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Authors: Owens, David, Larsen, Nicholas, and Nuessly, Gregg S.

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Post-harvest crop destruction effects on picture-winged fly (Diptera: Ulidiidae) emergence

David Owens[1,*], *Nicholas Larsen*[2], *and Gregg S. Nuessly*[1]

Abstract

Sweet corn grown in Florida that is not well protected by insecticides often becomes heavily infested by maggots of picture-winged flies (Diptera: Ulidiidae). Additionally, after marketable ears are harvested, remaining ears are left unprotected and can be exploited by female flies. Larvae leave the ears to pupate in the soil. Occasionally, crop residue removal is delayed, sometimes for several weeks. Sweet corn plots were established in Fall 2015 and Spring 2016 to determine how various crop destruction techniques might impact the successful completion of the corn-infesting picture-winged fly life cycle. After harvest maturity, untreated sweet corn plots were partially mowed, disked once, disked twice, or left standing in the fall. In the spring, plots were partially plowed, disked twice, or left standing. Emergence cages were erected over the soil to intercept newly emerging adults. In the fall, crop destruction did not reduce adult emergence compared with the standing corn plots. In the spring, both plowing and disking significantly reduced adult fly emergence from the soil. The species complex emerging from the soil in the spring after crop destruction differed from the adult species complex present earlier during the spring corn's reproductive stages. Seasonal differences may have contributed to this inconsistency. Crop destruction does not initially appear to be a reliable method to reduce 1st generation adult fly emergence from ears post-harvest, highlighting the importance of timely crop destruction to deny females an unprotected host in which to oviposit.

Key Words: *Euxesta*; *Chaetopsis*; tillage

Resumen

El maíz dulce cultivado en la Florida que no está bien protegido por los insecticidas a menudo se ve muy infestado por larvas de moscas con alas pintadas (Diptera: Ulidiidae). Además, después de que se cosechan los elotes comercializables, los elotes restantes quedan desprotegidos y pueden ser explotados por moscas hembra. Las larvas dejan los elotes para empupar en el suelo. Ocasionalmente, se retrasa la eliminación de residuos de cultivos a veces por varias semanas. Se establecieron parcelas de maíz dulce en el otoño del 2015 y la primavera del 2016 para determinar cómo varias técnicas de destrucción de cultivos podrían afectar la terminación exitosa del ciclo de vida de la mosca con alas pintadas infestando el maíz. Después de la madurez de la cosecha, las parcelas de maíz dulce no tratadas fueron segadas parcialmente, descascaradas una vez, dobladas dos veces o dejadas de pie en el otoño. En la primavera, las parcelas fueron parcialmente aradas, dobladas dos veces o dejadas de pie. Se pusieron jaulas de emergencia sobre el suelo para interceptar a los adultos recién emergidos. En el otoño, la destrucción de cultivos no redujo la emergencia de adultos en comparación con las parcelas de maíz no cortadas. En la primavera, tanto el arado como el hundimiento redujeron significativamente la emergencia de moscas adultas del suelo. El complejo de especies que emergen del suelo en la primavera después de la destrucción del cultivo difiere del complejo de especies adultas presente anteriormente durante las etapas reproductivas del maíz primaveral. Las diferencias estacionales pueden haber contribuido a esta inconsistencia. La destrucción de los cultivos no parece inicialmente ser un método confiable para reducir la aparición de moscas adultas de primera generación en las orejas después de la cosecha, esto destaca la importancia de la destrucción oportuna del cultivo para negar a las hembras un huésped desprotegido para ovipositar.

Palabras Clave: *Euxesta*; *Chaetopsi*s; labranza

Florida is the second largest producer of fresh market sweet corn (USDA/NASS 2016), and much of that is grown in southern Florida, where the picture-winged flies *Euxesta eluta* Loew, *Euxesta stigmatias* Loew, and *Chaetopsis massyla* Walker (Diptera: Ulidiidae) are severe primary pests of sweet corn (Goyal et al. 2011). Females deposit dozens of eggs in fresh, undamaged silks (App 1938; Seal & Jansson 1989). The larvae move into the silk channel, where they are protected from insecticides, and their feeding on the silks and kernels renders the ear unmarketable. Once larval feeding is completed, most maggots leave the ear to pupate in the soil (Link et al. 1984; Nuessly & Owens personal observation), although some will pupate in the dried silk channel (Seal et al. 1995). After pupal development is complete (7–12 d), flies emerge from the soil and seek new hosts nearby (Goyal et al. 2012).

Growers do not harvest fields if pre-harvest samples indicate that the field infestation rate exceeds minimum grade standards (U.S. no. 2: 10% of ears with damage including, but not limited to, insect feeding; USDA/AMS 1997). To prevent unacceptable economic loss, sweet corn is visually scouted 3 times per week to assess population intensity. If flies are observed, fields are treated with broad-spectrum insecticides (Anonymous 2009). Both *E. stigmatias* and *C. massyla* demonstrate reduced susceptibility to several commonly used pyrethroids (Owens et al. 2016). Obstacles, such as canals and electric cables, often pre-

[1]University of Florida, Institute of Food and Agricultural Sciences, Everglades Research and Education Center, Belle Glade, FL 33430, USA;
E-mail: owensd119@gmail.com (D. O.), gnuessly@ufl.edu (G. S. N.)
[2]International Responsible Farming Council, PO Box 282, Pahokee, FL 33476, USA; E-mail: nklagofarms@aol.com (N. L.)
*Corresponding author; E-mail: owensd119@gmail.com (D. O.)

vent adequate aerial coverage. When reduced susceptibility and inadequate coverage are combined with large populations migrating into fields from surrounding environments that serve as refugia [sugarcane, vegetable culls, urban centers (Goyal 2010; Goyal et al. 2012)], portions of fields are often rejected due to unacceptable infestation (Seal & Jansson 1989).

Insecticide applications cease several days prior to harvest. Female flies can then use these unprotected fields for oviposition and larvae develop in later-maturing primary or secondary ears. Corn fields post harvest are often mowed or disked to incorporate residue into the soil. When done promptly, this may help prevent ulidiid larvae from completing their feeding in the ear or successfully emerging from the soil as adults. Crop destruction and soil incorporation also prevents females from continuing to use sweet corn ears for further oviposition. However, this activity is sometimes delayed after harvest, both for harvested and rejected fields. These unprotected, standing fields serve as reservoirs for development of flies that, upon completion of the life cycle, will infest neighboring sweet corn fields, especially if they are in the early reproductive stages that are more attractive for oviposition than senescing fields (Seal & Jansson 1993).

The purpose of our study was to determine what effect residue destruction and residue incorporation into the soil has on preventing silk fly larvae from completing their life cycle in the soil. This could reduce the population of silk flies infesting nearby fields.

Materials and Methods

For both fall and spring experiments, three 20-row blocks of 'Obsession' sweet corn (Seminis Vegetable Seeds, St. Louis, Missouri) were planted on 76.2 cm wide beds at the Everglades Research and Education Center, Belle Glade, Florida, using a John Deere Max Emerge™ 4-row vacuum planter (John Deere, Moline, Illinois). The fall trial was planted on 16 Sep 2016, and seeds were spaced 20.3 cm apart. The spring corn trial was planted on 18 Feb 2016, and seeds were spaced 14.5 cm apart. Sweet corn was managed according to local standards (Ozores-Hampton et al. 2013). Each block in both trials was 45.7 m long and 20 rows wide. Insecticides were not applied for management of the corn-infesting ulidiid complex in these plots.

At harvest maturity of each experiment, 90 ears from each block were randomly removed for a concurrent experiment in the field. Strips of the untreated blocks were then destroyed by mowing, disking once (disk 1×), or disking twice (disk 2×). Control plots were left standing from each block. Emergence cages that were 2 m tall, with each cage covering an area of 0.58 m^2, were erected over the soil to collect newly eclosed flies as they emerged from the soil. Cage support frames were driven into the soil, and the bottom edges of the cage mesh were covered with soil to prevent lateral fly movement into and out of the cage area. Picture-winged flies were completely removed from the cage interior via aspiration 3 times per week and identified to species beginning 10 d after harvest (harvest occurred on 19 Nov) and continuing until no more silk flies emerged from the soil. Treatments were replicated 3 times.

In the spring trial, whole plants from 2 rows of each plot were visually examined 9 times over the course of the 3 wk period between silking and harvest to determine the species complex in the field. After harvest on 6 May, sections of each block were disked twice, plowed after disking, or left standing. In each treatment section, 2 cages covering 0.58 m^2 and a larger cage covering 3.34 m^2 were installed. Treatments were replicated 3 times. Adult flies emerging from the soil were removed from the cages twice weekly with the aid of sticky cards swung to intercept flies. They were identified to species beginning when first observed in the cages 6 d after harvest. Cages were monitored for 41 d. On 2 separate occasions, heavy rain combined with strong sustained winds and wind gusts blew cages down. Cages were reinstalled over the plots in the same locations from which they had been dislodged by the storms.

The total numbers of flies emerging per m^2 from the cages in both experiments were log transformed and analyzed using repeated measures analysis of variance in Proc GLIMMIX in SAS® software (SAS Institute Inc. 2008). Each year was analyzed separately. Data from 24 May was not included, because 20 of the 27 cages had been blown over. Tukey–Kramer honest significant difference (HSD) tests were used for means separations of all analyses.

Results

FALL EXPERIMENT

In the fall experiment, 2,582 picture-winged flies were removed from the 12 cages (Fig. 1). The vast majority of these flies (95.5%) were *E. stigmatias*, followed by *C. massyla* (2.9%). *Euxesta eluta* comprised only 1.0% of the emerging flies. Six bucket traps baited with torula yeast were deployed in the blocks during the corn reproductive stages for a different experiment and captured a slightly different species proportion (903 captured flies: 67.5% *E. stigmatias*, 29.3% *C. massyla*, and 3.2% *E. eluta*; unpublished data). There were no significant differences between the crop destruction treatments and the standing corn treatment on fly emergence from the cages (F = 1.58; df = 3,120; P = 0.199). Although there was a date × treatment interaction (F = 2.34; df = 42,120; P <0.001), no clear, consistent treatment pattern on fly emergence was observed. Fly emergence from the disked and mowed plots peaked on 7 Dec, and peak emergence from the standing corn plots occurred on 18 Dec.

SPRING EXPERIMENT

In the spring trial, 5,604 flies were removed from the 27 cages. The species complex composition during the first 2 wk (3,175 flies captured) was 60.2% *E. stigmatias*, 31.1% *E. eluta*, and 4.1% *C. massyla*. During the remainder of the experiment, the proportion of *E. stigmatias* decreased to 43.3%, whereas that of *E. eluta* increased to 45.8%. The proportion of *C. massyla* increased to 7.2%. The species composition emerging into the cages differed from what was observed during

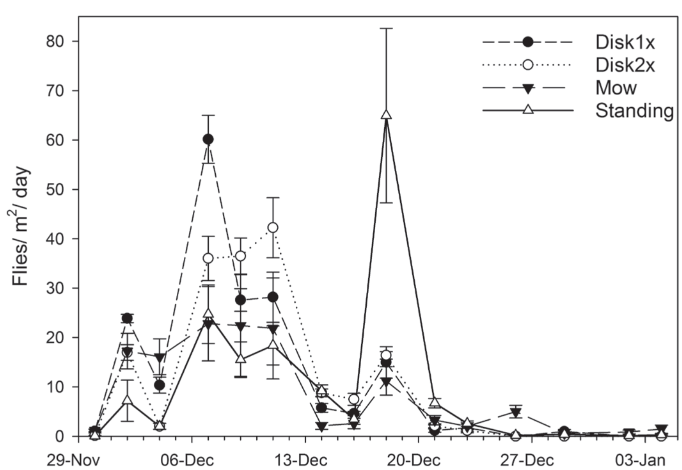

Fig. 1. Fall trial mean (± SE) adult silk fly emergence from soil within cages erected over the treatment plots where plants were disked once (1x), disked twice (2x), mowed, or left standing.

the corn reproductive stages prior to harvest maturity. Out of the 3,267 flies observed, 64.2% were *E. eluta*, 29.8% were *E. stigmatias*, and 1.7% were *C. massyla*.

Flies had already begun emerging out of the soil by the 1st sampling date, which occurred 5 d after harvest, indicating that many larvae had already finished development and left the ear before harvest and their development in the soil was nearly complete by the time cages were installed. Fly emergence per m^2 per day in the cages over standing corn initially peaked on 31 May, decreased, and then increased to a greater 2nd peak on 17 Jun (Fig. 2).

Fly emergence was significantly affected by treatment (F = 98.78; df = 2,270; P <0.001), date (F = 11.57; df = 11,270; P < 0.001), and the interaction between treatment and date (F = 2.19; df = 22,270; P = 0.002). For all sampling dates except 17 May, fewer flies emerged from disked plots than standing corn plots. Fly emergence from plowed plots did not differ significantly from standing corn plots on 17 May, 27 May, and 7 Jun. Data from 7 Jun were included in the analysis, even though 9 of the cages (combined from all 3 treatments) were blown down by a heavy windstorm the evening before; fly emergence on 7 Jun was not significantly affected by treatment (P = 0.062). Fly emergence between disked and plowed plots differed significantly only on 26 May (Fig. 2).

Discussion

The effect of crop destruction on reducing the emergence of corn-infesting ulidiid adults from the soil was inconsistent. There were 2 peaks in fly emergence during both experiments, possibly due to the maturation and emergence of larvae that were present as early instars or eggs at the time treatments were initiated. Seasonal weather variation, particularly temperature and moisture, may influence larval and pupal survivorship in the soil, as well as the ability of immature larvae to complete development on buried corn residue. For example, for the Caribbean fruit fly, *Anastrepha suspensa* Loew (Diptera: Tephritidae), survivorship from composting infested fruit was least in compost piles that were warmest (Kendra et al. 2007).

Heavy rains and waterlogged soil may have also contributed to reductions in fly emergence in the disked plots in our spring trial. Between 17 and 21 May, the research station received 14.1 cm of rain. During the month of Jun, the research station received 18.1 cm of rain. Disked plots often contained standing water after heavy rain events, whereas the standing-corn plots did not. In the fall trial, when disking did not decrease fly emergence, only 6.4 cm of rain were recorded throughout the duration of the emergence cage study.

In a greenhouse study in which mature larvae were allowed to leave test tubes containing a laboratory diet and drop into trays of soil, mean pupation depth was 2.4 cm (Owens et al. 2015). The tephritid fruit fly pupal parasitoid *Coptera haywardi* Ogloblin (Hymenoptera: Diapriidae) can locate pupae buried as deep as 5 cm. Parasitoid foraging success in laboratory experiments is affected by soil texture (sandy soil being detrimental) but not compaction or moisture level (Guillén et al. 2002). In the current experiment, sweet corn was grown on an organic soil (Dania muck), but in other locations in Florida, sweet corn is grown on sandy or rocky soil. It is possible that disking or plowing would affect silk flies differently on these soils.

It is also possible that disking leaves residue fragments large enough for even small larvae to complete their life cycle, and residue incorporation is shallow enough to not prevent newly eclosed adults from reaching the soil surface. Plowing buries residue deeper, and its effect on preventing maggot life cycle completion in drier soil needs to be investigated. Tillage has been observed to reduce the emergence of overwintering root maggots (*Delia* species; Diptera: Anthomyiidae). Fall and early spring tillage both reduced root maggot survivorship, but population impacts by a single tillage event in either season were less consistent (Dosdall et al. 1996).

Until the impact of soil moisture content following harvest on ulidiid survivorship can be determined, soil incorporation should not be considered as a reliable, remedial management strategy to prevent the corn-infesting ulidiid larvae present in the ear from completing their life cycle. Therefore, the crop should be removed as quickly as possible to prevent adult females already present in the field (now unprotected from insecticide application) from continuing to use the field for oviposition. The species composition of flies emerging from the soil differed from that observed in the field during the corn reproductive stages. The ecological interaction of the 3 species using the same reproductive host needs to be further examined to determine if the 3 fly species differ in terms of damage potential. Also, identifying how interspecific competition influences the population dynamics of the 3 species when they co-infest corn ears, especially if a field is treated with insecticides, is important. Understanding these relationships may change how the 3 species are weighted when they co-occur in a field when making insecticide application decisions. Currently, they are all summed together, but this may not be the best approach.

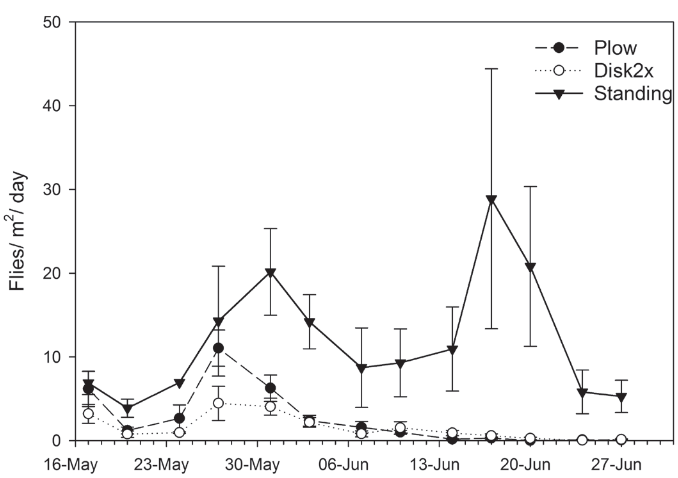

Fig. 2. Spring trial mean (± SE) adult silk fly emergence from soil within cages erected over the treatment plots where plants were plowed, disked twice (2x), or left standing.

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