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Evaluation of lures for monitoring silk flies (Diptera: Ulidiidae) in sweet corn

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Abstract

Several morphologically similar species of picture-winged flies (the silk fly complex, Diptera: Ulidiidae) are severe primary pests of sweet corn (*Zea mays* L.; Poaceae) in Florida. Monitoring traps for these pests may aid threshold development and species complex determination in the field. This study evaluated floral lures, some previously used to monitor pest Lepidoptera, and liquid protein baits, used for other pest Diptera, for efficacy in attraction of silk flies. Baited universal moth traps were deployed for several weeks and placed in a summer fallow field (field trial 1), a fall sweet corn field (field trial 2), and a spring sweet corn field (field trial 3). Flies were removed weekly during each experiment. In field trial 1, traps baited with 1,4-dimethoxybenzene captured the most flies. The majority of flies captured were *Chaetopsis massyla* Walker. In field trial 2, aged torula yeast–baited traps captured more flies than other treatments, (1,4-dimethoxybenzene, geraniol, phenylacetaldehyde, and fresh torula yeast). The majority of captured flies were *Euxesta stigmatias* Loew. In field trial 3, the aged torula yeast treatment resulted in greater fly capture than all other treatments (1,4-dimethoxybenzene, acetoin, anisole, and benzaldehyde). *Euxesta eluta* Loew was the dominant species captured in the spring. More females than males were captured from all 3 experiments and all treatments. These experiments demonstrate that all 3 silk fly species can be captured in traps currently used for pest monitoring. Torula yeast was the best attractant evaluated, and further semiochemical investigations of torula yeast are warranted.

Key Words: *Euxesta*; *Chaetopsis*; trap; semiochemical; yeast

Resumen

Varias especies morfológicamente similares de moscas de alas pintadas (el complejo de la mosca de la seda, Diptera: Ulidiidae) son las plagas principales mas severas del maíz dulce (*Zea mays* L., Poaceae) en la Florida. Las trampas de monitoreo para estas plagas pueden ayudar al desarrollo de umbrales y la determinación de complejos de especies en el campo. Se evaluaron los señuelos florales (algunos utilizados para monitorear las plagas de lepidópteros) y los cebos de proteínas líquidas (utilizados para otros plagas en Diptera) para la eficacia en la atracción de las moscas de seda. Se pusieron trampas cebadas universales para polillas por varias semanas y se colocaron en un campo de descanso en verano (prueba 1), un campo de maíz dulce de otoño (prueba 2) y un campo de maíz dulce de primavera (prueba 3). Se eliminaron las moscas semanalmente durante cada experimento. En la prueba 1, las trampas cebadas con 1,4-dimetoxibenceno capturaron la mayoría de las moscas. La mayoría de las moscas capturadas fueron *Chaetopsis massyla* Walker. En la prueba 2, las trampas con levadura tórula vieja capturaron más moscas que otros tratamientos (1,4-dimetoxibenceno, geraniol, fenilacetaldehído y levadura tórula fresca). La mayoría de las moscas capturadas fueron *Euxesta stigmatias* Loew. En la prueba 3, el tratamiento de la levadura tórula vieja resultó en una captura de moscas mayor que todos los demás tratamientos (1,4-dimetoxibenceno, acetoin, anisol y benzaldehído). *Euxesta eluta* Loew fue la especie dominante capturada en la primavera. Se capturaron más hembras que machos en los 3 experimentos y tratamientos. Estos experimentos demuestran que las 3 especies de moscas de seda pueden ser capturadas en trampas usadas actualmente para el monitoreo de plagas. La levadura tórula fue el mejor atrayente evaluado, y futuras investigaciones semioquímicas de la levadura tórula son necesarias.

Palabras Clave: *Euxesta*; *Chaetopsis*; trampa; semioquímico; levadura

In Florida, a multi-species complex of picture-winged flies (Diptera: Ulidiidae) infest sweet corn (*Zea mays* L., Poaceae) grown for fresh market consumption. These flies are locally referred to as 'silk flies.' The most common species are *Euxesta stigmatias* Loew, *E. eluta* Loew, and *Chaetopsis massyla* Walker. These and additional species of Ulidiidae infest corn in Central and South America (Painter 1955, Steyskal 1974, Frías 1981, Barbosa et al. 1986, Branco et al. 1994, Cruz et al. 2011). Female silk flies oviposit in young undamaged silks (App 1938, Seal & Jansson 1989). Maggot feeding on silks, cobs, and kernels renders sweet corn ears unmarketable and opens corn ears to secondary pests and fungal contamination (Bailey 1940, Nuessly & Webb 2010).

Growers seek to prevent silk fly damage by treating fields with broad spectrum insecticides before females oviposit in the crop. Chemical management is the only available control tactic, targeting adult females before they can oviposit in the crop because maggots are protected from insecticides (Walter and Wene 1951). Thresholds have not been developed for silk flies, and there is a general lack of information on the best scouting methods or sampling units for silk flies. Additionally, the 3 common species in Florida sweet corn are difficult to quickly and accurately identify in the field due to the small morphological features on the wings that differentiate them and the flies' extremely active behavior when performing wing displays. Recent work has shown that *E. stigmatias* and *C. massyla* are less susceptible than *E. eluta* to

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several of the commonly used pyrethroids (Owens et al. 2016), thereby necessitating the need for accurate fly species identification to select the most efficacious product.

Semiochemical-baited traps may assist crop consultants who scout fields in determining the silk fly species composition and population pressure in the field. A major objective of a long term strategic pest management plan for sweet corn in Florida is the identification and evaluation of attractive semiochemicals that could contribute to the development of additional management tactics (Anon. 2009). These attractants could be pheromones, kairomones, or food based chemicals. To date, no pheromones have been identified from the corn-infesting ulidiids. Pheromone production is suspected in another primary ulidiid pest of sugar beets, *Tetanops myopaeformis* Roder (Wenninger et al. 2002). The only kairomone known to be attractive to *E. eluta* is the cucurbit volatile 1,4-dimethoxybenzene (1,4-DMB, Tóth et al. 2014). In early 2015, love bug (*Plecia nearctica* Hardy; Diptera: Bibionidae) traps in turf fields in southern Florida baited with phenylacetaldehyde captured silk flies (R. Cherry unpublished). Phenylacetaldehyde is also a component of corn silk volatiles (Cantelo and Jacobson 1979). Few studies (Link et al. 1984, Cruz et al. 2011, and Souto et al. 2011) have investigated traps for silk flies and have used molasses, fresh corn, torula yeast, and a hydrolyzed corn protein preparation, Bio Anastrepha (Biocontrole Métodos de Controle de Pragas Ltda., Indaiatuba, Brazil) as bait. Semiochemical-baited traps could help to standardize a trapping system, provide consistent results, and be more selective for the target pest.

The purpose of this study was to evaluate the efficacy of both phenylacetaldehyde and 1,4-DMB for attractiveness in traps relative to fresh and aged torula yeast, a protein bait used for tephritid fruit fly monitoring. Additional floral volatiles evaluated included geraniol, an attractant for some Lepidoptera adults (Carlsson et al. 1999), and benzaldehyde, which is a corn-tassel produced volatile, as well as a protein-bait produced volatile (Buttery et al. 1980, Flath et al. 1989). The possible food-associated volatile, acetoin, was tested because it is a microbial metabolic product attractive to nitidulids and a component of Lepidoptera frass (Davis et al. 2013, Owens et al. unpublished data). Finally, anisole was evaluated due to its structural similarity to 1,4-DMB.

Materials and Methods

A preliminary test with floral volatiles and torula yeast was conducted in a fallow field with a low silk fly population to determine if traps were effective for silk flies. All lures were deployed in Universal Moth Traps (Great Lakes IPM Inc., Vestaburg, Michigan), consisting of a white bucket, yellow cone, and green rain shield. Floral volatiles and food-associated volatiles also were tested in 2 sweet corn fields (cultivar Obsession, Seminis Vegetable Seeds, St. Louis, Missouri) with larger silk fly populations. One mL of phenylacetaldehyde (Acros Organics, Bridgewater, New Jersey), geraniol (Acros Organics, Bridgewater, New Jersey), anisole (Acros Organics, Bridgewater, New Jersey), and benzaldehyde (Sigma Aldrich, St. Louis, Missouri) was pipetted onto individual sponges cut to fill 55 mL vials (IntraPac, Plattsburgh, New York) that were secured to the bottom of the traps. One gram of 1,4-DMB (Acros Organics, Bridgewater, New Jersey) and acetoin (TCI America, Portland Oregon) was dissolved in 1 to 2 mL acetone before application to the sponge. Traps also were baited with torula yeast pellets (Isca Technologies, Inc., Riverside, California) dissolved in water at a rate of 1 pellet per 300 mL. Fifty mL of fresh torula yeast solution (fresh yeast) or torula yeast that had aged in the laboratory at 28 °C for 2 weeks before use (aged yeast) were pipetted into larger 185 mL vials so as to not spill any in the trap. Vials were covered with a screen mesh cloth to prevent fly entry. An unbaited trap served as a control. An insecticide strip (Hercon® Vapor Tape II™, Road Co., Emigsville, Pennsylvania) was placed in each trap to kill silk flies. Traps were hung 1 m above the ground from white polyvinyl chloride (PVC) poles. Treatments were spaced 10 m apart and replicated 6 times with 15 m spacing between replicates in a randomized complete block design.

All experiments were conducted at the Everglades Research and Education Center, Belle Glade, Florida. Two 3 wk field tests were conducted in 2015. The first field trial, conducted in a weedy fallow field (weeds 0.75–1.0 m tall) was initiated on 17 Jul 2015. The second field trial (fall experiment) was initiated on 20 Oct 2015 in a sweet corn field that was planted on 16 Sep 2015. Row spacing in the field was 0.76 m. Plant population was 59,000 plants per hectare. Sweet corn was managed according to local standards (Ozores-Hampton et al. 2013). Traps for both summer and fall experiments were baited with phenylacetaldehyde, geraniol, 1,4-DMB, fresh yeast, and aged yeast, and silk flies were identified to species upon weekly removal from the traps.

The third field trial (spring experiment) was initiated on 15 Apr 2016 and lasted 4 wk in a sweet corn field planted on 18 Feb 2016. Traps were baited with acetoin, anisole, benzaldehyde, 1,4-DMB, and aged yeast. Row spacing was 0.76 m, and plant population was 74,000 plants per hectare. Silk flies were removed from traps and counted weekly. Vapor tape was replaced after the second week in the spring because capture rate in the fall experiment decreased between the second and third week. Traps in the second and third field trials were placed between corn rows.

Data were analyzed with analysis of variance (ANOVA) or Welch's ANOVA when variances were unequal among treatments in JMP® (SAS 2013). Means were compared using Tukey–Kramer HSD in JMP®.

Results

In the summer 2015 experiment (field trial 1), only 107 silk flies were captured over 3 wk. *Chaetopsis massyla* was the dominant species captured (74.8%). Of the remainder, 16.8% were *E. stigmatias* and 8.4% were *E. eluta*. Combined, females comprised 73.8% of the trap capture. Traps baited with 1,4-DMB captured more flies than untreated traps in weeks 1, 2, and total. Yeast baited traps captured an intermediate number of flies overall, and geraniol captured the fewest number of flies in weeks 1, 2, and total capture (Table 1). Aged yeast did not perform significantly better than fresh yeast. There were no significant differences among treatments during week 3.

In the fall trial (field trial 2), 1,317 silk flies were captured in the traps over 3 wk. Females comprised from 84.4 % (week 3) to 92.0% (week 2) of the captured flies. In week 1, 435 silk flies were captured; 73.1% were *E. stigmatias*, 24.8% were *C. massyla*, and 2.9% were *E. eluta*. In week 2, 752 flies were captured; 80.9% were *E. stigmatias*, 14.1% were *C. massyla*, and 5.0% were *E. eluta*. In week 3, traps captured only 129 silk flies. Of these, 56.6% were *E. stigmatias*, 39.5% were *C. massyla*, and 4.1% were *E. eluta*. Traps baited with aged yeast captured the greatest number of flies on all sampling dates. 1,4-DMB–baited traps captured fewer flies than the aged yeast, but more than the other treatments during week 1. The remaining treatments did not catch significantly more flies than the control traps for any sampling dates (Table 2).

In the spring experiment (field trial 3), traps captured 4,225 silk flies in 27 d. Overall, 61.1% of the captured silk flies were *E. eluta*, 30.8% were *E. stigmatias*, and 8.0% were *C. massyla*. The species composition in the traps was similar to the overall species composition of the field as determined by repeated visual observation over

Table 1. Mean ± SEM number of silk flies captured per trap and summed captures by species (*Euxesta eluta* – *Euxesta stigmatias* – *Chaetopsis massyla*) per treatment per week (7 d) in the summer experiment.

Lure	Week 1	Week 2	Week 3	Flies/trap/day
Control	0.8 ± 0.5ab (0-0-5)	0.4 ± 0.2ab (0-1-1)	0.2 ± 0.2 (1-0-0)	0.07 ± 0.03b
Phenylacetaldehyde	0.3 ± 0.3ab (0-0-2)	0.5 ± 0.1ab (0-0-3)	0.8 ± 0.5 (0-0-4)	0.07 ± 0.05b
Geraniol	0.0b	0.2 ± 0.2b (0-0-1)	0.2± 0.2 (0-0-1)	0.02 ± 0.01b
1,4-Dimethoxybenzene	3.5 ± 1.5a (2-12-7)	1.8 ± 0.5a (0-1-10)	1.2 ± 0.4 (0-1-6)	0.31 ± 0.10a
Fresh Yeast	2.5 ± 0.6ab (5-1-9)	0.6 ± 0.4ab (0-0-4)	0.5 ± 0.3 (0-0-3)	0.18 ± 0.04ab
Aged Yeast	2.7 ± 1.3ab (1-2-13)	0.7 ± 0.2ab (0-0-11)	0.7 ± 0.2 (0-0-4)	0.22 ± 0.06ab
ANOVA	F = 2.68, df = 5, 30.0, P = 0.04	F = 3.24, df = 5, 29.0, P = 0.020	F = 1.60, df = 5, 29.0, P = 0.193	F = 6.03, df = 5, 12.7, P = 0.004

Means within a column for a time period followed by the same letter are not significantly different (Tukey–Kramer HSD).

the course of the experiments. In summary, over 9 sample dates, 3,866 flies were observed and were 64.9% *E. eluta*, 29.0% *E. stigmatias*, and 2.8% *C. massyla*. During the course of the spring trial, 92.5% of the captured silk flies were female, and this was consistent among all the treatments. Six sweep net samples taken in the afternoon of 26 Apr netted 146 silk flies, 90 of which were male (61.6%). While sampling occurred only once, and it is possible that females were present lower in the canopy at the time of sampling, it gives some indication that the sex ratio in the field was not as female-biased as the trap captures indicated. Traps baited with aged yeast captured significantly more silk flies than any of the chemicals during weeks 2, 3, and 4 (Table 3). Captures increased dramatically as the yeast bait further decomposed in the field. Captures in the 1,4-DMB–baited traps generally increased over time, with the exception of a suppressed capture in week 3. Acetoin- and anisole-baited traps captured 35 and 18 silk flies, respectively, over the course of the study (Table 3). Of note, *C. massyla* comprised 48.5% and 55.6% of the trap capture from these 2 treatments, respectively, indicating that these 2 volatiles may be more important to this species than for the *Euxesta* spp. Traps baited with benzaldehyde captured 17 silk flies over the course of the study, 76.5% were *E. eluta* and 23.5% were *C. massyla*. Only 3 flies were captured in the control traps.

Overall, few beneficial insects were captured in the traps, with the exception of 1,4-DMB baited traps. After the first week of the fall trial, these traps captured numerous green orchid bees, *Euglossa dilemma* Brembé and Eltz (Hymenoptera: Apidae) (numbers were not quantified during week 1). In weeks 2 and 3, 27 and 15 green orchid bees were captured in the 6 traps. In the spring trial, only 2 green orchid bees were captured.

Discussion

Development of an effective monitoring trap for silk flies could aid growers and crop consultants with identification of the silk fly species composition in sweet corn fields. This in turn would help growers select the most efficacious insecticides appropriate to the species complex in an individual field. In this study, aged torula yeast, followed by 1,4-DMB, performed the best for capturing silk flies in Florida corn fields and both warrant further study.

Traps baited with aged torula yeast captured more silk flies than fresh preparations in the fall trial. Traditionally, torula yeast has been an effective liquid protein bait for monitoring *Anastrepha* spp. (Diptera: Tephritidae) pests in fruit orchards. Malo (1992) observed similar results with *Anastrepha* spp. capture in torula yeast–baited McPhail traps as the bait aged in the field. Upon further analysis of protein baits, Bateman & Morton (1981) discovered that ammonia (NH_3) was the primary attractant produced by protein baits for tephritids. Ammonia is further synergized by volatile amines, including butane-1,4-diamine (putrescine, Heath et al. 2004, Kendra et al. 2008), 1,5-diaminopentane (cadaverine, Kendra et al. 2008) and trimethylamine (Heath et al. 1997, Midgarden et al. 2004). Depending on environmental conditions, ammonia/putrescine lures can be more attractive to female tephritids than liquid protein baits, and ammonia/putrescine is more attractive to females than males (Heath et al. 1997, Kendra et al. 2009). Furthermore, protein cues are more attractive to female *Ceratitis capitata* Wiedemann (Diptera: Tephritidae) than trimedlure, and protein traps capture fewer released sterile males, making them more efficient for monitoring sterile male release success (Midgarden et al. 2004). Female tephritids require greater food resources, especially protein, for ovary development because they are anautogenous, or immature upon adult eclosion from the pupa. They are thus captured with greater frequency in traps baited with protein indicators. Since female ulidiids are also anautogenous at eclosion, it is likely that traps baited with protein cues also will be effective for silk fly monitoring in Florida. Sexually immature female tephritid antennae are also more sensitive physiologically to ammonia volatiles than antennae of mature females, and maturity state influences behavioral response to ammonia (Kendra et al. 2005a, Kendra et al. 2005b). During all 3 experiments, our traps captured mostly females although sweep samples in the spring trial captured more males, indicating that the universal moth traps were female-biased. This is beneficial because insecticidal management is ultimately aimed at adult females before they can oviposit in corn ears. Protein baits (e.g. torula yeast and Bio Aanastrepha) favoring female silk flies have previously been recorded for *E. eluta* and *E. mazorca* (Cruz et al. 2011). In those experiments, Bio Anastrepha also resulted in greater fly capture than torula yeast for several sampling periods. Some possible reasons for female bias could be that males are less responsive to the traps, lures, or release rates. In this study, release rate was not examined for the traps, but volatile release rates are extremely important. If an attractant is present at too high of a concentration, it can result in a negative behavioral response (Kendra et al. 2005b).

Table 2. Mean ± SEM number of silk flies captured per trap and summed captures by species (*Euxesta eluta* – *Euxesta stigmatias* – *Chaetopsis massyla*) per treatment per week (7 d) in the fall sweet corn experiment.

Lure	Week 1	Week 2	Week 3	Flies/trap/day	% *E. eluta*	% *E. stigmatias*	% *C. massyla*
Control	0.7 ± 0.3c (0-1-3)	1.0 ± 0.4b (0-5-1)	0.0b	0.08 ± 0.03b	0.0b	52.8 ± 18.5	30.6 ± 16.3
Phenylacetaldehyde	0.8 ± 0.5c (0-3-2)	1.8 ± 0.6b (0-11-0)	1.2 ± 0.4b (0-4-3)	0.18 ± 0.06b	0.0b	66.0 ± 14.2	17.4 ± 15.5
Geraniol	0.7 ± 0.3c (0-1-3)	0.8 ± 0.4b (0-2-2)	0.5 ± 0.3b (0-0-3)	0.10 ± 0.03b	0.0b	25.0 ± 17.1	58.3 ± 20.1
1,4-Dimethoxybenzene	22.7 ± 6.3b (0-124-12)	28.0 ± 15.1b (7-155-6)	1.0 ± 0.6b (0-5-2)	2.46 ± 1.00b	2.5 ± 1.0ab	84.5 ± 7.0	13.9 ± 7.3
Fresh Yeast	2.8 ± 1.3c (0-6-11)	4.8 ± 1.1b (0-23-6)	0.8 ± 0.4b (0-2-3)	0.40 ± 0.10b	0.0b	53.9 ± 12.7	46.1 ± 12.7
Aged Yeast	44.8 ± 8.3a (6-183-77)	88.8 ± 19.2a (28-412-91)	18.0 ± 5.5a (4-61-41)	7.22 ± 1.42a	3.2 ± 1.1a	67.5 ± 6.6	29.3 ± 7.3
ANOVA	$F = 7.2$, df = 5, 13.4, $P = 0.002$	$F = 6.27$, df = 5, 13.4, $P = 0.003$	$F = 8.42$, df = 5, 11.7, $P = 0.001$	$F = 7.01$, df = 5, 13.3, $P = 0.002$	$F = 4.84$, df = 5, 30.0, $P = 0.002$	$F = 2.20$, df = 5, 30.0, $P = 0.081$	$F = 1.62$, df = 5, 13.7, $P = 0.220$

Means within a column for a time period followed by the same letter are not significantly different (Tukey–Kramer HSD).

Table 3. Mean ± SEM number of silk flies captured per trap and summed captures by species (*Euxesta eluta* – *Euxesta stigmatias* – *Chaetopsis massyla*) per treatment per week in the spring sweet corn experiment.

Lure	Week 1 (6 d)	Week 2 (9 d)	Week 3 (8 d)	Week4 (4 d)	Flies/trap/day	% *E. eluta*	% *E. stigmatias*	% *C. massyla*
Control	0.0	0.2 ± 0.2b (1-0-0)	0.2 ± 0.2b (1-0-0)	0.2 ± 0.2b (0-1-0)	0.02 ± 0.01b	33.3 ± 21.1ab	16.7 ± 16.7	0.0b
Acetoin	0.2 ± 0.2 (1-0-0)	0.8 ± 0.4b (3-2-0)	2.8 ± 2.4b (10-0-7)	2.0 ± 1.0b (2-0-10)	0.22 ± 0.11b	33.4 ± 11.7ab	16.7 ± 16.7	50.0 ± 13.9a
Anisole	0.0	0.0 b	1.3 ± 1.1b (3-4-1)	1.7 ± 0.7b (0-1-9)	0.11 ± 0.03b	7.1 ± 7.1b	32.1 ± 16.5	60.7 ± 18.8a
Benzaldehyde	0.0	2.0 ± 1.8b (11-0-1)	0.3 ± 0.3b (1-0-1)	0.5 ± 0.3b (1-0-2)	0.10 ± 0.06b	52.7 ± 20.2a	0.0	14.0 ± 12.3b
1,4-Dimethoxybenzene	1.2 ± 1.0 (3-4-0)	7.7 ± 3.9b (37-9-0)	34.3 ± 10.7b (120-83-3)	4.7 ± 1.9b (13-13-1)	1.77 ± 0.47b	52.9 ± 11.1a	27.8 ± 7.4	2.4 ± 1.6b
Aged Yeast	3.2 ± 2.6 (2-17-0)	163.2 ± 56.1a (553-383-42)	136.0 ± 27.3a 534-211-70)	341.8 ± 72.6a (1283-575-189)	23.86 ± 5.00a	61.1 ± 5.5a	30.6 ± 5.2	8.2 ± 0.6b
ANOVA	$F = 1.26$, df = 5, 30.0, $P = 0.308$	$F = 8.22$, df = 5, 30.0, $P < 0.001$	$F = 6.14$, df = 5, 12.5, $P = 0.004$	$F = 5.81$, df = 5, 12.7, $P = 0.005$	$F = 7.78$; df = 5, 12.0; $P = 0.002$	$F = 6.31$, df = 5, 13.6, $P = 0.003$	$F = 0.98$, df = 5, 30.0, $P = 0.447$	$F = 5.84$, df = 5, 30.0, $P = 0.001$

Means within a column for a time period followed by the same letter are not significantly different (Tukey–Kramer HSD).

Phenylacetaldehyde is a component of corn silk volatile profiles and is attractive to numerous pest Lepidoptera (Cantelo & Jacobson 1979). Phenylacetaldehyde-baited traps have previously captured silk flies (R. Cherry unpublished), but in this study, capture was not significantly greater than the controls. Geraniol is an attractant for larval *Spodoptera littoralis* Boisduval (Lepidoptera: Noctuidae; Carlsson et al. 1999), but does not seem to be attractive to silk flies. Benzaldehyde-baited trap capture was not greater than unbaited traps in this experiment. Interestingly, of the flies captured in these traps, none were *E. stigmatias,* although this was the dominant species present in the field.

The chemical 1,4-dimethoxybenzene (1,4-DMB) is a cucurbit floral volatile that captured large numbers of *E. eluta* in Brazil as part of an experiment targeting *Diabrotica* spp. (Coleoptera: Chrysomelidae, Tóth et al. 2014). A similar chemical, 1,2-dimethoxybenzene, is produced by sweet corn husks (Buttery et al. 1978), and may play a role in host location. Anisole, or methoxybenzene, although structurally related to 1,4-dimethoxybenzne, did not result in increased capture compared with unbaited control traps. The proportion of *C. massyla* captured in the acetoin- and anisole-baited traps was greater than that in traps baited with torula yeast or 1,4-DMB in the spring trial (Table 3). Microbial decay may be partially responsible for Allen & Foote's (1992) observation that *C. massyla* is attracted to noctuid-damaged grasses. It is possible that acetoin plays a role in conjunction with other chemicals for *C. massyla* resource recognition.

Appropriate trap design is extremely important to optimize a monitoring technique. Silk flies have been captured using transparent side-funnel entrance traps baited with corn kernels (Link et al. 1984), plastic water bottles with holes in the side and baited with molasses (Souto et al. 2011), McPhail traps with a bottom funnel and baited with torula yeast and Bio Anastrepha (Cruz et al. 2011), and hat traps consisting of a yellow board placed inside and extending out of a bottom funnel that were baited with 1,4-DMB (Tóth et al. 2014). Plastic water bottles are inexpensive and, depending on the bait, can be more effective for intercepting *Anastrepha ludens* Loew than McPhail traps (Lasa et al. 2015). Universal moth traps, which consist of a top funnel entrance, were selected for this study because they were efficient in preliminary experiments and crop consultants are interested in using these traps for silk flies concurrently with pheromone lures for monitoring pest Lepidoptera in sweet corn. For this reason, torula yeast was placed inside a smaller container to keep the bottom of the trap dry. Pheromone traps are often hung from metal rebar driven into the soil, while our traps were suspended from white PVC poles. The PVC could present the flies with visual stimuli and a greater surface area to rest on which may increase capture rates.

Universal moth traps are effective at capturing silk flies when baited with protein baits or protein cues. Aged torula yeast should be further investigated to identify new attractant kairomones that could be incorporated into a trapping system. Limited research is available on the subject, and much can be gleaned from research conducted on the distantly related tephritid fruit flies. For example, protein bait evaluation, protein cues in dry traps (ammonium acetate + putrescine or trimethylamine), and other protein sources that may be important to flies in the field should be evaluated. Trapping efficiency and, ultimately, the relationship between trap capture and silk fly population should also be examined. More research comparing trap suspension, trap design, and ideal volatile release rates is warranted to improve silk fly monitoring efforts. Research into these areas can aid in the development of additional management tactics, as well as improving scouting practices and chemical control efforts to protect sweet corn from silk fly damage.

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