INFESTATION DYNAMICS AND DISTRIBUTION OF 
NOCTUIDONEMA GUYANENSE (NEMATODA: 
APHELENCHOIDIDAE) ON ADULTS OF SPODOPTERA 
FRUGIPERDA AND MOCIS LATIPES 
(LEPIDOPTERA: NOCTUIDAE) 

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ABSTRACT 

The infestation dynamics and distribution of an ectoparasitic nematode, Noctuidonema guyanense Remillet and Silvain, on moths of Spodoptera frugiperda (J. E. Smith) and Mocis latipes (Guenée) were studied. Nematodes transfer among hosts as moths mate. Subsequent dispersal and reproduction by N. guyanense on new hosts results in an aggregation of nematodes on the posterior abdominal segments of S. frugiperda moths. On M. latipes, nematodes aggregate on the posterior margin of the thorax and on the first and second abdominal segments. Nematodes are rarely found on the head of moths of either species. A significant, positive correlation exists between dispersal of nematodes on S. frugiperda and elapsed time after the initiation of host mating. 

RESUMEN 

Se estudiaron la dinámica de las infestaciones y la distribución del nematodo ectoparasitico, Noctuidonema guyanense Remillet y Silvain, en polillas de Spodoptera frugiperda (J. K. Smith) y de Mocis latipes (Guenee). Los nematodos fueron transferidos cuando las polillas estaban copulando. La dispersión y la reproducción de N. guyanense en los nuevos hospederos resulta en una agregación de nematodos en la región posterior de los segmentos abdominales de las polillas de S. frugiperda. En M. latipes, los nematodos se agregaron en el margen posterior del torax y en el primer y segundo segmento abdominal. Los nematodos se encontraron muy raramente en la cabeza de las polillas de las dos especies. Una correlación significante existe entre la dispersión de los nematodos en S. frugiperda y el tiempo que pasa después de la iniciación de la copula del hospedero.
The fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae), and "striped grass looper," *Mocis latipes* (Guenée) (Lepidoptera: Noctuidae), are pests of pasture grasses throughout the Americas east of the Andes and Rocky Mountain chains (Dean 1985, Sparks 1979). Although the immature stages of both species are attacked by several species of natural enemies (Ashley 1979, Santos 1989), the highly mobile moths effectively strand natural enemies as they migrate to new habitats. Because of the migratory behavior of these species (Dean 1985, Mitchell et al. 1991), an effective parasite of the moth stage would fill a vacant niche in augmentative biological suppression strategies for *S. frugiperda* and *M. latipes*.

*Noctuidonema guyanense* Remillet and Silvain (Nematoda: Aphelenchoididae), an obligate, ectoparasitic nematode, is a potential candidate for augmentative suppression of adult populations of *S. frugiperda* and *M. latipes* in the southeastern United States and French Guiana (Rogers et al. 1991). The nematode inflicts a chronic pathogenicity in its hosts (Marti et al. 1990) and is auto-disseminated and dispersed as infested moths mate and migrate (Rogers & Marti 1992, Simmons & Rogers 1991). In this paper, we discuss the parasitization dynamics and distribution of *N. guyanense* on *S. frugiperda* and *M. latipes* moths.

**Materials and Methods**

**Distribution**

The distribution of *N. guyanense* on infested *S. frugiperda* moths was studied in three female populations. The first population was composed of wild moths captured by hand on corn or grain sorghum in Tift Co., Ga., 1989-1990. The second and third populations were composed of laboratory-reared females that had mated with infested wild males captured in pheromone traps near corn in Tift Co., Ga., 1989-1990. Females of the second and third populations were selected from a larger population on the basis of a relatively moderate (100-300 nematodes/moth) or high (>300 nematodes/moth) infestation of nematodes, respectively. The distribution of *N. guyanense* on *M. latipes* in Tift Co., Ga. in 1990 - 1991 was determined from wild males and females captured on a 2 x 3 m white sheet illuminated by a 175-w mercury vapor lamp. Infested moths not immediately killed at the time of their capture were maintained at 27.8°C, 80% RH, and 14:10 (L:D) photoperiod for later sampling.

Moths were immobilized by lightly crushing the thorax. Wings and legs were removed and the moths were pinned through the thorax to the bottom of a wax-lined dish. Body segments of pinned moths were removed by gently stretching the abdomen posterially with forceps and cutting through the intersegmental membranes with dissecting scissors. Segments (including the head and thorax) were preserved individually in vials containing 10% buffered formalin with a few drops of diluted Tween 80* to aid in wetting the cuticle. Abdominal segments 1-2 and 8-10 were preserved as intact units in separate vials.

Nematodes were removed from preserved segments by gently scraping the scales with forceps. Nematodes were examined through a stereoscopic microscope and classified as egg, second stage juvenile (J2), third-fourth stage juvenile (J3-J4), adult male, or adult female. Nematodes from 10 female moths per *S. frugiperda* population, and from 15 and 16 *M. latipes* males and females, respectively, were used to analyze *N. guyanense* distribution by life stage per host segment. The number of nematodes was transformed by $\sqrt{v + 1}$ and analyzed by the General Linear Models (GLM) procedure of SAS (1985) (SAS Institute, Cary, N. C.). Significantly different means were separated by least significant differences, and back-transformed by $(value)^2 - 1$. 


Infestation Dynamics

The infestation dynamics of *N. guyanense* on *S. frugiperda* were studied by mating uninfested, laboratory-reared females with infested, wild males. Mated female moths were killed at irregular intervals from 15 min to 176 h after the initiation of mating and examined for nematodes. Procedures for acquiring and analyzing infestation and dispersal data for *N. guyanense* were reported by Rogers & Marti (1992). Also, mating behavior of *S. frugiperda* and *M. latipes* that may influence infestation dynamics of *N. guyanense* were reported by Simmons & Marti (1992) and Dean (1985), respectively.

RESULTS AND DISCUSSION

The distribution of *N. guyanense* among three populations of *S. frugiperda* females was similar; adult male and female nematodes, and their eggs, were found principally on abdominal segments 6-10. On wild females (Fig. 1A) (x, 10 nematodes/host), significantly more (*P<0.05*) nematodes occurred on abdominal segments 6-10 with relatively few nematodes on segments 1-5. On moderately infested, laboratory-reared female moths (Fig. 1B) (x, 100 nematodes/host), nematodes (particularly adults) aggregated on abdominal segments 8-10. Heavily infested female moths (Fig. 1C) (x, 658 nematodes/host) harbored the greatest number of nematodes on the seventh abdominal segment. In dense populations, a greater proportion of the nematodes moved anterior to the 6th abdominal segment. Most of the nematodes on *S. frugiperda* females were third-fourth stage juveniles.

The distribution of *N. guyanense* on wild *S. frugiperda* males differs slightly from the distribution on female hosts (Rogers & Marti 1992). Nematodes tend to aggregate on the anterior margin of the 8th abdominal segment and on the genitalia (segments 9-10) of *S. frugiperda* males. Whereas few nematodes are found anterior to the 6th abdominal segment on female moths, they are relatively common on abdominal segments 1-7 on male moths. Few nematodes colonize the thorax of *S. frugiperda*; they are rare on the host’s head. However, with both sexes of *S. frugiperda*, nematodes tend to aggregate on posterior segments of the host.

The distribution of *N. guyanense* on *M. latipes* differs from its distribution on *S. frugiperda*. On *M. latipes*, *N. guyanense* aggregates on the posterior margin of the thorax and on abdominal segments 1 and 2 (Figs. 2 and 3). On wild *M. latipes* males, more (*P<0.05*) nematodes of all stages except adult females occurred on the 1st and 2nd abdominal segments (x, 417) than on the posterior margin of the thorax (x, 234). Also, more nematodes occurred on the thorax than on abdominal segments 3-10 of male moths. On female *M. latipes*, empirically more nematodes occurred on abdominal segments 1-2 (x, 98) and on the posterior margin of the thorax (x, 81) than on other segments. The number of nematodes was greater (*P<0.01*) on male (x, 928) than on female (x, 271) *M. latipes* moths. Also, abdominal segments 8-10 of male moths harbored more (*P<0.01*) nematodes (x, 191) than the corresponding segments of female moths (x, 10). While adult *N. guyanense* tended to aggregate at the junction of the thorax and 1st abdominal segments of hosts of both sexes (*P<0.05*), immature stages were more numerous on abdominal segments 1-2 than on other segments of hosts. As with *S. frugiperda*, *N. guyanense* was rarely found on the head of *M. latipes*.

The reason for the dissimilar distribution of *N. guyanense* on *S. frugiperda* and *M. latipes* is unknown. The mating behavior of the respective host species apparently is not a major contributing factor affecting the subsequent dispersal of *N. guyanense*. Both *S. frugiperda* and *M. latipes* mate in tandem with heads oriented in opposite directions (Simmons & Marti 1992, Dean 1985). Based on observations on *S. frugiperda*, time would seem to be a factor limiting successful aggregation of *N. guyanense* on the thorax and anterior abdominal segments of *M. latipes*. A significant (*P<0.05*) positive
Fig. 1. Distribution of *N. gracilis* on a wild (A) and two laboratory-reared populations of *S. frugiperda* females harboring intermediate (B)(100-300 nematodes/host) and heavy (C)(>300 nematodes/host) populations of nematodes. (J2s = second stage juveniles; J3s - J4s = third-fourth stage juveniles.)
Fig. 2. Distribution of *N. guyanense* on wild *M. latipes* males, Tift Co., Ga. (1991). (*J*2s = second stage juveniles; *J*3s - *J*4s = third-fourth stage juveniles.)

correlation occurred between dispersal of the nematodes on *S. frugiperda* and the elapsed time after the initiation of host mating (Fig. 4). About 4 days were required for the first appearance of *N. guyanense* on abdominal segments 1-2 of a newly mated

Fig. 3. Distribution of *N. guyanense* on wild *M. latipes* females, Tift Co., Ga. (1991). (*J*2s = second stage juveniles; *J*3s - *J*4s = third-fourth stage juveniles.)
S. frugiperda female. It is possible that Noctuidonema infesting S. frugiperda and M. latipes are different species, since Anderson and Laumond (1992) recently described N. daphria n. sp. from Leomone porcia (Stoll) in Guadeloupe. Casual observations indicate that additional sympatric species of Noctuidonema may exist (unpublished data). If such were the case, behavioral differences may explain the dissimilar distribution of Noctuidonema on S. frugiperda and M. latipes, as well as possible differences in its distribution among additional noctuid hosts.

Infestation Dynamics

Unlike many species of entomogenous nematodes (Hominick & Reid 1990), N. guyanense lacks both symbiotic bacteria and a "free-living" infective stage. Hence, to maintain itself, N. guyanense must derive its nourishment directly from its host, and it must have an efficient mechanism for dispersing among hosts. Transfer during host mating is the dispersal mechanism used by N. guyanense. Simmons & Rogers (1990) and Rogers & Marti (1992) showed that N. guyanense moves from one moth to another as hosts mate. In the laboratory, N. guyanense females moved from infested S. frugiperda males to virgin females within 15 min from the initiation of host mating (Rogers & Marti 1992). Other mobile stages of the nematode moved between mating hosts within 1-2 hours of initial host coupling. About 48% of host matings resulted in the transfer of N. guyanense to new hosts (Rogers & Marti 1992). Simmons & Marti (1992) reported that 80% of S. frugiperda couplings exceed 45 min, with a mean mating

![Graph showing hours post mating vs. host segment](image)

Fig. 4. Mean number of hours required for the first appearance of N. guyanense on segments of a new S. frugiperda host following initiation of its mating with an infested host.
duration of 2 h 16 min in the laboratory. Also, in the laboratory, S. frugiperda females and males mated an average of 3.7 and 6.7 times, respectively (Simmons & Marti 1992). Hence, total copulatory time for S. frugiperda females and males may exceed 8 h, and 15 h, respectively. Such lengthy and frequent mating activity by S. frugiperda provides N. guyanense ample opportunities for transfer between hosts as well as for dispersal as infested moths migrate to new habitats.

Although the mating behavior of M. latipes is not as thoroughly understood as it is for S. frugiperda, Dean (1985) showed that coupling by M. latipes typically involves contact through abdominal segments with heads oriented in opposite directions. Thus, with both moth species, the transfer of N. guyanense from one host to another occurs via the apex of abdomens during mating. This mechanism for nematode transfer among hosts guarantees that N. guyanense is auto-dispersed by mating hosts. While the use of mating hosts is an efficient dispersal mechanism for N. guyanense, it is not without risks. Simmons & Marti (1992) reported that about 10% of the pairings by S. frugiperda moths results in locking, and ultimately in the death of both obligate hosts and harbored nematodes.

In summary, N. guyanense transfers among hosts as moths of S. frugiperda and M. latipes mate. Subsequent dispersal of N. guyanense results in the aggregation of nematodes on the posterior abdominal segments of S. frugiperda moths, and on the posterior margin of the thorax and abdominal segments 1-2 of M. latipes moths. Nematodes are rarely found on the head of moths of either species.

REFERENCES CITED


EFFECTS OF CONSTANT AND FLUCTUATING TEMPERATURES AND HUMIDITIES ON THE SURVIVAL OF SPODOPTERA FRUGIPERDA PUPAE (LEPIDOPTERA: NOCTUIDAE)

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ABSTRACT

Pupae of the fall armyworm, Spodoptera frugiperda (J. E. Smith), were maintained in the laboratory for emergence under selected constant and fluctuating temperatures and humidities. Temperatures ranged from 10 to 40°C, with a vapor pressure deficiency maintained constant at 8.5 mb in one study. No eclosion occurred at 10°C or at 40°C. Insects held at 15 and 35°C had low survival and a high percentage (39-62%) were deformed. The optimum rate of development occurred at 30 and 35°C, but a high percentage (58% of males, 39% of females) of the insects held at 35°C emerged deformed. In a comparison between the constant and fluctuating temperatures (the mean of the fluctuating temperature equalled the constant temperature treatment), survival was not affected, but development was generally faster with the fluctuating treatment. In another study, relative humidity ranged from 20 to about 100% (33.9 to about 0 mb) and was maintained at 30°C. Percentage survival, rate of development, or percent deformity were not affected by humidity. Weight loss was similar among insects held under different humidity treatments and was not affected by constant or fluctuating condition. Although survival was the same for the sexes, females developed at a faster rate and a smaller percentage emerged deformed as compared with males.

RESUMEN

Se mantuvieron pupas del cogollero del maíz, Spodoptera frugiperda (J. E. Smith) en el laboratorio a diferentes temperaturas y humedades para determinar su efecto en la emergencia. Las temperaturas fluctuaron desde 10 a 40°C, con una deficiencia de

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