Dispersal and Seasonal Occurrence of *Noctuidonema guyanense*, an Ectoparasitic Nematode of Adult Fall Armyworm (Lepidoptera: Noctuidae), in the United States[1, 2]

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ABSTRACT Migrant *Spodoptera frugiperda* (J. E. Smith) adult males were collected at 17 widely separated locations throughout the eastern half of the United States and were examined to determine if *Noctuidonema guyanense* Remillet and Silvain, an ectoparasitic nematode of adult Lepidoptera, were transported with the host. Nematodes were recovered from all locations where moths were captured. Nematode populations and parasitism of fall armyworm males were higher in the eastern states than in the Plains, Midwestern, and Central states (e.g., west Texas, Iowa, and Ohio). Percent parasitism and the number of nematodes per infested fall armyworm changed over time at each location. The initial immigrant fall armyworm males at a given location generally had few or no nematodes. These data suggest that moths with a moderate number of nematodes may be less able to disperse. Nematode populations peaked in mid-to-late August and then declined to a few or none by mid-October at locations north of the Gulf Coast area. Among other factors, temperature is apparently an important regulator of *N. guyanense* populations.

KEY WORDS Nematoda, biological control, *Noctuidonema guyanense*, *Spodoptera frugiperda*, fall armyworm, ecology, parasite.

Noctuidonema guyanense Remillet and Silvain (Nematoda: Aphelenchoididae), an ectoparasite, was found feeding on adults of the fall armyworm, *Spodoptera frugiperda* (J. E. Smith), during the early 1980's in French Guiana and Guadaloupe (Remillet and Silvain 1988). This is the first ectoparasitic nematode species reported from adult Lepidoptera. It is now known that *N. guyanense* occurs on at least 39 species of Lepidoptera, almost exclusively in the family Noctuidae (Remillet and Silvain 1988, Rogers et al. 1990a, 1990b). All stages occur on the moth; the nematodes die within about 24 h if separated from the host (Remillet and Silvain 1988, unpublished observations). Nematodes are transferred to new moths when the moths mate, but the nematodes die if their host dies. Because *N. guyanense* is an obligatory parasite and is only known on adult Lepidoptera (Remillet and Silvain 1988, Rogers et al. 1990a, 1990b) it is imperative that the hosts have overlapping generations year-round to sustain a population of nematodes at a given location.

We recently found this nematode occurring throughout tropical and subtropical America (including the Caribbean basin, South America, Central America, Mexico

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[2] This paper reports the results of research only. The mention of a commercial or proprietary product does not constitute an endorsement of this product by the USDA.

and into south Texas and south Florida (Simmons and Rogers 1990a); all are locations where the fall armyworm has continuous generations. Before the discovery of *N. guyanense* in the United States in late 1987 in south Texas and early 1988 in south Florida, this ectoparasitic nematode was not known to occur in the United States (Simmons and Rogers 1990a). Thus, it was not known if *N. guyanense* was restricted to subtropical areas in the United States. Although the fall armyworm has been extensively studied since it became recognized as a pest in the mid 1700's (Luginbill 1928), no ectoparasitic nematodes of adult fall armyworms had been described. Based on an examination of stored moths (housed at the Department of Plant Industry, Gainesville FL), *N. guyanense* occurred in south Flordia as early as 23 May 1972 (Simmons and Rogers 1990a).

The purpose of this study was to determine if *N. guyanense* is carried with fall armyworm moths as they migrate from overwintering sites to more northerly locations in the United States. If parasitized moths are able to migrate, our second objective would be to monitor changes in the incidence of nematodes during the season. These data are needed to help us understand the importance of this newly recognized nematode and its role as a biological control agent of *S. frugiperda.*

Materials and Methods

During the spring, summer, and fall of 1988, adult *S. frugiperda* males were collected using pheromone traps baited with artificial pheromone lure (Terochem Laboratories, Ltd, Alberta, Canada). Universal moth traps (International Pheromone Systems, Merseyside, England) were used at most locations. In certain instances, Hartstack 75 - 50 cm cone traps (Hartstack et al. 1979) were used as well. Dichlorvos was used to kill the entrapped moths. Traps were set up to collect fall armyworm moths at 18 widely separated locations in the eastern half of the U.S. The primary North American range of the fall armyworm was encompassed by our survey. The number of traps varied among locations. Collection sites were grouped into three regions of states in the United States (Fig. 1). Locations in eastern states (Region 1) were Belle Glade, FL; Quincy, FL; Tifton, GA; Florence, SC; Oxford, NC; Blacksburg, VA; and Durham, NH. Those in Region 2 (Central states) were Cheneyville, LA; Jackson, TN; Lexington, KY; and Wooster, OH. Collecting sites in the Plains and Midwest states (Region 3) occurred at Brownsville, TX; College Station, TX; Lubbock, TX; Garden City, KS; Bloomington, IL; North Platte, NE; and Ankeny, IA. Collections were made at about 3-wk intervals concurrently at all locations. The specific collection dates were 16-20 May, 6-10 June, 27 June to 1 July, 18-22 July, 8-12 August, 29 August to 2 September, 19-23 September, and 10-14 October during 1988. At the Georgia location, the collection began during 16-20 March 1988. In some cases, moths that were collected before or after a specific collection period were added to the samples from the closest designated collection period. The sample size during a specific sampling week and at a given location was generally limited to a maximum of 50 moths.

The abdomen of each moth was separated from the thorax, and placed in a vial containing 10% formalin; only one abdomen was stored per vial. Subsequently, the vials containing fall armyworm abdomens were sent to our laboratory in Tifton, GA, where they were microscopically examined for the presence of ectoparasitic nematodes. The total number of juvenile and adult nematodes, but not eggs, per infested moth was recorded. Mean daily temperatures and relative humidities

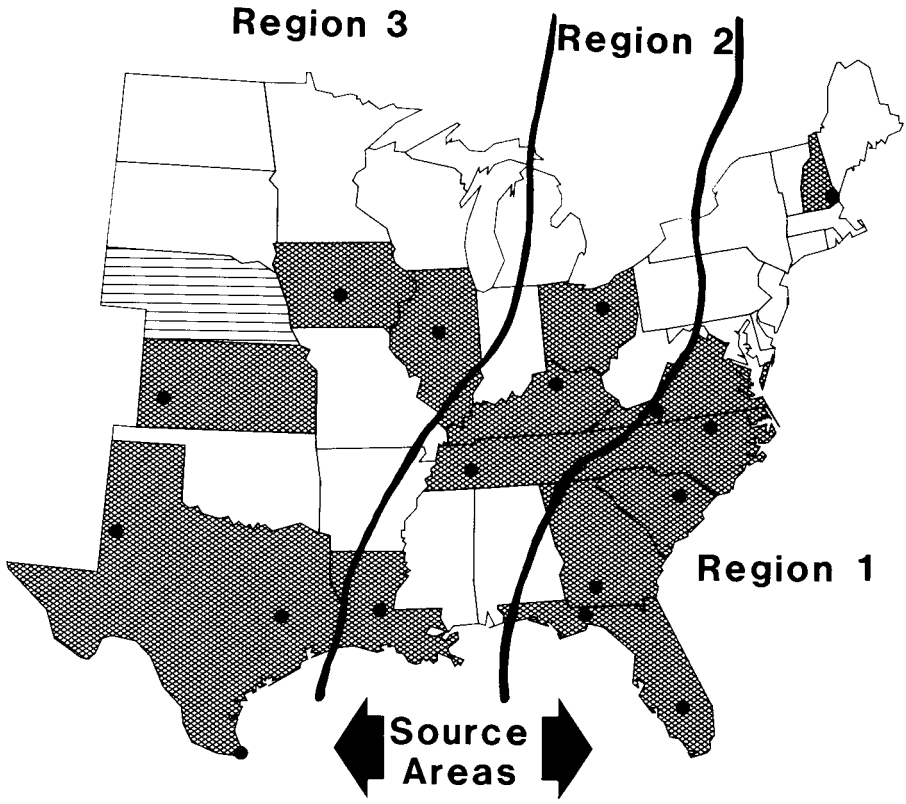

Fig. 1. Collection sites for *S. frugiperda* moths in 1988. Locations are indicated with dots.Nematodes were recovered from shaded areas. No moths were recovered from Nebraska, horizonal bars.

were averaged by month per location. Vapor pressure deficiency, expressed in mb, was determined using the temperature and humidity data, and was used as an index of humidity. Vapor pressure deficiency, which is independent of temperature, is biologically more relevant than relative humidity (Ferro and Chapman 1979). Voucher specimens of *N. guyanense* from each location were deposited with USDA-ARS Nematode Collection, Beltsville, MD.

All statistical procedures were run on Statistical Analysis System (SAS Institute 1985). Before any statistical analysis, percentage data were subjected to arcsine transformation while data on the number of nematodes were transformed using base 10 log transformation. Means presented herein are for back-transformed data. Data on number of nematodes and percent parasitism of moths were subjected to Pearson correlation. Unless stated otherwise, $P < 0.05$ level of significance was used.

Results and Discussion

Spodoptera frugiperda moths were collected at all locations except Nebraska (Fig. 1). At each location where moths were collected, *N. guyanese* was also recovered. During the winter months, *N. guyanense* is restricted to tropical and subtropical locations (Simmons and Rogers 1991). The nematodes were carried with *S. frugiperda* as the adults migrated from southern locations (south Florida, south Texas, or the Caribbean Basin). Apparently, *N. guyanense* may be dispersed throughout the eastern half of the U.S. by *S. frugiperda.* Although *S. frugiperda* may occur in each of the contiguous states of the U.S. and southern Canada (Snow and Copeland 1969), it is not known if *N. guyanense* may likewise be recovered from all such locations.

The distribution of *S. frugiperda* in different areas of the U.S. may result from different sources of migration; e.g., moths in states along the Atlantic seaboard (Region 1) may originate from south Florida while those in the Plains, Midwest, and Central states (Regions 2 and 3) may originate from south Texas (Luginbill 1928, Westbrook and Sparks 1986, Pair et al. 1987). It is probable that moths at some locations may have originated from more than one source. Notably, moths at some locations in Region 1 and 2 are more likely to be similar in origin than moths in Regions 1 and 3.

The percentage of *S. frugiperda* parasitized at each location was variable, but patterns were evident. Overall, parasitism of *S. frugiperda* moths was somewhat higher (32%) at locations in the Eastern states (Region 1) as compared with the central states (28%) and considerably higher than in the Plains/Midwest states (7%, excluding Brownsville) (Table 1). Similarly, the overall mean number of nematodes per infested moth was high (45) in Region 1 as compared with those in Regions 2 (41) and 3 (36) (Table 1). Two notable exceptions in the latter category were Brownsville and College Station, TX, each with an average of 104 and 107 nematodes per infested moth, respectively. General trends were a reduction in parasitism and the number of nematodes per infested moth with an increase in latitude and an increase in longitude. These trends were most apparent in the arid Plains and Midwest states (Region 3) and least apparent in the eastern states (Region 1) (Table 1). Parasitism and number of nematodes per infested moth at most of the eastern sites were similar to that found for *S. frugiperda* moths collected in tropical America (Simmons and Rogers 1990a). Juveniles represented 69% of the nematodes on moths in the United States. Percent parasitism was highly correlated ($P < 0.001$, $r^2 = 0.45$) with the number of nematodes per infested moth.

Nematode populations were not consistent over the sampling period. Because the exact date when *S. frugiperda* moths immigrated into each location is unknown, we do not know the magnitude of the initial nematode population. At most locations, however, there was an increase in parasitism and number of nematodes early in the season, a peak in mid-to-late August followed by a sharp decline (Tables 2 - 4). Low numbers of nematodes were also apparent at most locations for the earliest moths collected. Low rates of parasitism among the first moths collected at each location may suggest that these migrants were primarily free of nematodes. However, with a warm temperature, typical of August, nematode populations can increase dramatically within a few days (Simmons and Rogers 1990b). The response of the nematode to a warm temperature may help explain

Table 1. Percent parasitism of *Spodoptera frugiperda* and mean number of *Noctuidonema guyanense* per infested moth (± SEM) at selected locations in the United States during 1988.

Location*	No. of moths examined	% parasitized	Number of nematodes per infested moth	
			Mean	Maximum
	Region 1 States			
Belle Glade, FL	321	33.6(± 2.6)	29.3(± 3.1)	181
Quincy, FL	232	56.5(± 3.3)	55.4(± 5.7)	368
Tifton, GA	404	15.9(± 2.2)	42.0(±10.4)	548
Florence, SC	191	50.8(± 5.1)	44.6(± 3.6)	259
Oxford, NC	112	35.7(± 4.5)	42.9(±12.5)	496
Blacksburg, VA	38	39.5(± 8.0)	44.7(± 9.9)	117
Durham, NH	213	6.7(± 1.7)	107.3(±36.4)	432
	Region 2 States			
Cheneyville, LA	155	29.0(±3.7)	42.4(± 7.2)	180
Jackson, TN	174	32.8(±3.6)	56.8(±11.6)	406
Lexington, KY	140	29.3(±3.4)	21.6(± 4.3)	99
Wooster, OH	70	10.0(±3.6)	23.4(±15.1)	112
	Region 3 States			
Brownsville, TX	399	25.4(±2.1)	103.9(±19.0)	1,326
College Station, TX	112	11.6(±3.0)	106.8(±64.4)	864
Lubbock, TX	197	11.2(±2.2)	16.1(± 5.5)	116
Garden City, KS	140	7.9(±2.3)	13.9(± 8.3)	95
Bloomington, IL	176	5.1(±1.7)	14.0(± 4.0)	34
Ankeny, IA	162	1.2(±0.9)	10.5(± 9.5)	20

* No moth was captured at the North Platte, NE location.

the high early nematode populations at some of the locations. The decline in nematode populations and parasitism of moths during the fall may have been a result of decreased temperature as well as from other factors. Nematodes were not found later in the fall at most of the 17 locations, even though moths were still collected. This suggests that temperature may be an important regulating factor of the population dynamics of *N. guyanense*.

In south Georgia, where the fall armyworm does not normally occur year-round, moths were sampled almost daily from late March of 1988 until mid-June 1988. Hence, perhaps greater insight may be obtained on nematode population dynamics as related to *S. frugiperda* migration at the Georgia location than at other locations. Even though *S. frugiperda* moths were collected between late March and late May in Georgia, the first parasitized specimen was not captured until late May (Table 2). Thereafter, the number of nematodes per infested moth and percent parasitism gradually increased and peaked in mid-to-late August. A similar pattern in the population dynamics of *N. guyanense* occurred in Georgia in 1989 (Simmons et al. 1991). Likewise, daily collecting at the Georgia location in 1990 revealed that although moths were captured by early April, the first parasitized moth was not collected until mid-May.

Table 2. Temporal parasitism of *Spodoptera frugiperda* and number of *Noctuidonema guyanense* per infested moth in eastern states (Region 1) during 1988.

Location	No. moths examined*	% Parasitized	$\bar{x}$ No. nematodes per infested moth	
			Total†	Adult
Belle Glade, FL				
May 16 - 20	50	26.0	16.2	8.4
June 6 - 10	50	38.0	18.6	7.3
June 27 - July 1	na	-	-	-
July 18 - 22	45	40.0	29.4	10.7
August 8 - 12	48	45.8	46.5	18.8
August 29 - Sept. 2	51	19.6	28.8	9.3
September 19 - 23‡	27	14.8	3.5	3.5
October 10 - 14‡	50	38.0	11.3	-
Qunicy, FL				
May 16 - 20	0	-	-	-
June 6 - 10	3	33.0	1.0	1.0
June 27 - July 1	2	100.0	205.5	48.5
July 18 - 22	41	80.5	69.5	19.7
August 8 - 12	45	97.8	65.8	21.8
August 29 - Sept. 2	50	38.0	25.2	10.3
September 19 - 23	44	31.8	14.5	5.9
October 10 - 14	47	38.3	54.9	12.4
Tifton, GA				
April 4 - 8	6	0	0	0
April 25 - 29	59	0	0	0
May 16 - 20	30	3.3	2.0	0
June 6 - 10	71	12.7	21.2	6.6
June 27 - July 1	62	25.8	37.5	9.3
July 18 - 22	63	30.2	61.9	13.0
August 8 - 12	5	40.0	2.0	1.0
August 29 - Sept. 2	10	100.0	72.0	20.3
September 19 - 23	50	42.0	14.5	7.0
October 10 - 14	48	0.3	10.0	6.0
Florence, SC				
May 16 - 20	0	-	-	-
June 6 - 10	0	-	-	-
June 27 - July 1	1	0	0	0
July 18 - 22	10	80.0	57.8	15.3
August 8 - 12	44	88.6	53.8	18.7
August 29 - Sept. 2	60	46.7	49.3	8.9
September 19 - 23	76	28.9	17.3	5.0
October 10 - 14	0	-	-	-

Table 2. Continued.

Location	No. moths examined*	% Parasitized	x̄ No. nematodes per infested moth	
			Total†	Adult
Oxford, NC				
May 16 - 20	0	-	-	-
June 6 - 10	0	-	-	-
June 27 - July 1	0	-	-	-
July 18 - 22	0	-	-	-
August 8 - 12	12	75.0	69.0	15.7
August 29 - Sept. 2	44	43.2	37.3	12.4
September 19 - 23	51	21.6	34.8	10.2
October 10 -14	5	20.0	5.0	2.0
Blacksburg, VA				
May 16 - 20	0	-	-	-
June 6 - 10	0	-	-	-
June 27 - July 1	0	-	-	-
July 18 - 22	12	8.3	14.0	0
August 8 - 12	26	58.8	46.9	13.0
August 29 - Sept. 2	na	-	-	-
September 19 - 23	na	-	-	-
October 10 - 14	na	-	-	-
Durham, NH				
May 16 - 20	0	-	-	-
June 6 - 10	0	-	-	-
June 27 - July 1	0	-	-	-
July 18 - 22	0	-	-	-
August 8 - 12	101	7.9	41.1	12.6
August 29 - Sept. 2	112	5.4	195.5	53.5
September 19 - 23	0	-	-	-
October 10 - 14	0	-	-	-

* na = no attempt was made to collect moths; dash = not estimable.
† Total number of juvenile and adult *N. guyanense* on each moth.
‡ From Simmons et al. 1991.

Host and nematode populations have been continuously recovered from Belle Glade, FL since *N. guyanense* was initially found there in 1988. Seasonal dynamics of parsitism of *S. frugiperda* and number of nematodes per infested moth at Belle Glade were similar to populations at the other locations (Table 2). There was an early-season increase, mid-summer peak, then a rapid decline. The nematode population in Belle Glade also was similar in 1989 (Simmons et al. 1991).

Of the four northern-most locations, two sites (Iowa and Illinois) averaged 14 or fewer nematodes per infested moth and had less than 7% of *S. frugiperda* parasitized throughout the study period (Table 4). Likewise, parasitism was low in New Hampshire, but for the only 2 weeks in which moths were captured, the number of nematodes averaged 41 and 196 per moth, respectively (Table 2). Moths in New Hampshire were collected in mid-to-late August, while nematode populations were at a peak at most of the other locations. In Ohio, the first moths were

Table 3. Temporal parasitism of *Spodoptera frugiperda* and number of *Noctuidonema guyanense* per infested moth in Central states (Region 2) during 1988.

Location	No. moths examined*	% Parasitized	$\bar{x}$ No. nematodes per infested moth	
			Total†	Adult
Cheneyville, LA				
May 16 - 20	0	-	-	-
June 6 - 10	7	14.3	28.0	18.0
June 27 - July 1	0	-	-	-
July 18 - 22	10	10.0	20.0	3.0
August 8 - 12	13	61.5	68.4	14.3
August 29 - Sept. 2	50	26.0	34.6	12.4
September 19 - 23	23	43.5	57.9	11.7
October 10 - 4	52	21.2	25.6	10.2
Jackson, TN				
May 16 - 20	0	-	-	-
June 6 - 10	0	-	-	-
June 27 - July 1	0	-	-	-
July 18 - 22	2	0	0	0
August 8 - 12	23	69.6	48.3	8.8
August 29 - Sept. 2	49	26.5	7.3	3.5
September 19 - 23	50	56.0	84.7	21.9
October 10 - 14	50	0	0	0
Lexington, KY				
May 16 - 20	0	-	-	-
June 6 - 10	0	-	-	-
June 27 - July 1	0	-	-	-
July 18 - 22	0	-	-	-
August 8 - 12	18	55.6	37.1	10.8
August 29 - Sept. 2	24	37.5	23.4	7.8
September 19 - 23	46	47.8	14.5	4.8
October 10 - 14	52	0	0	0
Wooster, OH				
May 16 - 20	0	-	-	-
June 6 - 10	0	-	-	-
June 27 - July 1	0	-	-	-
July 18 - 22	0	-	-	-
August 8 - 12	4	25.0	112.0	56.0
August 29 - Sept. 2	8	0	0	0
September 19 - 23	52	11.5	8.7	4.2
October 10 - 14	6	0	0	0

* Dash indicates not estimable.

† Total number of juvenile and adult *N. guyanense* on each moth.

Table 4. Temporal parasitism of *Spodoptera frugiperda* and number of *Noctuidonema guyanense* per infested moth in Plains and Midwestern states (Region 3) during 1988.

Location	No. moths examined	% Parasitized	$\bar{x}$ No. nematodes per infested moth	
			Total*	Adult
Brownsville, TX				
May 16 - 20	27	59.3	143.6	38.0
June 6 - 10	108	30.5	77.4	26.9
June 27 - July 1	144	27.1	124.4	41.5
July 18 - 22	119	6.7	33.3	13.3
August 8 - 12	0	-	-	-
August 29 - Sept. 2	0	-	-	-
September 19 - 23†	0	-	-	-
October 10 - 14†	20	0	0	0
College Station, TX				
May 16 - 20	0	-	-	-
June 6 - 10	0	-	-	-
June 27 - July 1	10	30.0	365.0	108.0
July 18 - 22	6	0	0	0
August 8 - 12	96	10.4	29.4	11.9
August 29 - Sept. 2	0	-	-	-
September 19 - 23	0	-	-	-
October 10 - 14	0	-	-	-
Lubbock, TX				
May 16 - 20	0	-	-	-
June 6 - 10	11	0	0	0
June 27 - July 1	4	0	0	0
July 18 - 22	0	-	-	-
August 8 - 12	20	9.9	45.0	7.2
August 29 - Sept. 2	55	18.2	23.9	8.8
September 19 - 23	57	5.3	8.7	3.7
October 10 - 14	50	0	0	0
Garden City, KS				
May 16 - 20	0	-	-	-
June 6 - 10	0	-	-	-
June 27 - July 1	0	-	-	-
July 18 - 22	41	2.4	4.0	3.0
August 8 - 12	2	0	0	0
August 29 - Sept. 2	97	10.3	14.9	5.8
September 19 - 23	0	-	-	-
October 10 - 14	0	-	-	-
Bloomington, IL				
May 16 - 20	0	-	-	-
June 6 - 10	0	-	-	-
June 27 - July 1	0	-	-	-
July 18 - 22	0	-	-	-
August 8 - 12	14	0	0	0
August 29 - Sept. 2	15	6.7	13.0	5.0
September 19 - 23	147	5.4	14.1	4.0
October 10 - 14	0	-	-	-

Table 4. Continued.

Location	No. moths examined	% Parasitized	$\bar{x}$ No. nematodes per infested moth	
			Total*	Adult
Ankeny, IA				
May 16 - 20	0	-	-	-
June 6 - 10	0	-	-	-
June 27 - July 1	0	-	-	-
July 18 - 22	5	0	0	0
August 8 - 12	0	-	-	-
August 29 - Sept. 2	91	2.2	10.5	2.0
September 19 - 23	50	0	0	0
October 10 - 14	16	0	0	0

* Total number of juvenile and adult *N. guyanense* on each moth; dash indicates not estimable.
† From Simmons et al. 1991.

collected during the week of 8 - 12 August; one of these four moths was parasitized with 112 nematodes (Table 3). For the subsequent sampling period, none of eight collected moths was parasitized.

Humidity and temperature may play a vital role in the population dynamics of *N. guyanense*. Data from laboratory (Simmons and Rogers 1990b) and field (Simmons et al. 1991) studies indicate that both high temperature and high humidity are favorable for population increases of *N. guyanense*. Both of these environmental parameters (vapor pressure deficiency is used as an index of humidity) decreased from south to north through the Plains and Midwestern states (Tables 5 and 6). The impact of temperature may help explain the higher nematode populations at the south Georgia (Tifton) and north Florida (Quincy) locations than at south Florida (Belle Glade) in July and August (Table 3). During that period, mean daily temperature was lower in south Florida.

Marti et al. (1990) suggested that there may be a threshold infestation level of *N. guyanense* at which the flight of *S. frugiperda* may be impaired. The biology among individuals of the fall armyworm is highly variable. There were only a few locations from which at least one moth had greater than 500 nematodes (Tables 2 - 4). A notable example was a moth recovered at Brownsville, TX, harboring 1,325 nematodes (Table 4). Conversely, it was not uncommon to find between 1 and 10 nematodes on infested moths in this study.

In conclusion, not only does *N. guyanense* have a wide distribution in the tropical and subtropical Americas (Simmons and Rogers 1990a), but it also can be carried with its host on migratory flights to much of the fall armyworm range in the U.S. The impact of the nematode on the migratory ability of its host is not clear, though our data suggest that moths with a moderate number of nematodes may be less able to migrate long distances. Additional laboratory and field data are needed to ascertain the impact of *N. guyanense* on the flight capability of *S. frugiperda*. In addition, data collected in temperate regions combined with data collected at tropical locations in the Americas would further elucidate the importance of climate on the population dynamics of *N. guyanense*. The potential augmentative value of *N. guyanense* is unknown until further research on its biology, ecology, and host interactions is completed. However, because the nematode attacks the mobile, dispersing stage of its hosts, successful augmentation programs should be

Table 5. Mean monthly temperature (°C) at selected locations from mid-May to mid-October in 1988.

Location*	May†	June	July	Aug.	Sept.	Oct.†
			Region 1 States			
Belle Glade, FL	24.8	26.1	26.9	26.9	26.7	24.5
Quincy, FL	24.5	26.3	26.6	27.1	25.3	18.6
Tifton, GA	23.4	25.3	27.1	27.8	24.6	18.4
Florence, SC	21.4	23.4	26.6	26.9	22.8	14.6
Oxford, NC	20.9	23.1	26.5	27.1	20.4	12.6
Blacksburg, VA	16.6	19.6	22.1	22.7	16.0	8.9
			Region 2 States			
Cheneyville, LA	21.7	25.2	25.4	26.8	23.8	16.5
Jackson, TN	20.4	24.4	25.7	26.8	22.4	13.3
Lexington, KY	17.7	22.4	25.2	25.5	20.0	10.7
Wooster, OH	21.3	20.2	23.9	22.4	16.9	8.5
			Region 3 States			
Brownsville, TX	20.0	23.4	25.1	24.7	18.9	9.8
College Station, TX	21.4	27.3	29.6	32.9	27.7	20.7
Lubbock, TX	20.1	24.4	24.9	25.0	20.7	15.8
Garden City, KS	19.1	24.9	25.3	25.3	20.2	11.5
Bloomington, IL	20.0	24.0	26.3	26.4	20.8	11.2
Ankeny, IA	20.0	23.4	25.1	24.7	18.9	9.8

* Missing data for Durham, NH.
† 16-31 May; 1-14 October.

Table 6. Mean monthly vapor pressure deficiency (mb) at selected locations from mid-May to mid-October in 1988.

Location*	May†	June	July	Aug.	Sept.	Oct.†
			Region 1 States			
Belle Glade, FL	7.11	6.22	6.31	6.03	6.69	6.89
Tifton, GA	6.85	7.33	7.29	7.17	4.42	4.66
Blacksburg, VA	6.33	7.76	8.09	12.08	5.49	4.36
			Region 2 States			
Cheneyville, LA	8.31	8.69	6.36	6.27	5.81	5.95
Lexington, KY	7.37	12.03	11.83	9.72	8.02	5.43
Wooster, OH	7.35	10.63	10.56	6.61	-	2.21
			Region 3 States			
Brownsville, TX	10.66	11.25	12.42	10.45	8.46	9.00
College Station, TX	7.77	8.93	7.67	10.14	10.99	10.10
Lubbock, TX	8.42	14.36	10.74	11.24	8.76	7.97
Ankeny, IA	10.50	12.20	11.63	12.76	7.97	4.94

* Missing data for Quincy, FL; Bloomington, IL; Garden City, KS; Durham, NH; Oxford, NC; Florence, SC; and Jackson, TN.
† 16 - 31 May; 1-14 October.

facilitated by the natural yearly dispersal of the moth as infested fall armyworm moths migrate from overwintering, southern habitats to more northerly latitudes of the U.S.

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