Table 5. Minimum sample sizes needed to reliably estimate pre-plant *M. communis* larval population densities with rolled oat baits at three levels of *precision* for each of four subplot sizes and two bait sample depths.

Plot size (ha)	Wireworm population density								
	0.2 larvae/bait			1.0 larvae/bait			5.0 larvae/bait		
	Level of precision								
	10%	20%	40%	10%	20%	40%	10%	20%	40%
	Sample size (no.)								
	0-10 cm								
0.01	1,762	440	110	660	165	41	110	41	15
0.03	2,498	624	156	724	181	45	210	52	13
0.07	2,842	710	178	796	199	50	223	56	14
0.13	3,455	864	216	1,104	276	69	353	88	22
	0-20 cm								
0.01	678	169	42	440	110	27	285	71	18
0.03	2,275	569	142	852	213	53	315	79	20
0.07	2,663	666	166	1,032	258	64	402	101	25
0.13	2,990	748	187	1,404	351	88	660	165	41

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BIOLOGY AND MANAGEMENT OF CORN-SILK FLY, *EUXESTA STIGMATIS* LOEW (DIPTERA: OTITIDAE), ON SWEET CORN IN SOUTHERN FLORIDA

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Abstract. **Research is reported concerning the biology, behavior, and management of corn-silk fly (CSF), *Euxesta stigmatis* Loew. CSF immigrated into the sweet corn (*Zea mays* var. *saccharata* (Sturt.) Bailey) fields when plants were 2-week old. At harvest, between 80-90% of all ears in a non-treated field were infested with at least one life stage of this fly, and yield losses due to CSF were > 60%. Fresh, new ears were the preferred substrate for oviposition. Females oviposited on silks within the tips of the ears. Peak oviposition occurred during daylight between 11:00-13:00 EST. Total developmental period from egg to adult was 28.3 ± 0.6 days at 30C. Adult longevity averaged 26.7 ± 8.0 days at 24 ± 2C. Contact toxicity of parathion, carbaryl, chlorpyrifos, and methomyl to adults was assessed in the laboratory. Parathion was most toxic to CSF adults.**

Sweet corn is one of the most important crops in the southern U. S. In southern Dade county, sweet corn is valued at $5.7 million (1). Because of high crop values and aesthetics, tolerance levels for insect damage to ears are very low. Corn-silk fly (CSF), *E. stigatis*, is one of the most important economic pests of corn in South, Central and North America (2). This fly has been reported to attack sweet and field corn in the West Indies, Central America,

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South America, and North America, and has received considerable attention in Puerto Rico. In southern Florida, it is second only to corn earworm as a threat to maturing sweet corn ears (4). Heavily infested ears have no market value. Even low level infestations lower the grade of sweet corn. In southern Florida, growers can not tolerate > 2% damage of corn ears by insects (5). A recent survey in various sweet corn fields in southern Florida found 90-95% ear infestation by CSF in untreated sweet corn fields during the winter, spring, and fall (Seal and Jansson, unpubl. data).

Very little information is available concerning CSF's bionomics and management. App (2) presented brief observations on some aspects of its biology. Bailey (3) evaluated the effectiveness of insecticides at managing CSF in Puerto Rico. He recommended a 1:5 pyrethrin extract: mineral oil mixture for the control of adult flies. Hayslip (4) recommended several treatments of parathion at 3 to 4-day intervals where adult immigration into a planting was heavy. Currently, management of the fly relies solely on insecticides. Because of a lack of information, growers typically apply parathion every three days from the appearance of silk until harvest. To improve management programs for CSF, more information on its biology and effectiveness of management approaches is needed. The present paper presents new information on the biology and management of this fly.

Materials and Methods

Host range. Different fruits and vegetables fields in the Homestead area were checked for the presence of CSF. Deteriorated fruits and vegetables were collected and placed in polyethylene bags to collect CSF adults. Host range of CSF was determined by observing adults hovering on or around the hosts and by collecting different developmental stages of the fly from the hosts.

Mating behavior. Observations of mating behavior were made in a 0.4 ha sweet corn field. A hand lens (14x) was used to determine the sex of the CSF adults in the field and to record the succession of behaviors. Mating pairs (male x female) (n = 20) were observed until they separated and departed.

Oviposition behavior. Ovipositional behavior was determined visually for females (n = 20) observed on ears in a sweet corn field (0.4 ha) during day light hours. A hand lens (14x) was used to observe the movement of the ovipositor during the time of oviposition. Females were observed until they left the site of oviposition. After females oviposited, the tips of sweet corn ears were dissected to determine the number of eggs laid per female.

Egg-laying preference. Corn ears of different ages and freshness (old, new, open-tip, and rotten) were tested in the laboratory to determine ovipositional preference of CSF. One ear of each type was placed in a cage (32.5 x 20.0 x 37.5 cm) along with 10 CSF adults (sex ratio, 1:1). Flies were also provided sufficient honey, sugar, and water. Numbers of eggs laid were recorded every 24 hours. Ears were replaced every 7 days.

Another experiment was conducted in the field by using old ears with dry silk and ears in which dry silk was removed from the tips. Ten ears of each type were selected randomly. The plants were marked and the ears were cleaned of previously laid eggs and covered with polyethlene bags. The bags were removed and the ears were exposed to CSF between 9:00 EST-19:00 EST. The tips of ears were excised from plants and transported to the laboratory and numbers of eggs per ear were *recored. The* experiment was repeated 5 times.

Daily pattern of oviposition. The experiment was conducted in a nontreated sweet corn field during 5 consecutive weeks. On each of 3 days per week, 10 sweet corn ears were sampled every 2 hours between 9:00 EST and 19:00 EST and then again at 9:00 EST the following morning to characterize ovipositional patterns of CSF females. Ears were checked thoroughly prior to use; any eggs found were removed. Ears were then marked and covered with polyethylene bags to exclude CSF adults. Bags were removed and ears were exposed at *one of five 2-hour* periods. After exposure, ears were covered with bags to further exclude adults. Bags were removed and numbers of eggs in each ear were collected from the tip silks by using a camel hair brush.

Intra ear distribution of CSF larvae and pupae. To determine intra-ear distribution of CSF larvae and pupae, 50 corn ears were collected randomly from each quarter of a 1 ha nontreated field prior to harvest. Each ear was divided into 3 equal parts (tip, middle, base) and the numbers of CSF larvae and pupae were recorded on each part.

Percent corn ear infestation and abundance of eggs. A study was conducted in a 1 ha sweet corn field planted in Mar., 1989. Percentage of corn ear infestation by at least one developmental stage of CSF was determined by collecting 100 ears randomly from different parts of the field in the second week of each month (Apr., May, and June).

Developmental time and percent survival of CSF. The duration of different stages of CSF and their survival were studied in 3 temperature regimes: Fluctuating room temperature (24 ± 2C), and 2 constant temperatures (25 ± 0.5C, and 30 ± 0.5C). Eggs (2 hr old) were collected from the field and placed in equal numbers (n = 200) in each temperature. Eggs were checked every 4 hr to determine duration of egg stage. Hatched larvae were checked weekly until adult emergence.

The survival of different stages of CSF was determined at room (24 ± 2C) and constant temperatures (25 and 30C) on artificial diet.

Contact toxicity of chemical insecticides. A study was conducted to determine the contact toxicity of parathion, carbaryl, chlorpyrifos, and methomyl against CSF adults. Experimental flies were collected from a laboratory culture maintained at the University of Florida, IFAS, Tropical Research and Education Center, Homestead.

Technical grade of each insecticide was diluted with acetone (99.5%, class B). Various concentrations were prepared for each material and topically applied (1 μl/ insect) to the dorsal thoracic segments of CSF adults using a microsyringe. Control adults were treated with acetone. Ten adults (3-day old) were treated with each dosage and then placed in plastic boxes (25 x 20 x 10 cm) along with honey and water. Boxes were placed on a laboratory bench at 24 ± 2C. Mortality was recorded 24 hr post-treatment.

Importance of natural ememies. Both field and laboratory studies were conducted to identify important natural enemies of CSF and to determine their effectiveness against CSF. One unidentified earwig species was caged along with CSF eggs (n = 30) laid at the base of leaves.

The numbers of eggs eaten per earwig (n = 3) were recorded after 24 hr. A similar experiment was conducted in the laboratory. Fifty freshly laid eggs were placed on moistened filter paper in 9-cm Petri dishes (n = 15). One unidentified adult earwig was placed in each Petri dish. The numbers of eggs eaten per earwig were recorded after 24 hr.

Results and Discussion

CSF distribution and host range. App (2) reported that CSF is generally distributed throughout the Neotropics. CSF has been reported from the following locations:

West Indies: Puerto Rico, Cuba, Dominican Republic, Bahamas, Virgin Island
British West Indies: Barbados, Dominica, Vincent, Jamaica
Central America: Canal Zone, Panama
South America: Brazil, Bolivia, Paraguay, Peru
North America: Mexico, Florida

According to these records and a recent survey (Seal and Jansson, unpublished data) in Homestead, Florida, this fly has been collected from sugarcane (*Saccharum officinarum* L.), guava (*Psidium guajava* L.), corn (*Zea mays* L.), *Eugenia* spp., orange (*Citrus aurantium* L.), and the stem of banana (*Musa* spp.). In the Homestead area, different developmental stages of this fly were collected from sorghum (*Sorghum bicolor* Moench) and tomato (*Lycopersicon esculentum* Mill.). Adult flies were also found on volunteer potato (*Solanum tuberosum* L.), sugarcane, and various weeds species.

Mating behavior of CSF. Mating occurred during daylight, primarily at dawn and dusk. Adult insects aggregated during this time in large numbers on the tassels where they performed frequent short trivial flights before pairing. Males first courted females by touching the female's head, abdomen and other body parts with their antennae. Males then touched the rear end of female with their labella. Receptive females extended their ovipositor which was almost equal in size to the length of their body. Males then rubbed their labella over a female's ovipositor before climbing the female. Males then climbed females halfway up the abdomen and bent their genitalia 180° to meet the ovipositor. Mating lasted less than one second. A single male mated with a female 2 to 4 times during a 5 minute period. Unreceptive females flew away.

Oviposition behavior. Eggs are smooth, white, and slender, and are ca. 0.25 cm long. Eggs were laid predominantly within silks at the point where silks emerge from the tip of the ear. Females typically extended their ovipositors inside the tip of the ear between silks and deposited eggs in batches of 2 to 40. Undisturbed females often deposited eggs repeatedly in the same mass. Eggs were often found attached to each other, side by side.

Egg-laying preference. More eggs per ear (67.2 ± 12.0, $X^2 = 96.3$, $p < 0.01$) were laid in the silk of fresh, young ears than in old ears with intact tips (16.9 ± 5.9). Fewer eggs per ear (8.0 ± 6.6) were laid on ears with open tips. No eggs were laid on rotten ears. The number of eggs laid per ear did not differ ($t = 0.49$, $p > 0.05$) between ears with dry silk (15.9 ± 6.9 eggs/ear) and ears in which dry silk was removed (33.6 ± 8.0 eggs/ear). CSF females also laid eggs at the base of leaves when corn plants were young and occassionally when corn plants were old.

Daily pattern of oviposition. Females laid eggs throughout the day with peak oviposition (45.7 ± 3.0 eggs/ear) occurring at 11:00-13:00 EST (Table 1). Oviposition decreased after 13:00 EST. Few eggs (3.9 ± 1.0 eggs/ear) were laid between 17:00 EST and 9:00 EST the following morning.

Intra ear distribution of corn silk fly larvae and pupae. More larvae (13.0 ± 3.3) and pupae (19.1 ± 6.4) were collected at the tip followed by middle and base of the ear (Table 2). Hatched larvae moved down inside the ear and aggregated on the ear. Larvae fed on fresh and injured kernels. A range of 1-5 larvae were found in one kernel. Larvae often bored into the central tissue of corn ears and fed. Most pupae were found on dried silk at the tip of the ear (Table 2).

Percent corn ear infestation and abundance of eggs. Maximum corn ear infestation was observed in Apr. (90.0%) followed in decreasing order by May (63.0%) and June (58.0%). Higher numbers of eggs per ear were recorded in Apr. than in other months. Numbers of eggs per ear decreased in subsequent months (Table 3).

Developmental time and percent survival of CSF. The duration of egg development was the shortest (1.5 ± 0.1 days) at 30C (Table 4). No differences were observed between room temperature and 30C. The larval period lasted for 20.7 ± 0.7, 26.5 ± 0.6 and 23.2 ± 0.9 days at 30C, 25C and room temperature, respectively. The pupal period

Table 1. Daily patterns of oviposition of corn silk fly on sweet corn.

Time (EST[z])	Mean[y] ± s.e.	Range
09:00-11:00	27.3 ± 3.7b	0-193
11:00-13:00	45.7 ± 3.0a	0-189
13:00-15:00	14.1 ± 1.7c	0-96
15:00-17:00	7.6 ± 1.5d	0-145
17:00-09:00	3.9 ± 1.0d	0-97

[z]EST = Eastern Standard Time.
[y]Mean separation within column by Duncan's multiple range test, 5% level.

Table 2. Intra-ear distribution of corn-silk fly larvae and pupae.

Part of ear[z]	Mean no. ± s.e.[y]	
	Larvae	Pupae
Tip	13.0 ± 3.3a	19.1 ± 6.4a
Middle	4.5 ± 1.8b	2.4 ± 0.8b
Base	4.6 ± 1.9b	1.5 ± 0.4b

[z]Each ear was divided into three equal parts.
[y]Mean separation within column by Duncan's multiple range test, 5% level.

Table 3. Percentage of corn ears infested by at least one developmental stage of corn-silk fly and mean no. eggs per ear during 3 consecutive months in 1989.

Months	Percent infestation[z]	Mean[y] no. eggs/ear ± s.e
April	90.0	133.6 ± 24.4a
May	63.0	85.3 ± 18.8b
June	58.0	35.0 ± 14.7c

[z]Percentage infestation was determined by collecting 100 ears in the second week of each month.
[y]Mean separation within column by Duncan's multiple range test, 5% level.

Table 4. Percent survival and developmental time requirements of different stages of corn-silk fly at different temperatures (°C).

Stages	Survival %			Developmental time (days)		
	Room[z]	25	30	Room	25	30
Egg	90.0 ± 3.3	90.0 ± 3.2	96.0 ± 2.4	1.5 ± 0.1	1.5 ± 0.1	1.5 ± 0.1
Larva	62.5 ± 4.9	54.5 ± 5.5	46.3 ± 2.2	23.2 ± 0.9	25.5 ± 0.6	20.7 ± 0.7
Pupa	92.3 ± 3.2	80.0 ± 0.0	73.6 ± 8.9	6.8 ± 0.3	6.3 ± 1.8	5.6 ± 0.5
Egg-Adult				32.0 ± 0.6	33.8 ± 1.2	28.3 ± 0.6

[z]Room temperature, 24 ± 2°C.

ranged between 5.6 ± 0.5 and 6.3 ± 1.8 days at 30 and 25C, respectively. Total developmental period (egg-adult) was 28.3 ± 0.6 and 33.8 ± 1.6 days at 30 and 25C, respectively. The longevity of adult flies averaged 26.7 ± 8.0 days at room temperature.

Survival of different developmental stages was 90.0 ± 3.3, 62.5 ± 4.9, and 92.5 ± 3.2% at room temperature for egg, larva, and pupa, respectively. Survivorship of larvae and pupae decreased with an increase in temperature (Table 4).

Contact toxicity of four chemical insecticides. Results showed that parathion was the most toxic chemical tested (Table 5). Approximately 50% of CSF adults were killed at a dosage of 0.006 g per insect with parathion as compared with 0.015, 0.01, and 0.015 g per insect with carbaryl, chlorpyrifos, and methomyl, respectively.

Importance of natural enemies. CSF populations in corn fields increase initially by immigration of adults from neighboring fields and by reproduction of the resident population. Adult females started laying eggs before the appearance of ears when plants were 2 to 4 weeks old. Most eggs were eaten by earwigs (Forficulidae, Labiidae) (Seal and Jansson, unpublished data). Three groups of eggs, each consisting of 30 eggs, were placed at the base of leaves. After 24 hr, all eggs were eaten by an unidentified earwig species. Earwigs also predated upon eggs deposited at the tip of the ear. In addition, some unidentified mites and hemipterans also predated upon CSF eggs. In a preliminary experiment in the laboratory, an unidentified earwig species consumed an average of 48 eggs in 24 hr.

Table 5. Percentage mortality of CSF adults treated with different dosages of insecticides.

Dasage[z] (g/fly)	Mortality of CSF (%)			
	Parathion	Carbaryl	Chlorpyrifos	Methomyl
0.5	100	90	100	100
0.3	100	80	100	100
0.1	80	70	100	100
0.05	77	70	80	70
0.03	73	50	60	60
0.015	80	50	60	50
0.010	65	40	50	40
0.006	50	40	40	30
0.0042	45	—	—	—
0.00333	40	—	—	—
Control	5	10	10	5

[z]Actual dosage of parathion = Tabulated dosage x specific gravity of parathion (1.267).

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