigena* and now appearing on the market should resist attack on most fields in S.E. England, for group E contains populations mainly from that area. The populations on our Woburn Farm are also of this kind. The presence of pathotype 1,2 in fields from the Wash northwards also helps to explain the disappointing performance of ex *multidissectum* plants. When two plants of type H_1H_2 were compared, one bred at the Scottish Plant Breeding Station showed some additional resistance to pathotype 1,2. Indeed, its resistance was about equal to that of the resistant *S. vernei* (*balsii*), and would be useful against most populations of nematodes in England. (Jones and Parrott)

To study the inheritance of the ability of *H. rostochiensis* to attack potatoes of different genetic constitution, virgin females and adult males of different pathotypes were isolated and the first controlled crosses between pathotypes were made. (Webster)

Pea cyst-nematode, *H. goettingiana*. An experiment with plants in pots studied how varying levels of the pea cyst-nematode affected plant growth,

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the rate plants were invaded, the survival of larvae and the sex ratio. Cysts were added to 3-in.-diameter pots containing sterilised soil to give 0, 1, 2, 4, 8, 16 thousand larvae respectively, but even the largest number failed to affect the growth of the plants or the size of their root systems. The eggs in the cysts hatched freely (average 46%), the percentage of larvae that reached maturity 6 weeks after inoculation was similar for all inoculum levels (49%), and the sex ratio was consistently 1 : 1. The maximum invasion rate at which larvae developed to maturity was 4,000/g of root, after which the later invaders failed to mature. (Shepherd)

Population changes under peas were studied in microplots containing field soils. One set with a wide range of population densities gave the theoretically expected curve for the relationship between population density and growth. At low densities plants were little affected; as densities increased the growth of the plants was depressed, but not in direct proportion to density, for, as the density became greater, more nematodes were needed to exert the same depressing effect. With more than about 300 eggs/g soil increasing the density had little further effect on yield. Contrary to the results in the pot experiments, the number of new females produced was almost constant over the whole range of population densities, for at 4 eggs/g soil about 50% and at 350 eggs/g soil about 1% of the larvae became females. Another feature of the experiment was that those females that completed their development produced on average the same number of eggs. The results indicate that competition by larvae for root space is sometimes intense, but females that succeed in developing are no longer subject to competition. They help to explain why populations tend to increase to the same maximum regardless of the initial population density and suggest that the size and form of the root system may be a factor determining the maximum. This suggests that nematode-capturing fungi and nematicides usually remove from the soil only those larvae of cyst-nematodes that are surplus to the carrying capacity of roots. Enemies of the maturing females or compounds that prevent reproduction might check population growth more effectively. (Jones and Parrott)

Developmental morphology of cabbage cyst-nematode, *H. cruciferae*. The development of *H. cruciferae* was studied in detail. Cephalids, hemizonid and hemizonion are present in adult males and second-stage larvae. Rectal glands are visible, as rudiments, in the pre-infective second-stage larvae; they become more prominent in third- and fourth-stage larvae, are fully formed in the adult female, when the entire group is only 45 μ across, very much smaller than those of *Meloidogyne* spp. The glands seem to be arranged thus: 1 dorsal, 1 ventral, 2 subdorsal and 2 subventral. With the development of the vulval cone in the female, the egg-sac matrix begins to be expelled through the vulva. This secretion seems to dissolve the anal region of the encircling fourth-stage cuticle, for this cuticle merges imperceptibly into the egg sac. Later, fluid of a different kind is expelled through the anus and seems to push out the overlying fourth-stage cuticle without dissolving it. The fourth-stage cuticle may serve to anchor the developing egg mass to the female and encourage the flow of secretion back along her body.

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Adult males usually have the anterior cephalids opposite the third annule behind the constriction of the lip region. Posterior cephalids usually lie opposite annules 9 or 10. In *H. glycines* they lie opposite annules 6–8, and their positions in *Heterodera* species may be of taxonomic value. (Doncaster)

Dormancy in encysted eggs of *H. rostochiensis*. The term "dormancy" applied to *Heterodera* means a temporary failure of the eggs to hatch even when given the usual necessary stimulus. Whether it happens with *H. rostochiensis* was uncertain, although it has been reported to be brought on by changes in the environment. The conditions obtaining in soil in the late summer or early autumn have been said to induce dormancy; eggs in cysts brought into the laboratory before July were not dormant in October. To test this, infested soil was collected in mid-July, just as the year's first generation of cysts was turning brown and falling from the roots. Soil was also collected in mid-August, September and October. Each month's soil was divided into five lots and stored in polythene bags at 15° and 20° C, and at 5°, 15° and 30° C for 6 weeks followed by 20° C. Superimposed on these main treatments were two subtreatments, storage (*a*) in soil at the moisture content when collected and (*b*) in soil air-dried for 1 week. Hatching tests at monthly intervals indicated that cysts stored moist gave a smaller hatch than those stored air-dry. Regardless of the month during which the soil was collected, the hatch declined during late autumn and early winter, but the decline was least for cysts from soil collected in mid-July. Hence, a period of dormancy seems intrinsic to the life cycle rather than being created by soil conditions. The temperature treatments did not change the onset of dormancy, but a period at 30° C broke the dormancy sooner than other treatments. The factors inducing dormancy started to act as early as mid-July, but did not become pronounced until August. Soil temperature changes alone were not responsible; nor was drying, which increased rather than decreased hatch. (Shepherd and Cox)

Hatching of cyst-nematodes. The soil sterilant metham sodium ($CH_3.NCS.SNa$) inhibits hatching of *H. schachtii* eggs, whereas nabam $(CH_2.NCS.SNa)_2$ stimulates hatch. In view of the contrasting behaviour of these two closely related dithiocarbamates, their action on *H. schachtii* was studied in more detail. Because simple N-substituted and unsubstituted dithiocarbamates are neither stimulatory nor toxic, the dithiocarbamate group itself is probably inactive.

Nabam and metham sodium readily decompose. In alkali the main breakdown product of metham sodium is methyl isothiocyanate, which is very toxic to nematodes and inhibits hatching. Some of the minor decomposition products inhibit hatching, others stimulate it slightly, but their effects would be suppressed where much methyl isothiocyanate was formed. The stable breakdown products of nabam, which is not a nematicide, include ethylene- and polyethylene-thiuram monosulphide, both of which stimulate hatching of *H. schachtii* at 10^{-3}–10^{-4} *M*, the first as much as does standard beet root diffusate. These two compounds can

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be classified with another group of hatching compounds, the thioureas. All have the grouping –NH–C=S in their molecules.

The hatching activity of more than 400 compounds was tested with *H. rostochiensis*; these included most of the compounds previously tried with *H. schachtii*. About 30 were active; their structures differ greatly and they include indamines, heterocycles, dyes and some dicarboxylic acids. Of 30 compounds that hatched *H. schachtii* eggs as well as did beetroot diffusate, the only three that also strongly stimulated hatching of *H. rostochiensis* eggs were tolylene blue, anhydrotetronic acid and picrolonic acid. The other 27 were inactive. Thus, synthetic chemicals that stimulate hatching, like the natural hatching factors, are specific. No compound yet tested was very active with *H. rostochiensis* but inactive with *H. schachtii*, but some having moderate activity with *H. rostochiensis* were less active with *H. schachtii*. (Clarke and Shepherd)

It is still impossible to get *H. goettingiana* eggs to hatch *in vitro*, although they hatch freely in soil where peas are grown. To see whether removing cysts from soil inhibited hatch, a pot experiment was done to compare the hatch of eggs from cysts: (*a*) in infested soil; (*b*) removed from infested soil and replaced in potting soil; (*c*) removed from infested soil and replaced in sand; (*d*) in infested sand; (*e*) removed from infested sand and replaced in potting soil; and (*f*) removed from infested sand and replaced in sand. Because hatch required the presence of pea seedlings, the pots were sown with peas and, because hatch could not be assessed directly, the number of larvae within the roots of the pea plants after 3 weeks was taken as a measure of hatch. Cysts were also extracted from the soil, sand and potting soil and the loss of egg contents estimated. Removing cysts from soil or sand did not influence hatch, and hatch was stimulated equally by pea roots growing in soil or sand. (Shepherd)

Nematicide Trials

In collaboration with the Shell Chemical Company and the West Norfolk Farmers' Manure and Chemical Company, the effects on *H. rostochiensis* populations of applying "D-D" at different times in a rotation were tested on a silty loam soil at Outwell, Norfolk. Potatoes were grown in the 1st and 6th year and insusceptible crops in the 2nd to 5th years. On some plots "D-D" at 400 lb/acre was applied only in single, but different, years; on others it was applied in 2, 3, 4 and 5 years. The mean annual rate of decline of *H. rostochiensis* (hatchable larvae) under crops other than potatoes was 50%. Single injections of "D-D" had much the same effect on populations at the end of the rotation whatever the year they were applied. Where injections were repeated, the greatest benefit was from the first, which killed on average 67%. Subsequent injections killed 52, 26 and 2% of the remaining populations. Only injections repeated in 4 or 5 years lessened the population so much that it did not recover completely when potatoes were grown in the 6th year. Crops other than potatoes showed no large benefit from treatment with "D-D": for potatoes only, it killed insufficient nematodes to be economic. (Doncaster)

Chloropicrin and "D-D" at 100 lb/acre in plots in a field of sugar beet

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affected by "Docking disorder" greatly improved the vigour and colour of the plants. Mean heights of plants in July were 15·9, 13·6 and 7·8 cm and yields of roots were 13·2, 9·9 and 5·8 tons/acre on the chloropicrin, "D-D" and untreated plots respectively. Available soil nitrogen slightly increased after treatment, but this was not correlated with crop response. After harvest saprophytic nematodes had re-established their original population in the 0–8 in. layer of soil, but ectoparasitic nematodes had not and *Longidorus attenuatus* were not found in the samples. Both fumigants killed about 94% of the nematodes. The better plants obtained by using chloropicrin may mean this killed other soil-borne pathogens unaffected by "D-D", or "D-D" may have been toxic to the beet and depressed growth and yield. (Greet)

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