SYSTEMS TO MONITOR AND SUPPRESS *CERATITIS CAPITATA* (DIPTERA: TEPHRITIDAE) POPULATIONS

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ABSTRACT

A synthetic food-based attractant, and a painted cylindrical dry trap that protects the synthetic lures from the environment, were developed to replace liquid protein-baited traps. This trapping system was tested for capture of the Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann). The dry trap is constructed of acetate film with a painted band that provides a visual cue; it contains internally-placed toxicant panels to kill flies that enter the trap. Field trials conducted in Guatemala suggested that a solid-colored material could be substituted for the painted trap body. We also evaluated a sticky insert made from commercially produced adhesive paper as a replacement for the toxicant panels. Unlike paintable sticky adhesives, the sticky material on the adhesive paper insert does not adhere to the skin of personnel who service the traps. An open-bottom trap made of green opaque plastic with a sticky insert captured more *C. capitata* than the closed-bottom painted trap with a toxicant panel. When used in conjunction with sterile insect release technology, the open-bottom dry trap baited with food-based synthetic attractant often caught wild *C. capitata* in numbers equal to those caught by trimedlure-baited Jackson traps, but the dry trap caught many fewer sterile *C. capitata*.

Key Words: *Ceratitis capitata*, trapping, food-based attractant, dry trap.

RESUMEN

Para sustituir trampas cebadas con proteina líquida fueron desarrollados un fagoatrayente y una trampa seca cilíndrica pintada que protege los cebos sintéticos del ambiente. Este sistema de trampa fue probado para la captura de la mosca mediterránea de las frutas, *Ceratitis capitata* (Wiedemann). La trampa seca está construida con una película de acetato con una banda pintada que provee una señal visual y contiene paneles internos tóxicos para matar a las moscas que entren. Las pruebas de campo conducidas en Guatemala sugieren que un material sólidamente coloreado podría ser substituido por el cuerpo pintado de la trampa. También evaluamos un dispositivo adhesivo hecho de papel engomado comercial para sustituir los paneles tóxicos. A diferencia de los adhesivos que pueden pintarse, el material adhesivo en el dispositivo de papel no se adhiere a la piel del personal que debe trabajar con las trampas. Una trampa de fondo abierto hecha de plástico opaco verde con un dispositivo adhesivo capturó más *C. capitata* que una trampa pintada de fondo cerrado con un panel tóxico. Cuando es usada con la tecnología de sueltas de insectos estériles, la trampa seca de fondo abierto cebada con fagoatrayente sintético a menudo capturó *C. capitata* salvaje en número igual al capturado por las trampas de Jackson cebadas con trimedlure, pero la trampa seca capturó mucho menos *C. capitata* estériles.

A number of traps have been developed for detecting or monitoring populations of adult pest tephritids (reviewed in Cunningham 1989, Economopoulos 1989). Some of the earliest traps were baited with carbohydrates and fermenting fruit or sugar solutions. Subsequently traps have used hydrolyzed proteins as bait. All of these substances emit food-based chemical cues. Synthetic chemicals and food-related chemicals are the primary basis for the baits in traps used currently to monitor populations of the Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann). These traps include trimedlure-baited Jackson traps (Beroza et al. 1961, Harris et al. 1971) for male *C. capitata* (Nakagawa et al. 1970) and McPhail traps with aqueous protein bait solutions (Newell 1936) which capture both female and male *C. capitata*. Traps baited with aqueous protein solutions have been the primary tool for capturing female *C. capitata*. These traps are cumbersome and have numerous other operational disadvantages as follows. Bait solution may be spilled easily while handling the trap and spilled bait provides an attractant source outside the trap. Removal of insects trapped is time consuming and tedious. The contents of the trap must be filtered through a screen to separate the insects from the bait solution. Trapped fruit flies are often found severely decomposed with parts missing and thus, when these traps are used in conjunction with marked flies dispersed in sterile insect release programs, it is often difficult to determine if a trapped fly is sterile or wild. Additionally deployment of McPhail traps is difficult because of the size and weight of the trap. Also protein baits attract a number of non-target insects and considerable time is required to sort the trapped insects. Due to these difficulties associated with the use of liquid protein baits, we investigated the development of a synthetic food-based lure (ammonium acetate and putrescine) that could be used in a dry insect trap that would capture both female and male *C. capitata* (Heath et al. 1995, Epsky et al. 1995).

We report herein a brief description of the original dry trap with food-based synthetic attractant and of subsequent improvements.

Materials and Methods

Cylindrical Dry Trap with Painted 7.5 cm Band

The original trap is fully described in Heath et al. (1995). Briefly, it consists of a clear plastic cylinder (9 cm diam by 15 cm long) made from acetate film with a painted band (7.5 cm wide) in the middle of the trap which provides a visual cue for the fruit fly (Fig. 1A). The ends of the traps are plastic Petri dishes glued shut that fit snugly into the cylindrical trap body. A wire hanger that pierces both bottom and top allows the trap to be hung in the crop canopy. The trap body has three equally-spaced holes (2.2 cm diam) around the circumference of the cylinder midway between the ends to allow release of volatile chemicals and access for the responding flies. Flies enter the trap in response to the attractant and are killed after feeding on toxicant-bait panels that are placed on the inside surface of the top and bottom of the trap. Captured flies are removed from the trap by lifting the cylinder from the bottom and dumping the flies into a small container for transport to the laboratory.

Comparison of Cylindrical Dry Trap and Standard McPhail Trap

Field trials were conducted in an orange and coffee finca (farm) located near Guatemala City, Guatemala. Traps were placed in orange trees for all tests, with placement within a tree following standard protocol (Anonymous 1989). Traps tested were dry traps with green painted bands, dry traps with orange painted bands, and

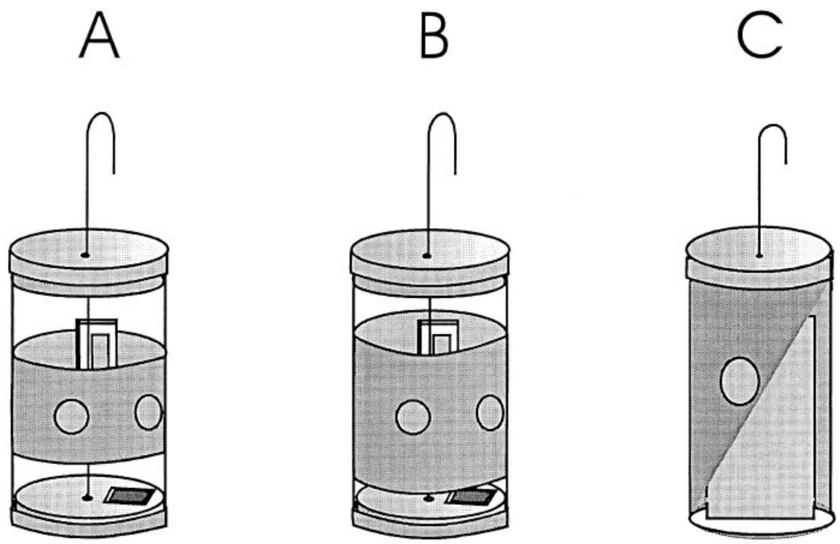

Figure 1. Illustration of the three types of cylindrical dry traps (9 cm diam by 15 cm long) that were used in field studies conducted in Guatemala to test a food-based synthetic attractant for *C. capitata*. A) Trap body constructed from clear acetate film with a painted band (7.5 cm). The closed-bottom trap had toxicant panels placed on the top and bottom to retain responding flies. B) Trap body constructed from clear acetate film with a painted band (12 cm). The closed-bottom trap had toxicant panels placed on the top and bottom to retain responding flies. C) Trap body constructed of green opaque plastic. The open-bottom trap had a sticky paper insert to retain responding flies. Synthetic attractant, which was formulated in membrane-based lures, can be seen in the painted, closed-bottom traps.

McPhail traps baited with five torula yeast-borax pellets. Separate comparisons were conducted with the dry traps baited with low, medium and high dosages of the synthetic lures (Heath et al. 1995). To obtain the different doses, the release rate from the ammonium acetate lure (Concep, Bend, OR) was adjusted by reducing the exposed area of the release membrane. The area of exposed surface of the membrane tested was 1.0 cm^2 (low dose), 1.4 cm^2 (medium dose), and a full patch having a membrane surface of 4.0 cm in diam (high dose). Putrescine was formulated using polypropylene vials (1 cm internal diam by 2.2 cm) and was tested at 50, 100, or 200 µl (low, medium and high doses, respectively). The vials were closed and hung in the trap in an upright position so that the putrescine was allowed to pool in the bottom of the vial. Flies were removed from traps every 2-3 d, and numbers of male and female *C. capitata* recorded. The experiment was replicated over time and there were 18 consecutive replicates for each dose. The mating status of *C. capitata* females from the different traps was determined by dissecting a subsample of the trapped females and checking for presence or absence of sperm in the spermathecae.

Dry Trap Visual Cue Modifications

Field trials were conducted in an orange and coffee finca located near Guatemala City, Guatemala, to determine optimal width of the visual cue band on the dry trap for capture of *C. capitata*. All traps were baited with ammonium acetate lure at the medium dose. The putrescine was formulated in a manner similar to the lures used for Japanese beetle monitoring (Consep, Bend, OR) with a 3 mm diam area of exposed membrane surface. In all trials, traps were placed in orange trees that were bearing fruit. Treatments tested were traps with visual cue widths of 3, 7.5, 12 or 15 cm. Separate tests were conducted for traps with green bands and with orange bands. All four treatments were placed around the periphery of a tree with approximately one to two meters between adjacent traps. Initially, treatments were placed randomly within a given tree, followed by sequential displacement of each trap to the next position around the tree when the traps were sampled every 2-3 d. On each sample date, flies were removed from traps, and numbers of male and female *C. capitata* were recorded. Sets of traps were placed in three trees spaced approximately 20-30 m apart, and the total number of flies trapped per treatment was the sum of each sex collected that day. The experiment was replicated over time, and there were 14 consecutive replicates of tests of traps with each color. Sum totals were converted to percentage trapped per trap type for analysis to facilitate comparisons among the range of fruit fly population densities sampled.

Development of Open-Bottom Dry Trap with Sticky Insert

All tests were conducted with dry traps baited with the medium dosage of ammonium acetate and putrescine. Trap bodies were either acetate cylinders 15 cm tall painted with 12 cm green visual cues (designated "painted") or green opaque cylinders 15 cm tall (designated "opaque"). Moreover, the cylinders were either closed at both ends with toxicant panels on the inside of the top and bottom (designated "closed-bottom"), or they lacked a bottom and had a sticky insert (8 by 13 cm rectangle with adhesive on both front and back) hung from the top (designated "open-bottom"). Traps were tested in a citrus orchard near Guatemala City, Guatemala. There were four lines of traps with all four trap types placed randomly within each line, one per tree, according to standard protocol. Traps were checked every 3-7 days depending on population levels, and the numbers of *C. capitata* females and males were recorded. Data were converted to percentage per trap type per sample date for statistical analysis. The experiment was replicated over time and there were 6 consecutive replicates of the test.

Open-Bottom Dry Trap - Jackson Trap Comparison for Wild and Sterile Fly Capture

Green opaque cylindrical traps with sticky inserts were field-tested in Guatemala to compare performance of the dry trap with that of the trimedlure-baited Jackson trap. One of the tests was conducted in a coffee finca with a population of wild flies. This site was at a high elevation (about 1300 m) and was located near Coatepeque, Guatemala. Five lines of traps were placed at the site, with 50 m between each line. Jackson traps with standard white inserts and open-bottom dry traps were placed in each line along with other trap configurations. Traps were placed alternately 30 m apart along a line. Ten traps of each type were placed following standard protocol. Approximately 20,000 sterile flies were released weekly distributed evenly over the trapping area. Traps were checked weekly, and numbers of *C. capitata* females and males were recorded. All flies captured were sent to the Moscamed laboratory in Coatepeque to be examined to determine if they were sterile or wild, following standard protocol. Tests were conducted for 8 consecutive weeks.

Statistical Analysis

Data were analyzed with two sample *t*-tests using Proc TTEST or factorial analysis of variance (ANOVA) using Proc GLM (SAS Institute 1985), depending on the number of test factors in the study. Data were assessed by the Box-Cox procedure (Box et al. 1978) and were transformed appropriately when necessary to stabilize the variance prior to ANOVA. Chi-square analysis using Proc FREQ (SAS Institute 1985) of contingency tables of mating status by trap type within each dosage were made to compare mating status of females trapped in the dry trap-McPhail trap comparisons.

Results

Dry Trap and McPhail Trap Comparison

The dry traps baited with either the medium or the high dosage of synthetic attractant caught numbers of Mediterranean fruit flies equal to those captured in McPhail traps (Table 1). Although McPhail traps caught more female Mediterranean fruit flies than dry traps baited with the low dosage of synthetic blend, more unmated females were captured in the dry traps (Table 2). Increase in dosage of the synthetic lure increased the percentage of mated females captured in the dry traps. A green dry trap baited with a medium dose of synthetic attractant was selected for further evaluation because it was equal to a protein-baited McPhail trap in capture of females and approximately 50% of the females captured were unmated.

Table 1. Comparison of the average number (SEM) of *Ceratitis capitata* captured in cylindrical dry traps with painted 7.5 cm bands and baited with food-based synthetic attractants at three doses, and standard McPhail traps baited with five torula yeast pellets in aqueous solution. Field trials were conducted in Palin, Guatemala ($N = 18$).[1]

	Orange	Green	McPhail	*F*	*P*
Low Dose					
C. capitata females	13.2 (2.08)	23.6 (3.95)	35.4 (5.46)	8.0	0.0009
C. capitata males	4.8 (0.71)	9.8 (1.44)	14.2 (2.37)	13.0	0.0001
Medium Dose					
C. capitata females	10.6 (1.19)	10.9 (2.11)	18.6 (3.89)	1.5	ns
C. capitata males	3.8 (0.62)	3.4 (0.59)	6.6 (1.65)	0.6	ns
High Dose					
C. capitata females	12.6 (2.07)	16.9 (4.44)	17.2 (3.15)	0.6	ns
C. capitata males	4.3 (1.18)	6.2 (2.19)	5.4 (1.32)	0.1	ns

[1]Oneway analysis of variance on log [x + 1.0] transformed data, non-transformed means present; ns = not significant, $P > 0.05$.

TABLE 2. THE MATING STATUS OF FEMALE *CERATITIS CAPITATA* CAPTURED IN CYLINDRICAL DRY TRAPS WITH PAINTED 7.5 CM BANDS AND BAITED WITH FOOD-BASED SYNTHETIC ATTRACTANTS AT THREE DOSES, AND STANDARD MCPHAIL TRAPS BAITED WITH FIVE TORULA YEAST-BORAX PELLETS IN AQUEOUS SOLUTION. FIELD TRIALS WERE CONDUCTED IN PALIN, GUATEMALA, AND MATING STATUS DETERMINED FROM SUBSAMPLE DISSECTIONS (N = 50).[1]

Dosage of Synthetic Blend	Unmated Females Trapped (%)				
	Orange	Green	McPhail	Chisquare	*P*
Low	54.8b	69.0b	22.0a	21.00	0.0001
Medium	45.4b	51.7b	25.0a	7.25	0.027
High	12.6ab	4.0a	21.0b	6.59	0.037

[1]Chisquare analysis based on 2 by 3 contingency table within each dosage. Means within a row followed by the same letter are not significantly different (2 by 2 contingency tables of two-at-a-time comparisons within a dose, P = 0.05).

Dry Trap Visual Cue Modifications

Average (std. dev.) captures of *C. capitata* females and males were 104.9 (69.2) and 49.0 (59.5) respectively. Width of the visual cue affected percentage capture of *C. capitata* females but not of *C. capitata* males (Table 3). More *C. capitata* females were captured in traps with green visual cues that were 12-15 cm wide than in traps with 3-7.5 cm wide cues. We used a green dry trap with a 12-cm wide visual cue and baited with the medium dose of synthetic attractant for subsequent tests (Fig. 1B).

Development of Open-Bottom Dry Trap with Sticky Insert

The results of the comparisons among all four trap body/insect retention system configurations are shown in Fig. 2. Capture of females was significantly higher in the green opaque open-bottom trap than in the other traps tested (F = 16.09; df = 3, 20; P = 0.0001). The green opaque open-bottom trap captured an average of 3.4 times as many females as the painted traps. Capture of males was also affected by trap type (F = 5.16; df = 3,20; P = 0.0084). The female:male ratio in the open-bottom dry trap was about 6:1 and 82% of the *C. capitata* captured were females. We used a green opaque

TABLE 3. AVERAGE PERCENTAGE (SEM) OF *CERATITIS CAPITATA* CAPTURED IN CHOICE TESTS OF CYLINDRICAL DRY TRAPS WITH INCREASING SIZE OF THE PAINTED GREEN VISUAL CUE ON TRAP BODY AND BAITED WITH A MEDIUM DOSE OF FOOD-BASED SYNTHETIC ATTRACTANT (N = 14).[1]

	3 cm	7.5 cm	12 cm	15 cm	*F*	*P*
Females	18.4 (2.16)	18.5 (1.91)	31.5 (2.46)	31.7 (2.55)	10.36	0.0001
Males	20.8 (4.04)	24.6 (4.29)	32.4 (3.18)	22.2 (3.07)	1.90	ns

[1]Oneway analysis of variance on square root [x + 0.5] transformed data, non-transformed means presented; ns = not significant, P > 0.05.

open-bottom dry trap baited with the medium dose of synthetic attractant for subsequent tests (Fig. 1C).

Open-Bottom Dry Trap - Jackson Trap Comparison for Wild and Sterile Fly Capture

Numbers of wild and sterile *C. capitata* captured over time are shown in Fig. 3. Capture with the open-bottom dry trap was greater than with the Jackson trap for

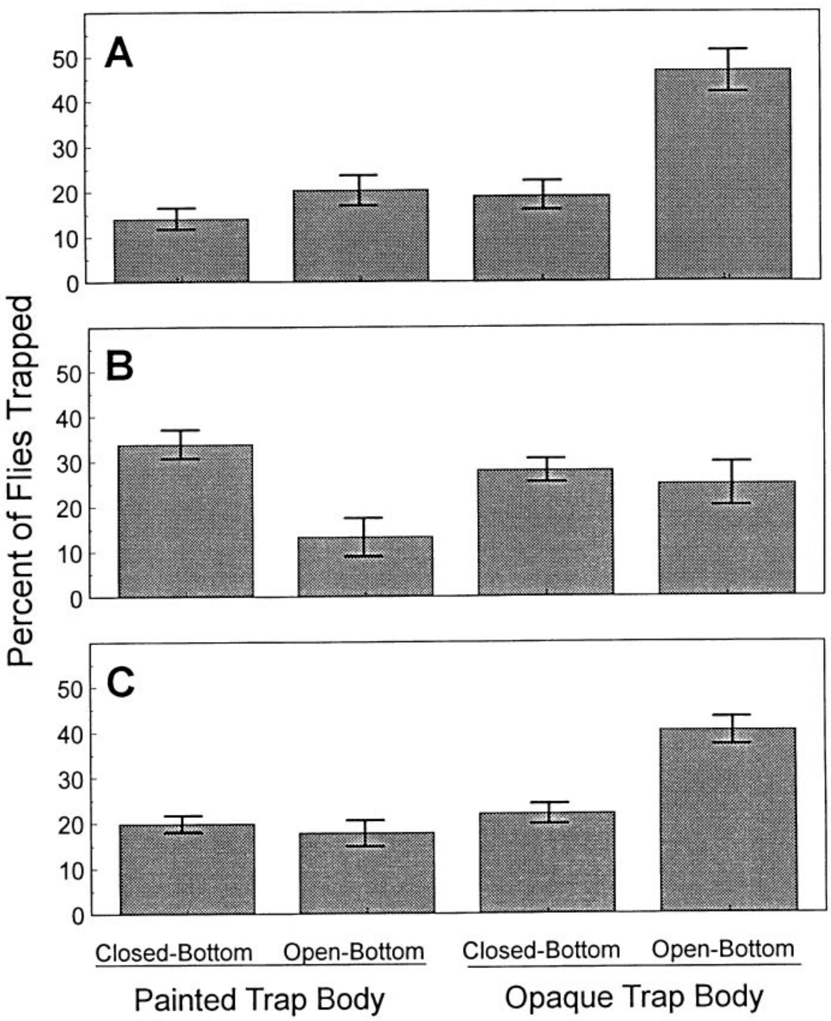

Figure 2. Percentage and standard error of *C. capitata* females (A), males (B) and total females plus males, C) captured in four configurations of cylindrical dry traps baited with food-based synthetic attractants in field trials conducted in Palin, Guatemala.

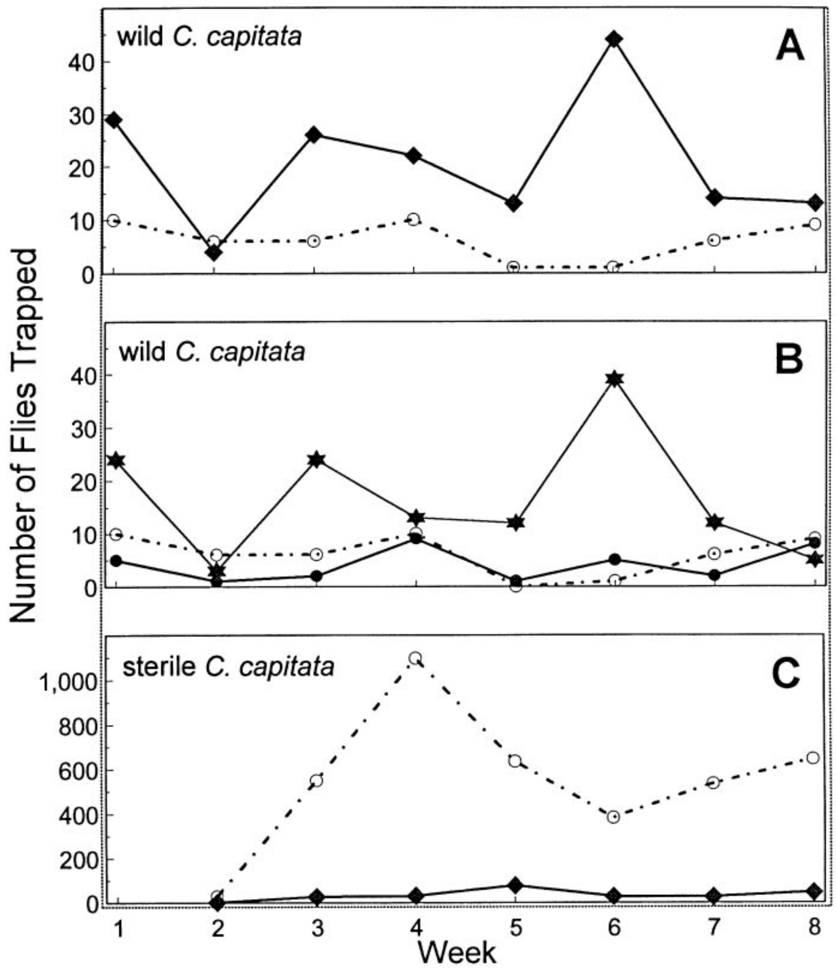

Figure 3. Capture of (A) wild male *C. capitata* in Jackson traps (open circle, dashed line), wild male plus female *C. capitata* in open-bottom dry traps (solid diamond, solid line), (B) wild male *C. capitata* in Jackson traps (open circle, dashed line), wild male (solid circle, solid line), and female (star, solid line) *C. capitata* in open-bottom dry traps, and (C) sterile males in Jackson traps (open circle, dashed line) and sterile males plus females (solid diamond, solid line) in open-bottom dry traps in field trials conducted in Guatemala.

seven of the eight weeks and was approximately equal in the remaining week. The female to male ratio in the open-bottom dry trap was 4:1. There were 3,875 sterile males captured in the Jackson traps compared to 235 sterile males captured in the open-bottom dry trap. Thus, approximately 16.5 times more sterile males were captured in the Jackson trap than in the open-bottom dry trap. The open-bottom dry trap captured 415 sterile females.

DISCUSSION

The development of the open-bottom dry trap offers several advantages in addition to the increase in capture of *C. capitata*. The panel is easy to insert and to remove from the trap, and no pesticide is needed. Field personnel in Guatemala reported that they like this trap because it is similar to the insert system currently used in Jackson traps containing trimedlure, it is very "user friendly", and it is even more durable than the closed-bottom, painted dry trap. It also appears to be more sensitive to low density populations of *C. capitata* and could provide an improved detection tool for areas in which *C. capitata* populations are not established.

Continued research in the development of facile trapping systems will afford several new opportunities in efforts to control and eradicate the Mediterranean fruit fly. It is envisioned that additional attractants will be identified and further optimization of visual cues and trap design will occur. Use of the trapping systems described will enable better utilization of resources related to sterile insect release technology, including but not limited to decreased efforts and greater accuracy in sterile/wild insect identification and minimized capture of sterile males after release. Related research indicates that the synthetic lure could be used in traps for capture of several of the *Anastrepha* spp. that also are economically important pests of fruit.

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