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Movement of the Entomogenous Nematodes of the Families Heterorhabditidae and Steinernematidae in Soil

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The entomogenous nematode species *Heterorhabditis heliothidis* (Kahn, Brooks, and Hirschmann), *H. bacteriophora* Poinar, *Neoaplectana carpocapsae* Weiser, and *N. glaseri* Steiner are promising biological control agents for a broad range of soil-inhabiting insect species (6). Many factors in soil affect nematode survival, movement, and infectivity: Moisture is probably the most important physical factor affecting survival (5,7), whereas movement and infectivity are influenced by soil texture (2,4), presence or absence of a host (1), behavior of the species (8,9), and moisture (3).

The objective of this research was to study the comparative movement of *H. heliothidis, H. bacteriophora,* two strains of *N. carpocapsae,* and *N. glaseri* in soil over a 30-day period.

Materials and Methods

Infective juveniles of *H. heliothidis, H. bacteriophora, N. carpocapsae* (Breton and Mexican strains), and *N. glaseri* were obtained from Biosis, Palo Alto, California. Stock suspensions were maintained on moist sponge at 10 C.

A Lakeland sandy soil (thermic, coated typic quartzipsamments, 95% sand, less than 5% clay–silt) was packed to a density of 1.60 g/cm^3. Soil was oven dried at 105 C for 48 hours, and the moisture was adjusted to 9.1% (w/w) with distilled water.

Polyvinyl chloride (PVC) pipes (3.8 cm i.d. × 1 m long) were filled with soil. Ten thousand nematodes in 5 ml water were added to the surface of the soil at one end of the pipe and both ends were capped with tape. The pipes were positioned with the nematodes at top or bottom (vertical) or with the nematodes at one end (horizontal). There were four replications per treatment. The test was repeated with *N. glaseri* with 2-m-long tubes, 100,000 nematodes per tube, six replications per treatment. All tubes were maintained at 26 ± 2 C for 30 days. At harvest, each pipe was cut into 15-cm sections. The soil was washed three times with 150 ml water which was poured into a separatory funnel and allowed to settle for 15 minutes. A 50-ml sample was then drawn from the bottom of each funnel, and nematodes were quantified from an average of three 1-ml subsamples.

To verify infectivity, nematodes recovered were placed in petri dishes with lab-reared *Galleria mellonella* (L.) larvae (6). After 6 days, the *G. mellonella* larvae were examined for the presence of developing nematodes.

Results

When infective juveniles of *H. heliothidis, H. bacteriophora,* and *N. carpocapsae* (Breton and Mexican strain) were placed on the surface of a vertical column of soil, no *H. heliothidis* or *N. carpocapsae* (Breton and Mexican strain) were recovered from below 15 cm from the surface after 30 days (Table 1). Only 4% of the *H. bacteriophora* recovered were from the 15–30-cm depth, the deepest they migrated. *N. glaseri* migrated throughout the entire 90-cm col-

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TABLE 1. Distribution of *Heterorhabditis heliothidis, H. bacteriophora, Neoaplectana carpocapsae,* and *N. glaseri* 30 days after introduction at the top or bottom of a vertical column or at one end of a horizontal column of Lakeland sandy soil.

Distance from point of introduction (cm)	Percentage of nematodes recovered (mean)				
	H. heliothidis	*H. bacteriophora*	*N. carpocapsae* (Breton)	*N. carpocapsae* (Mexican)	*N. glaseri*
Nematodes placed on top of vertical column					
0–15	100 (3,172)	97 (3,937) a	100 (4,050)	100 (6,925)	68 (3,161) a
15–30	0	4 (325) b	0	0	14 (720) b
30–45	0	0	0	0	9 (405) bc
45–60	0	0	0	0	3 (136) c
60–75	0	0	0	0	3 (125) c
75–90	0	0	0	0	3 (81) c
Nematodes placed in bottom of vertical column					
0–15	92 (4,650) a	83 (3,662) a	43 (2,875) a	93 (6,350)	6 (275) a
15–30	8 (400) b	12 (537) b	57 (3,687) a	6 (512)	6 (255) a
30–45	0	5 (212) b	0	1 (—)	11 (436) a
45–60	0	0	0	0	18 (703) ab
60–75	0	0	0	0	25 (1,015) bc
75–90	0	0	0	0	34 (1,334) c
Nematodes placed at one end of horizontal column					
0–15	96 (5,025)	98 (4,637) a	100 (3,062)	100 (4,687)	4 (172) a
15–30	3 (175) b	2 (300) b	0	0	4 (180) a
30–45	1 (—)	0	0	0	5 (215) a
45–60	0	0	0	0	7 (318) a
60–75	0	0	0	0	21 (965) a
75–90	0	0	0	0	59 (2,667) b

Means followed by the same letter are not significantly different ($P = 0.05$). ANOVA and Duncan's new multiple-range test.

umn, although the greatest number (68%) remained in the top 0–15-cm section.

When infective juveniles were placed at the bottom of the soil columns, *H. heliothidis* and *N. carpocapsae* (Breton and Mexican strain) were found in the 15–30-cm section from the bottom. *H. bacteriophora* were recovered 30–45 cm above the area of introduction. *N. glaseri* were recovered from the entire 90-cm column with a significantly ($P = 0.05$) higher number (34%) in distal 15 cm (75–90 cm) than in the four sections (0–60 cm) near the point of introduction. The number of *N. glaseri* recovered from the bottom 0–15-cm section (point of introduction) also was significantly lower than from the distal two sections.

Placement of infective juveniles at one end of horizontal columns showed that movement of *H. heliothidis* and *H. bacteriophora* was limited to 0–30 cm. *N. carpocapsae* (Breton and Mexican strain) did not move more than 15 cm laterally. Significantly ($P = 0.05$) more *N. glaseri* (59% of total) were located 75–90 cm from the point of introduction (Table 1).

When all tests were repeated with a 2-m column with *N. glaseri,* nematodes were recovered from all sections of the column when introduced at the bottom of vertical columns or at one end of horizontal columns (six replications). When placed on top, nematodes were recovered 155–170 cm deep in five replications and 170–185 cm deep in one replication.

H. heliothidis, H. bacteriophora, N. carpocapsae (Breton and Mexican strain), and *N. glaseri* recovered from the soil from any section 30 days following application readily infected larvae of *G. mellonella.*

DISCUSSION

The results showed that in Lakeland sandy soil *N. glaseri* moved more readily than the three other species of nematodes. There was little difference in dispersal be-

tween *H. heliothidis, H. bacteriophora,* and *N. carpocapsae.*

All species dispersed more readily upward than downward when placed in soil columns. There was some lateral dispersal of *H. heliothidis, H. bacteriophora,* and *N. carpocapsae.* If insect larvae had been present, migration would probably have been greater (2). *N. glaseri* moved through the entire length of the columns. Variation in movement of the different species of entomogenous nematodes in sandy soil suggests that nematode biology could dictate the method of field application. For species that do not move, broad dispersal in the root zone would be required. Application techniques will require evaluation in order to effectively utilize nematodes as a biocontrol agent.

Literature Cited

1. Byers, J. A., and G. O. Poinar, Jr. 1982. Location of insect hosts by the nematode *Neoaplectana carpocapsae* in response to temperature. Behavior 79: 1–10.

2. Georgis, R., and G. O. Poinar, Jr. 1983. Effect of soil texture on the distribution and infectivity of *Neoaplectana glaseri* (Nematoda: Steinernematidae). Journal of Nematology 15:329–332.

3. Laumond, C., H. Mauleon, and A. Kermarrec. 1979. Donnees nouvelles sur le spectre d'hôtes et le parasitisme du nematode entomophaga, *Neoaplectana carpocapsae.* Entomophaga 24:13–27.

4. Moore, G. E. 1973. Moisture requirements of the DD-136 strain of *Neoaplectana carpocapsae* (Nematoda: Rhabditidae) as related to host infection. Journal of Experimental Parasitology 33:207–211.

5. Moyle, P. L., and H. K. Kaya. 1981. Dispersal and infectivity of the entomogenous nematode, *Neoaplectana carpocapsae* Weiser (Rhabditida: Steinernematidae), in sand. Journal of Nematology 13:295–300.

6. Poinar, G. O., Jr. 1971. Use of the nematodes for microbial control of insects. Pp. 181–203 *in* H. D. Burges and H. W. Hussey, eds. Microbial control of insects and mites. New York: Academic Press.

7. Poinar, G. O., Jr. 1979. Nematodes for biological control of insects. Boca Raton, Florida: CRC Press.

8. Simons, W. R., and G. O. Poinar, Jr. 1973. The ability of *Neoaplectana carpocapsae* (Steinernematidae: Nematodea) to survive extended periods of desiccation. Journal of Invertebrate Pathology 22:228–230.

9. Wallace, H. R. 1958. Movement of eelworms. II. A comparative study of the movement in soil to *Heterodera schachtti* Schmidt and of *Ditylenchus dipsaci* (Kuhn) Filipjev. Annals of Applied Biology 46:86–94.