Mermithid Parasites of Agricultural Pest Insects[1]

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Plant and insect nematologists generally agree that nematodes are well adapted to the soil environment. And since over 90% of all agricultural pest insects spend at least a part of their lives in the soil, a situation exists which favors an encounter between the two organisms. When the encounter involves an insect susceptible to a mermithid nematode, a parasitic relationship may ensue. Additionally, infective stages of several species of mermithids climb low-growing plants to infect susceptible host insects which feed on the leaves or in stems. Nematologists can find the infective stage of mermithids, called preparasites, in soil samples from agricultural fields. They are about 1 mm in length, narrow, and resemble long *Tylenchus* sp. larvae in their shape and moving habits. After infecting their host, the preparasites continue their development through the several larval stages and egress from the host insect as fully grown postparasites which no longer feed. Egress from the host insect causes a large hole from which the insect loses its essential fluids and dies. The postparasites, 2–25 cm in length, re-enter the soil and move to a depth of 15–50 cm, often well beneath the plow layer where the soil is more sterile and free from fungal parasites and predators. Here they molt to adults and mate. In the fall, they often form balls (Fig. 1) consisting of a female and one or more males. The eggs

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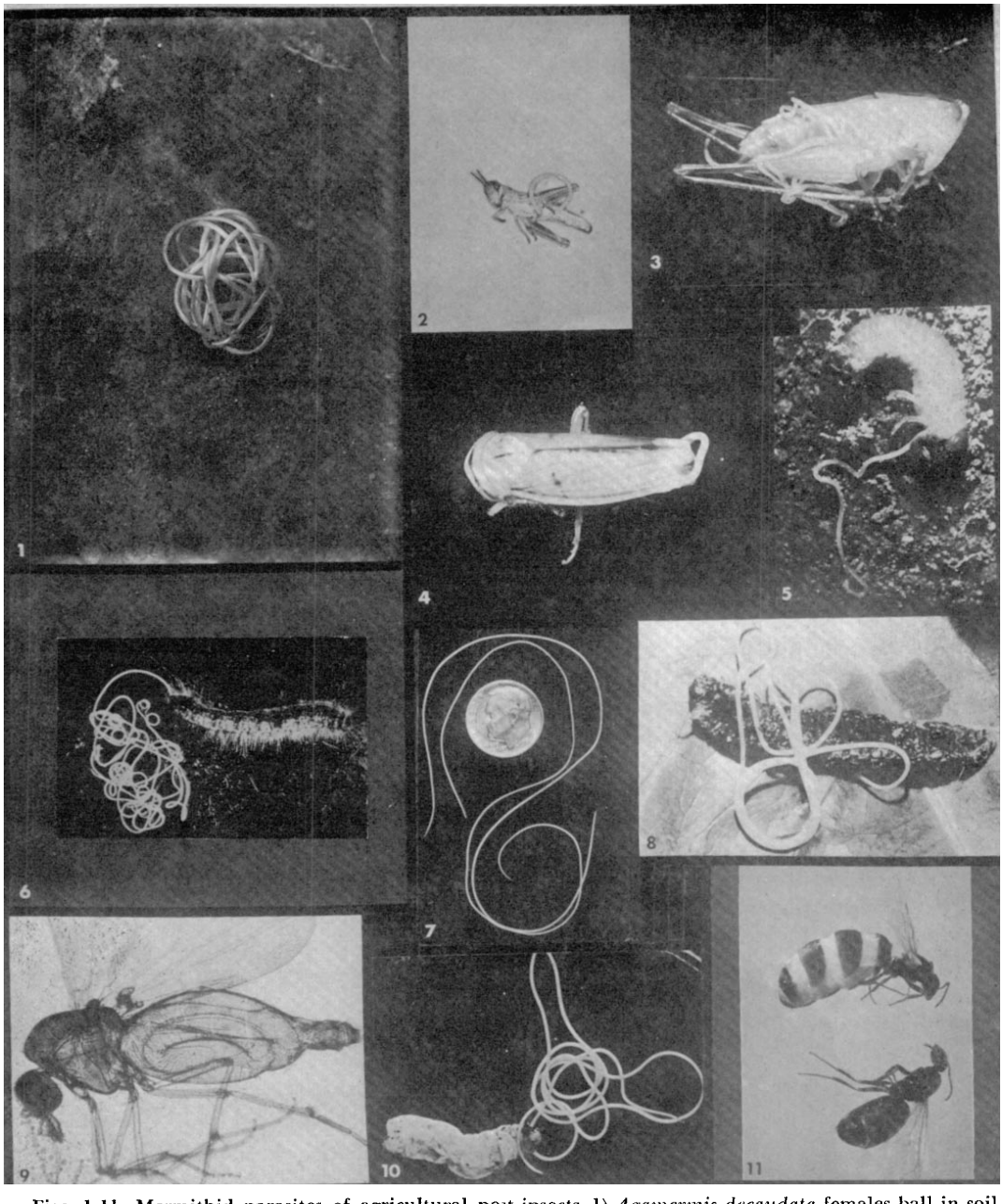

Figs. 1-11. Mermithid parasites of agricultural pest insects. 1) *Agamermis decaudata* females ball in soil from Virginia. 2) Grasshopper from Montana with *Mermis nigrescens*. 3) Long-horned grasshopper from Maryland with *Agamermis decaudata* 4) Clover leafhopper from Maryland with *Agamermis decaudata* 5) Japanese beetle grub from Vermont with a *Psammomermis* sp. 6) Tent caterpillar from Virginia with a *Hexamermis* sp. 7) Gypsy moth mermithid of the genus *Hexamermis* from Europe. 8) Mohagany shoot borer from Costa Rica with a *Hexamermis* sp. 9) *Culicoides* biting fly from New York with a *Heleidomermis sp.* 10) Armyworm with *Hexamermis* mermithid from Nicaragua. 11) Ant from Austria with mermithid (courtesy of H. Kaiser).

are sometimes deposited within the ball. In the spring, when soil temperatures increase and rain water is available, the mermithid eggs hatch and the preparasites move to the surface and penetrate the larval, pupal, and sometimes adult host insects. At least six variations of this life cycle, have been described; some are much more complicated.

Observations on penetration of preparasitic stage mermithids into larval army

worms and root worms show that esophageal secretions are used to attach the nematode to the host while other secretions, perhaps chitinase, along with rasping tooth action facilitate penetration. Infection usually culminates in host death. High percentages of parasitism of certain agricultural pest insects by nematodes have been reported (9, 12,13,18). These will be discussed under the orders of insects: Orthoptera, Coleoptera, Lepidoptera, Diptera, and other miscellaneous groups.

ORTHOPTERA

Much of the early work in mermithid parasites of agricultural insects concerned *Mermis nigrescens* and *Agamermis decaudata* on grasshoppers (2,4). In the spring, after a rain or when the dew is heavy, *M. nigrescens* females, which are about 8 cm in length, move out of the soil and crawl onto the existing vegetation to lay their eggs. The eggs may then be ingested by grasshoppers feeding on the vegetation. Ingested eggs hatch within the gut of the insect and the preparasites penetrate into the body cavity where they enlarge (Fig. 2). Farmers and home gardeners occasionally send in these grasshopper mermithids which they find on their vegetables for identification along with a request for control measures for these nematodes. It is contended that mermithids are important in the control of grasshopper populations in the eastern part of the United States (J. Christie and G. Thorne, personal communication). At Beltsville, *A. decaudata* also was found to parasitize new hosts in nature, such as long-horned grasshoppers (Fig. 3), crickets, wolf spiders, and leafhoppers (Fig. 4) (Nickle, unpublished data).

COLEOPTERA

Mermithids are parasitic on leaf- and root-feeding beetles. Sixty percent of the June beetles in parts of the USSR are infected by *Psammomermis* spp. (16). Sixty percent of the Japanese beetle grubs (Fig. 5) from lawns in the northeastern United States were found by Klein et al. (8) to be parasitized by a similar mermithid nematode. This mermithid is about 20 cm in length and can be seen coiled inside the insect, extending from the thoracic region to the preultimate abdominal segment. Sixty percent of the grubs collected from sandy soil from the town green at Brattleboro, Vermont, were infected by this mermithid. Poinar and Gyrisco (14) reported that up to 33% of the alfalfa weevils in parts of New York State were parasitized by the mermithid *Hexamermis arvalis*. Cuthbert (3) reported that 50–100% of the banded cucumber beetle larvae collected from fields in Charleston, South Carolina, were parasitized by a nematode named *Filipjevimermis leipsandra* by Poinar and Welch (15). Most of the insects parasitized by this nematode died before they pupated, which is the normal situation. Of the 219 insects studied, 86% were last-instar larvae when the mermithids emerged, 6% were prepupae, 7% were pupae, and 1% were adults. Infected larvae became slightly swollen and assumed a characteristic light tan color. They were sluggish, their movement was uncoordinated, and well-developed mermithids could be seen through the body wall.

In cooperative research with Dr. R. Schroder, Beneficial Insect Introduction Laboratory, Beltsville Agricultural Research Center, and Dr. J. Krysan, Northern Grain Insects Research Laboratory, Brookings, South Dakota, we are studying a South American mermithid parasite of corn root worms. This is the first caged field release of an exotic nematode. Research is also being done at Beltsville, Maryland, on a *Hexamermis* from Colorado potato beetle sent from Austria by Dr. H. Kaiser, University of Graz. It is part of a Small Farms Research Project at BARC. We are running some studies on ladybugs and other beneficial Coleopterans and have met with APHIS and have set up requirements for a field release of this introduced insect parasitic nematode.

LEPIDOPTERA

Mermithids can be found in caterpillars and other larval lepidopterans. They were found by Kaburaki and Imamura (6) in 76% of the rice borers, *Chilo simplex*, in Japan. We found a *Hexamermis* sp. from tent caterpillars (Fig. 6) on *Prunus* from New Jersey to Virginia. Artyukhovsky (1)

reported that up to 60% of the gypsy moth caterpillars were parasitized by a *Hexamermis* sp. south of Moscow. We periodically receive living specimens of this nematode from the USDA European Parasite Laboratory but have not established a permanent culture as yet. We now have living postparasites (Fig. 7) of gypsy moth mermithids from Europe. Nickle (10) infected the fall armyworm with a *Hexamermis* mermithid nematode (Fig. 10). Plant nematologists would be interested in knowing that the infective stage, which was 1 mm in length, grew to a postparasitic nematode 20 cm in length (Fig. 11) in only 20 days inside the armyworm caterpillar. Nickle and Grijpma (11) found up to 25% of the shoot borers, *Hypsipyla grandella* (Zeller) (Pyralidae), (Fig. 8) were infected by *Hexamermis albicans* at the end of the wet season in Costa Rica. They list 70 other species of Lepidoptera which are parasitized by mermithids.

DIPTERA

Mosquitoes and black flies are only marginally important in agriculture and are dealt with elsewhere in this symposium. Some *Culicoides* spp., which transmit blue tongue and other virus diseases of cattle, sheep, and deer, are parasitized by mermithids in the genus *Heleidomermis* (Fig. 9). Mermithids also parasitize tabanids.

OTHER INSECT ORDERS

Kaburaki and Imamura (7) reported that the mermithid nematode, *Agamermis unka,* played an important role in the natural control of certain rice leafhoppers in Japan. Parasitism and resultant death occurred in 70% of the entire population of *Sogota furcifera* and 41% of the total popultion of *Nilaparvata oryzae*. In Beltsville, the clover leafhopper was a good host of our local *Agamermis decaudata* following early spring rains (personal observations).

Ants are often parasitized by mermithids (Fig. 11). In 1747, Gould (5) noted mermithids parasitizing the ants, *Lasius flavus,* in England. Wheeler (17) described distinct morphological alterations induced in ants parasitized by mermithids. Mermithogynes are parasite-induced forms that are shaped halfway between workers and mated female ants. Mermithostratiotes are female forms with heads shaped like those of soldier ants. Mermithogynes and mermithergates have swollen abdomens, whereas their heads and thoraces remain normal or are reduced in size.

CONCLUSIONS

Mermithid nematodes have the potential to suppress populations of agricultural pest insects including grasshoppers, several beetles and caterpillars, and some leafhoppers, ants, and other insect groups. The moist soil habitat is ideal for the life cycles of mermithid nematodes. The effect on insects parasitized by mermithids is usually death. Most agricultural pest insects spend some time in the soil where they would be susceptible to parasitism by mermithids when temperature and moisture are favorable. Infective stage mermithids resemble plant parasitic nematodes in appearance and behavior.

Mass rearing and release of mermithids with potential as biocontrol agents should continue. Importation of exotic mermithids from abroad should also be undertaken for future releases on agricultural pests.

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