Biological Control of the Grasshopper *Hesperotettix viridis pratensis* by the Nematode *Mermis nigrescens*[1]

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Abstract: Decline and disappearance of a natural population of the grasshopper *Hesperotettix viridis pratensis* was related to severe infection by *Mermis nigrescens.* In contrast the numbers of slightly infected *Melanoplus bivittatus* did not decrease. Uninfected *M. sanguinipes, M. differentialis* and *M. femur-rubrum* also did not decrease. The high percentage of infection in *H. viridis pratensis* was related to low, wet habitat, where the grasshopper fed primarily on *Solidago missouriensis*; infected individuals failed to develop ovaries or mature testes. This is believed to be the first reported occurrence of a nematode parasitizing *H. viridis pratensis.* In juvenile *M. nigrescens* the unreported shape of the stoma, the stylet shape and paired oval structures in the cerebral region were photographed. Factors affecting biological control of grasshoppers by using *M. nigrescens* were discussed. *Key Words: Melanoplus bivittatus, Melanoplus sanguinipes, Melanoplus differentialis, Melanoplus femur-rubrum, Solidago missouriensis,* Environmental factors, Anatomical changes, Anatomical features.

Millions of acres of land are sprayed with insecticides to reduce grasshopper numbers (23). Parasites have been observed infecting high percentages of grasshoppers and may be of interest for biological control. Nematodes of the genus *Mermis* parasitize many species of grasshoppers (3, 10, 16, 24) in which they disrupt host reproduction and eventually kill the immature or adult hosts (2, 6, 8, 10, 26). *Mermis nigrescens* Duj. (*M. subnigrescens* Cobb) is most commonly reported (3, 4, 6, 9, 13, 15, 18, 24) and is believed to play an important natural role in suppressing grasshopper populations (4, 18). *M. nigrescens* and *M. subnigrescens* may be the same species (1, 12, 14, 20) or may be separate species (6, 9). They have been reported infecting up to 70% of grasshopper populations (3, 4, 5, 9, 10). Incidence of their parasitism has been much higher in moist, than in dry areas (2, 26). *M. nigrescens* also infects earwigs (1, 8, 14) and has been reported parasitizing Coleoptera and Lepidoptera species (16). Polozhentsev (20) lists *M. subnigrescens, M. meisneri* Meisn., *M. euprepiae* Siebold, *Filaria liparidis chryssorrhoea* Hammerschmidt, *Gordius Leblond* (authority unknown) and *Gordii* sp. Geoze as synonyms for *M. nigrescens.*

Females of this nematode emerge from the ground during the growing season and deposit eggs on the foliage of plants. Emergence and egg laying are stimulated by moisture and light. The eggs are eaten by grasshoppers (probably juveniles and adults) and hatch in the grasshopper alimentary canal, from which the juvenile nematodes move to the grasshopper body cavity. In the body cavity the juvenile nematodes grow in size until they leave the dying or dead grasshopper in late summer or early autumn and enter the soil. They mature in the soil and the following season or more often the second following season, the females emerge and lay their eggs (4, 6).

While *M. nigrescens* has not been used

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to control grasshoppers, *Neoapletana dutkyi* Jackson (22) experimentally controlled the cabbage worm (*Pieris rapae* L.), the corn borer (*Pyrausta nubilalis* Hbn.) and the cabbage root maggot (*Hylemya brassicae* Bouché). Compared with an insecticide *N. dutkyi* killed similar percentages of insects, but the insecticide apparently killed insects at a younger age resulting in less insect damage in the insecticide-protected plots (25). *N. dutkyi* and/or other neoaplectanids have been used with slight to no success against the Japanese beetle (*Popillia japonica* Newm.), soil-inhabiting pasture grubs, the Colorado potato beetle (*Leptinotarsa decemlineata* Say), the artichoke plume moth (*Platyptilis carduidactyla* Riley) and the corn earworm (*Heliothis armigera* Hbn.) (19). Schmiege (21) studied and discussed a number of physical, chemical, and biological factors related to using a neoaplectanid nematode to control insects. Welch reviewed our knowledge of Entomophilic nematodes (26).

In southeastern North Dakota the grasshopper *Hesperotettix viridis pratensis* Scudder feeds primarily on the Missouri goldenrod, *Solidago missouriensis* Nutt., growing on low moist ground. Four other hosts of *M. nigrescens* present in this area are the grasshoppers *Melanoplus bivittatus* Say, *M. sanguinipes* Fabricus, *M. differentialis* Thomas and *M. femur-rubrum* DeGeer, but these primarily feed on different plants on drier ground (17). In the laboratory prior to 1970, it was observed that some adults of *H. viridis pratensis* were nematized and died before depositing their eggs. The purpose of this investigation was to determine the incidence and intensity of nematode parasitism of five grasshoppers occupying different ecological niches, to explore factors related to biological control of the grasshopper and to learn more about the anatomy of the infected insect and the nematode.

MATERIALS AND METHODS

During the 1970 growing season grasshoppers were collected weekly from moist sites in the sandhills prairie, from alfalfa fields, and from roadside areas in Richland, Ransom, and Cass Counties, North Dakota, U.S.A. Density of grasshopper populations was estimated from numbers of grasshoppers present in one yard square quadrats. *H. viridis pratensis* was counted in five quadrats on low, moist ground in the sandhills prairie in Richland and Ransom Counties. *M. bivittatus* was counted in five quadrats in alfalfa fields in Cass County. Specimens of *H. viridis pratensis* and *M. bivittatus* were taken for dissection from areas adjacent to the quadrats. *M. sanguinipes*, *M. differentialis* and *M. femur-rubrum* were collected from alfalfa fields and roadsides in Richland and Ransom Counties. Adult grasshoppers were dissected and the numbers of males and females infected with nematodes, the maximum numbers of nematodes per grasshopper, and the maximum lengths of nematodes in grasshoppers were recorded. Specimens of the nematodes were sent to Dr. W. R. Nickle (Research Nematologist, USDA Crop Protection Research Branch, Beltsville, Maryland) for identification. Host and habitat preferences of the grasshoppers were noted. The vitality and anatomy of infected grasshoppers were compared to those of healthy grasshoppers, and the movement of the juvenile nematode was followed from dead grasshoppers to the soil (sand). Juvenile nematodes were mounted in glycerine, and one was photographed.

RESULTS

H. viridis pratensis fed primarily on *S. missouriensis* in low, moist habitats. *M. bivittatus* was distributed over the entire area of study feeding primarily on alfalfa and other plants on drier ground. *M. sanguinipes*, *M. differentialis* and *M. femur-*

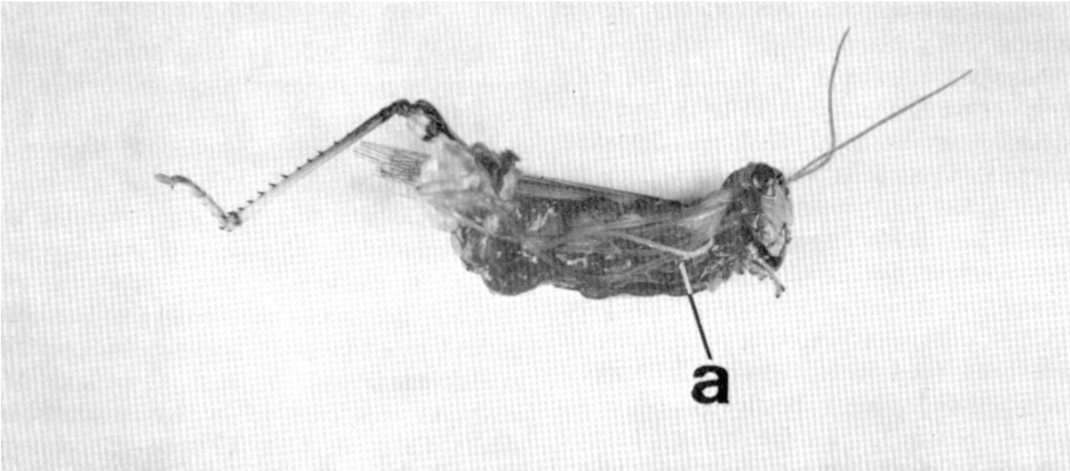

FIG. 1. Adult *Hesperotettix viridis pratensis* bisected longitudinally to show *Mermis nigrescens* juveniles (a) in the body cavity. Grasshopper 3.5 cm from head to tip of abdomen.

TABLE 1. Correlation of grasshopper (*Hesperotettix viridis pratensis*) decline and disappearance with per cent infection by *Mermis nigrescens*, southeastern North Dakota 1970. Corresponding data for the grasshopper *Melanoplus bivittatus* are presented for comparison.

Date Observed		Popuation per square yard[a]	Number Dissected		Per Cent Infected	
			Male	Female	Male	Female
Hesperotettix viridis pratensis						
July	22	18–20	54	108	51.9	70.4
	29	13–15	48	91	27.3	50.0
Aug	5	10–12	32	73	15.6	35.6
	12	8–10	29	58	13.8	19.0
	19	5–7	24	40	4.2	12.5
	26	0–2	4	2	0.0	0.0
Sept	2	0	0	0	0.0	0.0
Melanoplus bivittatus						
July	22	4–6	61	84	3.3	2.4
	29	6–8	39	61	2.6	3.3
Aug	5	7–9	44	68	4.5	1.5
	12	10–12	41	59	2.4	1.7
	19	12–14	45	57	2.2	1.8
	26	14–16	49	51	0.0	2.0
Sept	2	15–17	56	50	1.8	0.0
	9	17–19	58	42	0.0	0.0

[a] Each population range estimate is based on the number of adult grasshoppers in five one-square-yard quadrats

TABLE 2. Highest numbers and maximum lengths of *Mermis nigrescens* juveniles in individual grasshoppers related to time of year, southeastern North Dakota 1970.

Date Observed		*Hesperotettix viridis pratensis*				*Melanoplus bivittatus*			
		Maximum no. of nematodes		Maximum lengths of nematodes (in cm.)		Maximum no. of nematodes		Maximum lengths of nematodes (in cm.)	
		male	female	male	female	male	female	male	female
July	22	5	7	11.4	18.3	1	2	13.5	13.7
	29	2	4	13.2	13.7	1	1	11.9	13.2
Aug	5	2	15	11.4	13.2	2	3	11.4	12.2
	12	3	4	10.4	15.5	1	2	10.4	13.5
	19	2	3	9.7	11.7	1	1	13.2	14.2
	26	0	0	......	......	0	1	......	11.9
Sept	2	0	0	......	......	1	0	14.0	......
	9	0	0	......	......	0	0	......	......

rubrum fed on alfalfa and other plants on drier ground. The population of *H. viridis pratensis* was severely infected with nematodes and declined as the summer progressed; the grasshopper disappeared during late August to early September, prior to the period of oviposition (Table 1). Although slightly infected, the number of adults of *M. bivittatus* increased as the nymphs matured (Table 1). Five hundred and fifty-three specimens of *M. differentialis* and approximately five hundred and thirty specimens each of *M. sanguinipes* and *M. femur-rubrum* were collected throughout the growing season. None of these specimens were infected, and although exact measurements were not made, their adult numbers appeared to increase. The nematodes infecting *H. viridis pratensis* and *M. bivittatus* were identified by Dr. Nickle (personal communication) as juveniles of *M. nigrescens*. The highest number of nematodes and the maximum lengths of nematodes in individual grasshoppers were recorded in Table 2.

Nematized (infected) *H. viridis pratensis*, which contained one to fifteen nematodes coiled in the body cavity (Fig. 1, Table 2), became inactive and jumped poorly; body and wing color faded slightly. Females infected by even one nematode failed to develop ovaries, and infected males remained sexually immature. When nematized grasshoppers died, the juvenile nematodes left the grasshopper body by holes made in the right or left side of the meso-or meta-thorax and entered the soil (sand) within 30 to 60 min.

The internal anatomy of one juvenile nematode mounted in glycerine was extremely clear. The nematode was 0.35 cm wide at its mid-region and 8.3 cm long. The head region (Fig. 2) and the cephalic sensory organs (Fig. 3) resembled earlier descriptions and drawings of *M. nigrescens* and *M. subnigrescens*. The stoma (Fig. 3, 4) was more heavily sclerotized and shaped differently than that illustrated by Hagmeier (13) for the adult *M. nigrescens*. The stylet

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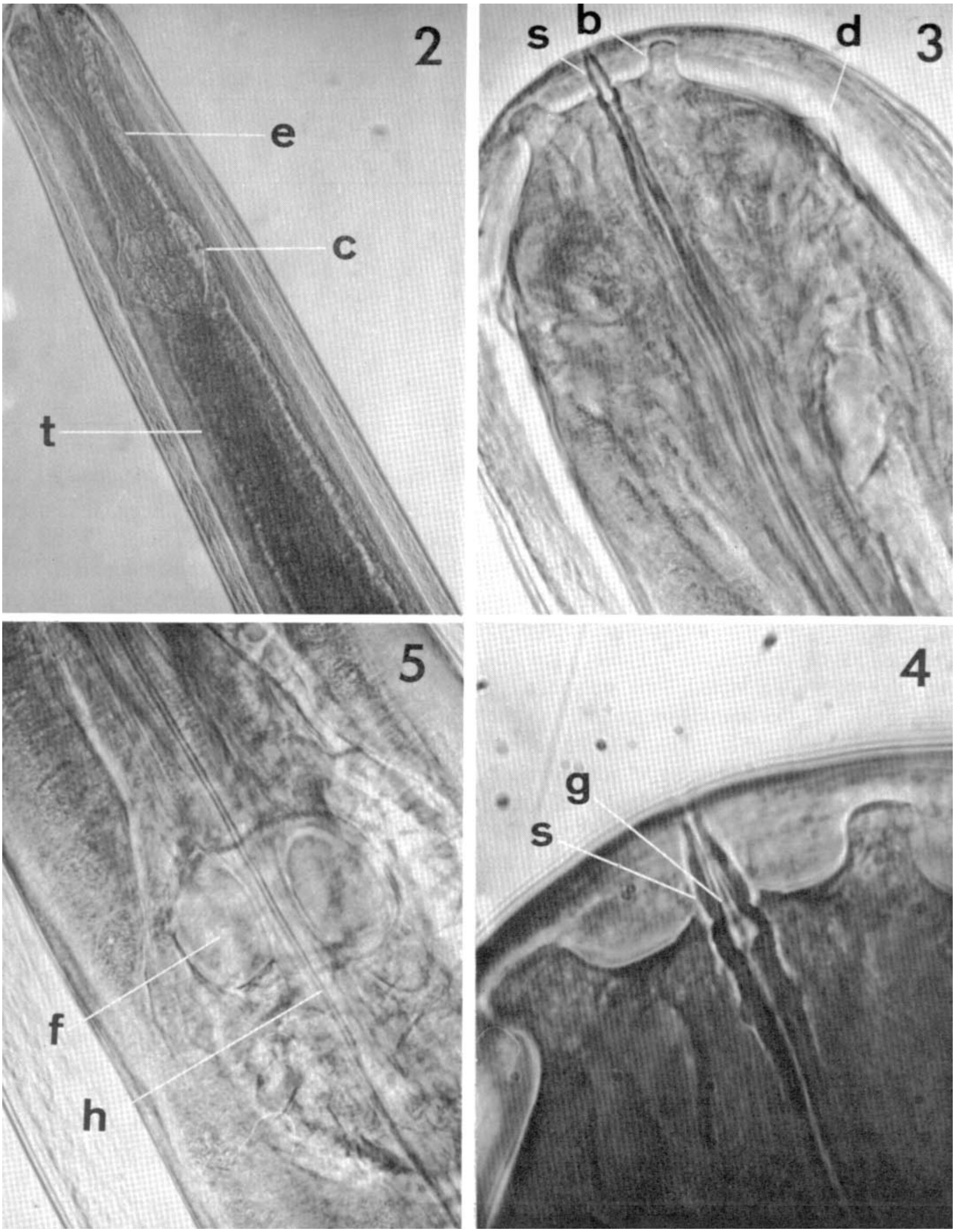
FIG. 2–5. Morphological features of *Mermis nigrescens*, a nematode parasitic on the grasshopper *Hesperotettix viridis pratensis*. **2.** Anterior end of juvenile showing the cylindrical esophagus (**e**), oval cerebral region (**c**), and cylindrical trophosome (intestine) (**t**). (130×); **3.** Sclerotized stoma (**s**), lateral oral papilla (**b**) and lateral papilla (**d**) in the head end of a juvenile. Submedian papillae not



in focus. (546×); **4.** Stylet (**g**) (basal width 0.8, length 11.8 μ) in stoma (**s**) (16 μ from mouth opening to base of stylet, then 7.4 μ to lobed stomal base, 6 μ wide at widest part) and paired lateral oral papillae of juvenile (1310×); **5.** Large oval structures—right (**f**) 37.0 × 21.8, left 37.0 × 18.5 μ, on each side of the lumen (**h**) in the fore part of the cerebral region of a juvenile (590×).

(Fig. 4) had a thick basal part and extended to a long slender point at its anterior end. The base was distinctly divided into two parts as diagrammed by Baylis (1) but may also have had a very indistinct third part similar to that diagrammed by Cobb (6). In the fore part of the cerebral region on each side of the lumen was located a large oval structure (Fig. 2, 5) similar to that illustrated by Hagmeier (13) for *Paramermis contorta* v. Linstow emend. Kohn. In *M. nigrescens* Hagmeier (13) illustrated the nerve ring above what may be these two oval structures.

DISCUSSION

The population of *H. viridis pratensis* was totally destroyed prior to egg laying by parasitism of *M. nigrescens*. Throughout the season *M. bivittatus* was only slightly infected, and *M. differentialis*, *M. sanguinipes* and *M. femur-rubrum* were uninfected, although they have been previously reported as being commonly infected by *M. nigrescens* (3, 6, 9, 10). This indicated that some factor(s) in the environment of *H. viridis pratensis* promoted high infection. Unlike the other grasshoppers *H. viridis pratensis* lived in a low, damp, sandy soil habitat and fed primarily on *Solidago missouriensis*. Also, the occurrence of the highest degree of parasitism in *H. viridis pratensis* prior to July 22 (Tables 1 and 2) correlated with abundant early spring rains. This supports the findings of others (2, 26) that moist habitat is related to high infection. Whether or not *S. missouriensis* is a factor related to high infection, such as a preferred egg laying site for the nematode, is as yet undetermined. Soil type might be yet another undetermined factor.

Denner (9) reported infected grasshoppers, other than *H. viridis pratensis*, in which ovaries were reduced but not destroyed and testes were not noticeably affected. As in some earlier reports (9), he found infection of a higher percentage of female grasshoppers than males. In this study ovaries failed to develop and males remained immature in infected *H. viridis pratensis*. A higher percentage of *H. viridis pratensis* females were infected compared to males, but infection of *M. bivittatus* males and females was approximately equal (Table 1).

Some features of the internal anatomy of *M. nigrescens* have been described in this (Fig. 2–5) and earlier studies (1, 6, 7, 13). Conflicting reports (1, 6) on the shape of the stylet base are not resolved.

Using *M. nigrescens* to control grasshoppers may be advantageous in that it should selectively kill grasshoppers without harming beneficial insects. Except for one unconfirmed report (16) in 1899, *M. nigrescens* has been found parasitizing only grasshoppers and earwigs. The anatomy and host preferences of *M. nigrescens* should be investigated further to distinguish whether or not there is one type that parasitizes earwigs (*M. nigrescens*) and another type that parasitizes grasshoppers (*M. subnigrescens*). Since severe parasitism by *M. nigrescens* is associated with damp habitat it might be possible to introduce the nematode as a biological control in moist areas where grasshoppers are pests. Such areas might be the monsoon region of Southeast Asia, where grasshoppers become a problem during the rainy season, and irrigated areas of the United States. Also, the nematode might be reared on grasshoppers or other media (11), and nematode eggs collected and sprayed on foliage to increase the severity and spread of nematization. G. B. Mulkern (personal communication) has suggested that coating the eggs with a food preferred by grasshoppers might enhance per cent infection. Christie (4) reported that *M. subnigrescens* lives under many soil and climatic conditions, persists in high numbers in areas of low grasshopper population, and produces large numbers of easily secured eggs which remain viable for months and are easily shipped. To produce consistent epidemics as biological controls useful in agriculture, more should be learned about the conditions favoring severe infection by *M. nigrescens* early in the growing season. This might include studies on nematode egg laying, survival of eggs, number of eggs required on the foliage for grasshopper control, ingestion of eggs by grasshoppers, moisture required on the foliage and in the soil by the nematode, effect of soil type, light and heat requirements (7), plant preferences of the grasshoppers and possibly plant preferences of the nematode.

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