Towards Development of A mass Trapping Device for Mexican Fruit Fly Anastrepha ludens (Diptera: Tephritidae) Control

Authors: Lasa, Rodrigo, Ortega, Rafael, and Rull, Juan

Source: Florida Entomologist, 96(3) : 1135-1142

Published By: Florida Entomological Society

URL: https://doi.org/10.1653/024.096.0354

TOWARDS DEVELOPMENT OF A MASS TRAPPING DEVICE FOR MEXICAN FRUIT FLY *ANASTREPHA LUDENS* (DIPTERA: TEPHRITIDAE) CONTROL

Rodrigo Lasa*, Rafael Ortega and Juan Rull
Red de Manejo Biorracional de Plagas y Vectores, Instituto de Ecología, A.C., 91070 Xalapa, Veracruz, México

*Corresponding author; E-mail: rodrigo.lasa@inecol.edu.mx

Abstract

The use of simple and economic traps with long lasting lure dispensers is key for implementation of mass trapping strategies against pestiferous fruit flies. Simplicity, cost, ease of assembly, storage and transportation were considered during evaluation of a folding conical trap for mass trapping the Mexican fruit fly, *Anastrepha ludens*. The application of deltamethrin to the lid of the trap resulted in a cost-effective treatment, which helped retain flies in dry traps for at least 10 wk. However, the conical trap design and the diam, type and disposition of entry-holes, negatively affected performance of the trap under laboratory conditions. High numbers of flies could escape the trap over a short period of time after their release into its interior, although most of them died after escaping because of the delayed effect of exposure to deltamethrin. Under field conditions, no significant differences were observed between orange and yellow traps in capturing either *A. ludens* or lacewings. In contrast, the folding conical trap model was significantly more efficient in capturing Mexican fruit flies when baited with CeraTrap® lure than when baited either with the conventional hydrolyzed protein or with BioLure®. CeraTrap® lure was also significantly more attractive to beneficial lacewings than the other 2 lures. These results indicated that additional studies on fly population suppression under field conditions will be necessary before deciding to use the folding conical trap as part of a mass trapping strategy to control the Mexican fruit fly.

Key Words: *Anastrepha ludens*, deltamethrin, BioLure, CeraTrap, retention system, conical trap

Resumen

El uso de trampas sencillas y económicas con cebos duraderos es la base para la implementación de estrategias de trampeo masivo contra moscas de la fruta. La sencillez, costo y otras características como la facilidad de montaje, almacenamiento y transporte fueron considerados para la evaluación de una trampa cónica ensamblable para su uso en sistemas de trampeo masivo de la mosca mexicana de la fruta, *Anastrepha ludens*. La impregnación de la tapa de la trampa con deltametrina resultó ser un tratamiento efectivo y económico para favorecer la retención de mosca en trampas secas durante al menos 10 semanas. Sin embargo, el diseño de trampa cónica y el diámetro, tipo y disposición de los agujeros de la trampa, afectó negativamente el comportamiento de la trampa en condiciones de laboratorio. Una gran cantidad de moscas podían escapar de la trampa en un corto período de tiempo después de la liberación en su interior, aunque la mayoría de ellas murieron después de escapar debido al efecto de la deltametrina. En condiciones de campo, no se observaron diferencias significativas en la captura de *A. ludens* o crisopas entre las trampas anaranjadas o amarillas. Por el contrario, las trampas fueron significativamente más eficientes en la captura de la mosca Mexicana de la fruta cuando se utilizó el cebo CeraTrap® que cuando se usa la proteína hidrolizada convencional o BioLure®. Este cebo también fue significativamente más atractivo para las crisopas benéficas. Los resultados indican que son necesarios estudios adicionales de supresión de poblaciones de moscas en condiciones de campo antes de la implementación de este modelo de trampa como componente de una estrategia de trampeo masivo para el control de la mosca mexicana de la fruta.

Palabras Clave: *Anastrepha ludens*, deltametrina, BioLure, CeraTrap, sistema de retención, trampa cónica

Mass trapping is currently being used with good results over large areas in the Mediterranean region to control the Mediterranean fruit fly *Ceratitis capitata* (Wiedemann) (Martínez-Ferrer et al. 2010; Navarro-Llopis et al. 2008). Much progress has been made in developing potent lures and attractive traps for different *Anastrepha* species (Heath et al. 1997; Epsky et al. 1995, 1999), but such progress has not been applied successfully in the implementation of mass trapping strategies against these species. The efficacy of mass trapping is dependent on the attractiveness of traps and lures. Trap design and the retention system are important factors that increase efficacy in 2 ways, by favoring fly entrance and by preventing fly escape. In the development of traps, most attention has focused on parameters governing attraction such as size, shape and color (Prokopy 1968; Economopoulos 1989; Cytrynowicz et al. 1982; Sivinski 1990; Robacker 1992). However, the retention capacity of a trap is an important feature to be considered when the device is intended for use in monitoring or mass trapping. Retention can be considered as the mechanism of the trap that prevents fly escape after entry. Although each trap has its intrinsic physical retention capacities (Lasa et al. submitted), additional retention systems improve fly capture. In wet traps, the liquid is used as the retention method. In dry traps, retention systems are mainly based on the use of chemical insecticides (Martinez-Ferrer et al. 2010; Navarro-Llopis et al. 2008; Heath et al. 1995; Epsky et al. 1995) or sticky panels (Robacker & Rodriguez 2004).

The impregnation of clothes and other surfaces with pyrethroids has proven to be effective in the control of some disease vector mosquitoes and other dipteran pests (Ladoni et al. 1994; Khoobdel et al. 2005). In recent years, the pyrethroid deltamethrin (DM) has been included as an effective substitute of diclorvos (DDPV) in dry traps used for monitoring and mass trapping tephritids, and its use has been permitted as a retention system in organic production within the European Union (Alemany et al. 2005). Deltamethrin has been proven to be effective against *C. capitata* with 2 kind of impregnated devices introduced inside traps: Scalibor® (Intervet International B.V., Boxmeer, Netherlands) commercially available as an anti-tick dog collar, and PermaNet® (Vestergaard Frandsen A/S, Lausanne, Switzerland) commercially available as a bed-net used to control some disease vector mosquitoes (Alemany et al. 2005). However, when compared with DDPV, these commercial products are too expensive to be used as a retention system in mass trapping strategies in developing countries. The impregnation of a deltamethrin insecticide to the lid of traps also seems to be effective. Probodelt Company (Amposta, Spain) supplies a specific "KILL-TAP®" that is supposedly impregnated with a pyrethroid insecticide.

Here, we attempted to emulate commercial lids using DM to treat trap lids. In the laboratory, we evaluated efficacy when DM was impregnated directly on the polyethylene lid and compared this system with a conventional sticky panel introduced inside the trap; and we measured the long term residual effect of this DM treatment against laboratory *A. ludens* Loew across 10 wk. We also evaluated the efficacy of treated traps under field conditions by comparing the attractiveness of orange and yellow folding traps, and by assessing the improvement in trap captures with liquid baits that were introduced in a cellulosic film pouch. Finally, we evaluated the effects of different trap colors and lure types on captures of the natural enemy, *Chrysoperla* spp. (Neuroptera: Chrysopidae), which are considered important natural predators in citrus fruit crops. We discuss potential use of this trap in mass trapping strategies.

Material and Methods

Experiment 1. Fly Retention in Conical Traps Either with Deltamethrin-Treated Lids or Internal Sticky Panels

A initial test was performed under laboratory conditions to compare the efficacy of 2 retention systems used along with fruit fly dry traps. The efficacy of an adherent panel placed within the trap was compared with a chemical treatment applied to the trap lid. Both retention systems were evaluated within the orange conical folding trap Conetrap (Probodelt, Amposta, Spain) (Fig. 1). Deltamethrin EC formulation was selected for retention systems trials due to ease of application and good adsorption to the plastic surface of lids. Each trap lid was treated with 250 µL of an aqueous solution of deltamethrin (2.5% Deltamethrin EC, Urbatrine, Agroquímica Tridente, Mexico City) containing 0.05% v/v active ingredient (A.I.) evenly applied using a small paintbrush. When dry, a second treatment was applied in the same manner. A total treatment of 0.25 mg of active ingredient (A.I.)/trap (~10 mg/m^2) was applied.

A yellow foam panel was treated on both sides (21 cm^2 each) with a thin layer of the adherent Stikem® (Consultoría Integral, México City) and placed inside the trap at the bottom. The foam panel has 2 tabs at the top to keep it upright and allows fly captures on both sides. For this experiment, all traps were baited with BioLure® (Suterra LLC, Bend, Oregon) consisting of 2

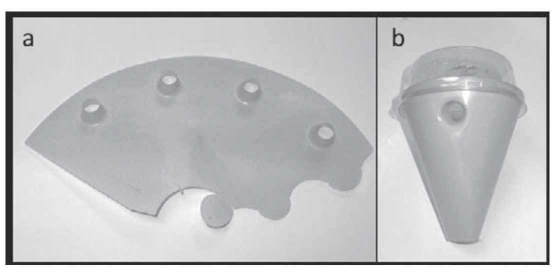

Fig. 1. A) Unfolded base of the orange conical folding trap, or Conetrap, and B) Assembled conical folding trap, or Conetrap.

components, ammonium acetate and putrescine, supplied in separate sachets and with an adhesive on the back for attachment to the interior of the trap. Volatilization of lures began after the protective cover was removed from the sachet.

Each trap was placed inside a Plexiglass cage (30 × 30 × 30 cm). The retention capacity of both systems was evaluated by counting the number of flies that died after 12 flies (6 males and 6 females) were carefully released inside the trap with an entomological aspirator, avoiding direct contact with treated surfaces during release. Laboratory-reared *A. ludens* were obtained from a colony maintained at the Instituto de Ecología A.C., Xalapa, Mexico. Adult flies had access to hydrolyzed yeast, sugar and water, and the flies were used for experiments at 4 days post-eclosion. The numbers of flies that were observed to be alive or were knocked down after 30 minutes, 2 hours and 24 h were counted inside and outside of each trap. For evaluation at 30 min and 2 hours, traps were not removed from the cage and flies were observed carefully through the screen cage or by looking through the transparent lid of the trap. Flies were considered knocked down when no movement was detected during 5-8 s at the moment of observation or when flies remained face up. After a 24 hour exposure, the cage and the trap were opened and flies checked to evaluate mortality. Experiments were carried out at 12:12 h L:D, 26 ± 1 °C and 55 ± 10% RH. The first assessment was determined just 1 wk after the trap lids or the adherent panels were prepared. Four simultaneous replicates, including a control treatment without any retention system, were evaluated. Total number of knocked down flies (inside and outside) were counted at each observational period for the 2 treatments.

Due to the poor performance of adherent panels to retain flies within this trap model, only the deltamethrin treatment was subsequently evaluated over a period of 10 wk to determine long-term residual activity. The same traps were used for this purpose and evaluated weekly during 10 wk. During the long-term residual test, traps were stored in an open shed at the Instituto de Ecología A.C. under shaded ambient conditions (18 to 28 °C). All traps were maintained together inside a screen cage to prevent insect intrusion during storage and were only taken back to the lab on the test day. For evaluation, total fly mortality and percentage of flies that died outside of the trap were recorded after 24 h. This time, direct observation was selected as the evaluation method because some flies that were observed immobile or face up during 30- and 120-min observations due to a knock down effect of the insecticide were able to revive later. Four treated and 4 control traps were evaluated during the 10-week experiment. Total percentage of knocked down flies was rank transformed and compared with a two-way analysis of variance (ANOVA) including treatment and time of observation. Percent mortality in the long term residual activity test and percent of flies that died outside of the trap were normally distributed and were analysed by time in a one-way ANOVA. All analyses were performed using SPSS v.19 (SPSS Inc., Chicago, Illinois).

Experiment 2. Field Evaluation of Yellow and Orange Folding Conical Traps

The attraction of folding conical traps of 2 different colors, whose caps or lids had been treated with deltamethrin, was evaluated under field conditions. The efficacy of a yellow molded plastic trap and an orange plastic extruded trap, both manufactured by Probodelt TM (Amposta, Spain), were evaluated in a grapefruit (*Citrus* × *paradisi* Macfad.; Sapindales: Rutaceae) orchard between May and Jun 2012. Both traps were baited with Biolure® (Suterra LLC, Bend, Oregon), which consisted of 2 components, ammonium acetate and putrescine. Traps were placed in grapefruit trees selected within a commercial orchard in Martinez de la Torre (N 20° 0'31.06" W 97° 10' 53.63"). Both trap types were placed in the same tree, 3 m apart, one on the eastern portion and one on the western portion of the tree canopy. A total number of 6 traps (3 replicates × 2 colors) were evaluated every 7 days during 3 consecutive wk. Experimental trees were separated by a distance of at least 15 m. Trap positions were randomized initially, and thereafter their positions were rotated every wk. Captured insects were collected in containers with 70% ethanol, sorted and counted in the laboratory according to fruit fly species and sex. The numbers of lacewings trapped were also recorded every wk.

Total captures per wk were transformed to flies/trap/day (FTD). To stabilize the variance, FTD were $\sqrt{(x + 0.5)}$ transformed and subjected to two way ANOVA with sex and trap as factors. As the effect of sex was not statistically significant, effect of trap color was tested with one way ANOVA on the total number of flies trapped. Mean separation was achieved by Fisher´s least significant difference (LSD) tests. Lacewings trapped were also transformed to lacewings/trap/day (LTD), $\sqrt{(x + 0.5)}$ transformed to stabilize variance and subjected to one way ANOVA. All analyses were performed using SPSS v.19 (SPSS Inc., Chicago, Illinois).

Experiment 3. Field Evaluation of Various Lures with Orange Conical Trap

The influence of various lures on the efficacy of the orange conical trap was examined under field conditions in the same grapefruit orchard at an experimental plot located at 400 m from traps in experiment 2 to avoid interference. The liquid lure CeraTrap® (Bioibérica, Barcelona, Spain) and the standard hydrolysed protein (HP) were evaluated and compared against the synthetic lure BioLure® (Suterra LLC, Bend, Oregon). Hydrolysed protein is the lure currently used for fruit fly monitoring in Mexico by the National Campaign against Fruit Flies. CeraTrap® is a liquid bait consisting of a mixture of enzymatic hydrolysed proteins that release a series of volatile compounds, mostly amines and organic acids attractive to adult flies, especially females. CeraTrap has been proven to be effective in the capture of *A. ludens* (De los Santos et al. 2011; Lasa et al. submitted). Hydrolysed protein was formulated with 10 mL of hydrolysed protein Captor 300 (Promotora Agropecuaria Universal S. A de C. V., México City), 5 g of Borax (J. T. Baker, México City) and 235 mL of water, with a total volume of 250 mL.

Due to the dry nature of the trap, liquid baits were introduced in a cellulosic membrane used for sausage stuffing (Viscofán S. A., Cáseda, Spain). A 50 mL liquid suspension of CeraTrap® or hydrolyzed protein was prepared as a liquid sausage. The liquid sausage was placed in the trap as if it was a dry lure. A total number of 12 traps (4 blocks × 3 lures) were evaluated every 7 days during 6 consecutive wk. Trees holding traps were separated by at least 10 m in the same block. Trap position was randomized initially, and positions were rotated sequentially every wk. Captured insects were collected in vials with a 70% alcohol solution, were sorted according to fruit fly species and sex, and were counted. The number of lacewings captured was also recorded every wk.

Total captures were transformed to FTD, $\sqrt{(x + 0.5)}$ transformed to stabilize variance and subjected to two way ANOVA by sex and lure. Mean separation was achieved by Fisher´s least significant difference test (LSD). The percentages of females captured per trap were normally distributed, therefore not transformed, and were subjected to one way ANOVA. Lacewings trapped were also transformed to lacewings/trap/day (LTD) and $\sqrt{(x + 0.5)}$ transformed to stabilize variance and subjected to one way ANOVA. All analyses were performed using SPSS v.19 (SPSS Inc., Chicago, Illinois).

Results

Experiment 1. Fly Retention in Conical Traps Either with Deltamethrin-Treated Lids or Internal Adherent Panels

Adherent ("sticky") panels were significantly less effective in retaining files than deltamethrin-treated lids ($F = 111.48$; df = 1;18; $P < 0.001$). No statistical differences were observed between observations after different exposure intervals ($F = 0.254$; df = 2,18; $P = 0.778$), however, a significant treatment*time interaction was observed ($F = 6.91$ df = 2,18; $P = 0.006$). The significance of this interaction could be explained because some knocked down flies managed to escape the trap and revive during the period between 120 min and 24 h (Fig. 2). All knocked down flies observed at 24 h were dead at this time of observation. No mortality was observed in control traps.

Percent mortality of *A. ludens* inside the deltamethrin-treated folding cone traps after 24 h and the percent mortality also at 24 h but outside the traps of flies that had escaped from the traps after 2 h are displayed in Fig. 3. No significant losses in the insecticidal activity of deltamethrin were observed during the 10-week evaluation ($F =1.52$; df = 9,30; $P = 0.187$) although a total average mortality reduction from 83% to 69% was recorded. An average of ~40% of flies died outside the trap and that this percentage did not vary during the duration of the experiment ($F = 0.291$ df = 9,30; $P = 0.972$).

Experiment 2. Field Evaluation of Yellow and Orange Folding Conical Traps

A total of 1,016 fruit flies were trapped in orange and yellow conical traps during the 3-week experiment. Over 97% were *A. ludens* while less than 3% (31 flies) were males and females of *A. obliqua* Macquart and *A. serpentina* Wiedemann. A total of 169 lacewings were also recovered from the traps. During the second wk, the flies recovered in 2 trees were excluded from statistical analysis, because these traps were found on the ground, probably having been knocked down by wind or birds.

Results observed revealed a similar performance for both yellow- and orange-colored traps

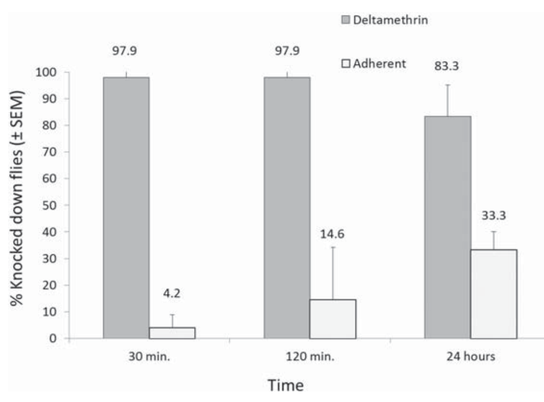

Fig. 2. Total percent of knocked down *Anastrepha ludens* flies (± SEM) observed 30 min, 120 min and 24 h after flies were released inside conical traps each either with a deltamethrin-treated lid or an adherent ('sticky") panel. Knocked down flies observed at 24 h were confirmed to be dead.

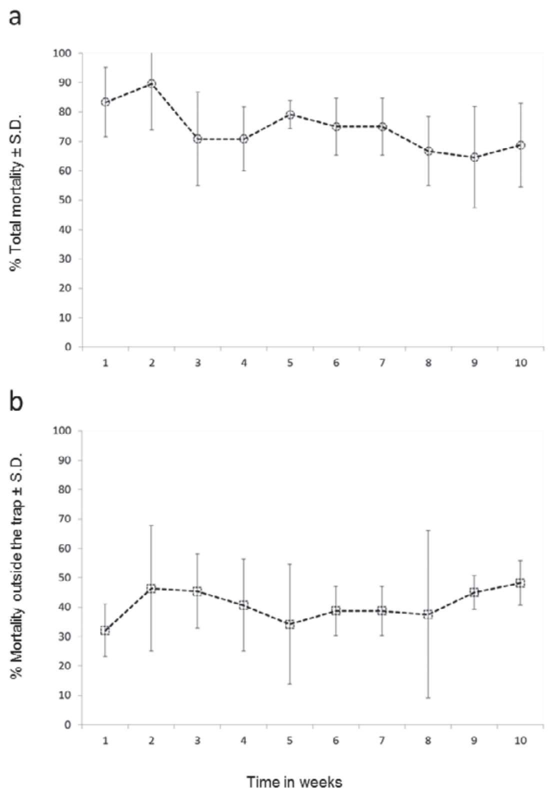

Fig. 3. Long-term residual activity as indicated by mean percent mortality (± S.D.) of *Anastrepha ludens* observed a) inside and b) outside of deltamethrin treated traps. Assessments are presented for results observed 24 h after flies were released inside each trap.

(Table 1). No significant differences were observed between traps of different colors in reference to the total number of trapped flies/trap/day (FTD) (F = 0.209; df = 1,12; P = 0.656), percentage of captured females (F = 1.194; df = 1,12; P = 0.995) or the number of lacewings/trap/day (LTD) (F = 0.296; df = 1,12; P = 0.338).

Experiment 3. Field Evaluation of Various Lures with Orange Conical Traps

A total of 3,950 fruit flies were trapped during the 6-week experiment by the 12 traps baited with the 3 different lures. Over 97% were *A. ludens* while ~3% (128 flies) belonged to other fruit fly species such as *A. obliqua* and *A. serpentina*. A total of 939 lacewings were also recovered from all traps during the experiment. Statistical analyses revealed that both variables, sex (F = 18.73; df = 1,90; P < 0.001) and lure (F = 3.87; df = 2,90; P = 0.024) had a significant effect in relation to the number of females and males captured within traps baited with different lures. However, the interaction between sex and lure was not significant (F = 0.237; df = 2,90; P = 0.789). Higher numbers of females (68-73%) were trapped in comparison to males (27-32%). No significant difference was observed between traps when the percentage of females was analysed (F = 2.76: df = 2,45; P = 0.074) (Table 2). In reference to the total number of flies captured, CeraTrap lure-baited traps captured approximately twice as many flies as traps baited with BioLure (Table 2). In reference to lacewings trapped, the number of captures/trap/day was also significantly higher for traps baited with CeraTrap (F = 7.16; df = 2,45; P = 0.002) than either with hydrolysed protein or BioLure (Table 2).

Discussion

We assessed the effectiveness of an inexpensive folding trap for potential use in mass trapping *A. ludens*. Simplicity, cost, ease of assembly, storage and transportation, made this conical trap model potentially interesting. We evaluated the efficacy of a chemical retention system, 2 trap colors and 3 different lure types under field conditions. Our experiments provided definitive results in some respects but not in others.

The efficacy of deltamethrin treated lids proved to be a very cost-effective fly-retention method for traps. The main advantages of use of this insecticide in dry traps are its prolonged residual activity, low cost, simplicity and ease of deployment, and approval for use in organic crops within the European Union (Alemany et al. 2005). Treatment cost for each trap at the evaluated dose is ~ 0.01 $MXN (~US$ 0.008). Additional tests with different deltamethrin concentrations should be carried out to further optimize the use of this retention system, along with tests to evaluate various plastic surfaces to improve longevity. The low cost of this treatment could allow it use as an additional retention system to increase trap ef-

Table 1. Mean (± SEM) number of flies per trap per day (FTD), % females captured and number of Lacewings per trap per day (LTD) captured by traps of yellow and orange conical traps.

Trap	File/Trap/Day FTD ± S.E.	% Females ± S.E.	Lacewings/Trap/Day LTD + S.E.
Yellow trap	9.14 ± 0.97 a	57.14 ± 2.20 a	1.97 ± 0.21 a
Orange trap	11.51 ± 1.39 a	67.38 ± 2.27 a	1.29 ± 0.07a

Numbers in columns followed by the same letter are not significantly different (LSD test, P = 0.05).

TABLE 2. MEAN (± SEM) NUMBER OF TOTAL *ANASTREPHA LUDENS* FLIES, FEMALE OR MALE FLIES PER TRAP PER DAY (FTD), % OF FEMALE FLIES AND LACEWINGS PER TRAP PER DAY (LTD) CAPTURED WITH THE USE OF VARIOUS LURES IN ORANGE CONICAL TRAPS.

Trap	Flies/Trap/Day FTD ± S.E.	Females /Trap/Day FTD ± S.E	Males/Trap/Day FTD ± S.E	% Females ± S.E.	Lacewings/Trap/Day FTD ± S.E
BioLure	7.81 ± 1.29 a	4.98 ± 0.73a	2.77 ± 0.73 a	68.46 ± 3.87 a	2.22 ± 0.38 a
Hydrolysed protein	10.44 ± 1.77 ab	6.99 ± 0.73 ab	3.42 ± 0.98 ab	71.91 ± 3.13 a	1.67 ± 0.30 a
Certrap	15.79 ± 3.70 b	9.81 ± 1.72 b	5.76 ± 2.06 b	72.87 ± 3.50 a	3.92 ± 0.61 b

Numbers in columns followed by the same letter are not significantly different (LSD test, $P = 0.05$).

ficacy for traps baited with liquid lures that lack a good intrinsic retention capacity. Different studies have proven the efficacy of pyrethroid insecticides to control disease vectors or other insects when impregnated in different materials such as clothes (Koobdel et al. 2005), bed-nets (Carnevale et al. 1998) and other surfaces (Ladoni et al. 1994; Williams et al. 1983). However, deltamethrin is one of the insecticides recommended by the World Health Organization (WHO) for indoor spraying against mosquitoes (WHO 2001), and is one of the insecticides used for treating mosquito nets (Barlow et al. 2001). Deltamethrin impregnated nets PremaNet ™ have been found to be effective even after several washings (Rubio-Palis & Guerra 2003). This insecticide is also effective when applied to plaster, mud and wooden surfaces (Abtahi et al. 2011). Recently, a yellow deltamethrin impregnated carton, Magnet Med®, used as a lure and kill device, has been successfully used to control *C. capitata* (Navarro-Llopis et al. 2012). A similar approach using other insecticides has been developed by Wright et al. (2012) for control of the apple maggot fly, *Rhagoletis pomonella* (Walsh). These authors, using visually attractive red spheres impregnated with spinosad and covered with a sugar-cap as a feeding stimulant and placed along the perimeters of apple orchards, achieved levels of control similar to 2 pesticide applications.

However, we found that the effectiveness of the trap model we evaluated may have important limitations for *A. ludens* control. The large number of flies that escape from the trap over a short period of time can greatly increase the chances of underestimating the number of flies in the crop system. This deficiency decreases the use of this trap for monitoring purposes. However, if the trap were used for fruit fly control, fly escape might not have a deleterious effect on pest population suppression, because most of the flies that escaped soon died outside the traps. However, when flies escape from traps, some of them may survive if they acquired a sublethal dose of insecticide and this can facilitate the future development of resistance. Therefore, the efficacy of this model for *A. ludens* suppression should be evaluated under field conditions using an approach similar to that of Wright et al. (2012). In relation to the high percentage of flies that escaped the trap within a short period of time, this trap model should not be considered as a specific trap for mass trapping but as a mixed effect trap that acts as a mass trapping and as a lure and kill device (El Sayed et al. 2006, 2009). The low physical retention capacity of this trap model has been previously described by Lasa et al. (submitted) who found that more than 50% of the flies could escape the trap within the first 30 min of evaluation. The trap shape, and the type and diam of the hole (17 mm) seem to be the main features that contribute to fly escape. In view of results observed under cage conditions, the numbers of flies captured in the field experiments do not accurately represent the level of pest suppression. However, the numbers of fruit flies and lacewings captured did not differ significantly between yellow and orange traps. Yellow and orange are the colors most commonly used in commercial traps. By contrast, liquid lures, previously placed in a cellulose membrane, were more effective in trapping flies than the dry synthetic BioLure. Several authors have mentioned poor performance of dry BioLure on *A. ludens* captures in comparison with liquid lures (Heath et al. 1995; Conway & Forrester 2007; Lasa et al. submitted). The superior attractiveness of CeraTrap for *A. ludens* has already been observed (Lasa et al. submitted), and more females than males were trapped by this lure. Several authors have found this response pattern, where more females than males were trapped in traps baited with proteinaceous lures (Aluja et al. 1989; Houston 1981; Piñero et al. 2002; Conway & Forrester 2007; Martínez et al. 2007).

Mass trapping can be a good option for fruit fly control when integrated with other methods. However, to make this strategy attractive to growers, the technique must be easy to deploy and economically competitive with other control methods. One of the main advantages mass trapping is that it avoids the widespread application of chemical insecticides in orchards, with all the benefits that this entails. More studies that compare traps and lures are necessary to achieve the best trap/lure combination. Until now wet traps have been more effective than dry traps, but wet traps are more expensive. The introduction of liquid lures in cellulosic devices can be a good option to reduce external microbial contamination for use of liquid lures in dry traps. However, additional studies should be carried out. To improve the efficacy of this technique, longer lasting dispensers that remain effective for the entire growing season, and more efficient and cheaper traps are still necessary. More studies, such as this one, are needed on trap density, pre-harvest timing and trap placement, and they should be carried out and guided by information of the fly dynamics in the region.

We believe that our results provide some new knowledge about traps and lures for trapping *Anastrepha*. The main purpose of this investigation was to contribute to the development of improvements in fly trapping devices to reduce cost, increase effectiveness and allow the use of this technology in developing countries.

ACKNOWLEDGMENTS

The authors would like to express their gratitude to Probodelt Company for supplying the conical trap, to Adolfo Sanzol and Viscofán S.A. for supplying the cellulosic membrane and to Sr. Julio Salas for access to the experimental field site. This work was partly funded by the Mexican Campaña Nacional Contra Moscas de la Fruta (Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación-Instituto Interamericano de Cooperación para la Agricultura) and by the Consejo Nacional de Ciencia y Tecnología (Conacyt) with the Project 181222 grant to the company Cítricos S.A. de C.V. We wish to declare that there is no conflict of interest on the commercial products evaluated.

REFERENCES CITED

ABTAHI, M., SHAYEGHI, M., KHOOBDEL, M., VATANDOOST, H., ABAEI, M. R., AND AKBARZADEH, K. 2011. Persistence and residue activity of deltamethrin on indoor residual spraying surfaces against malaria vectors in Southeastern Iran. Asian Pacific J. Trop. Biomed. S271-S275.

ALEMANY, A., MIRANDA, M. A., VESTERGAARD, T., AND ABDALI, A. 2005. Deltamethrin as a replacement for diclorvos (DDVP) strips used as a retention system in fruit fly traps *In* Development of improved attractants and their integration into fruit fly SIT management programmes. Joint FAO / IAEA Programme of Nuclear Techniques in Food and Agriculture and held in Vienna, 5-7 May 2005.

ALUJA, M., CABRERA, M., GUILLÉN, J., CELEDONIO, H., AND AYORA, F. 1989. Behavior of *Anastrepha ludens*, *A. obliqua* and *A. serpentina* (Diptera: Tephritidae) on a wild mango tree (*Mangifera indica*) harboring three McPhail traps. Insect Sci. Appl. 10: 309-318.

BARLOW, S. M., SULLIVAN, F. M., AND LINES. J. 2001. Risk assessment of the use of deltamethrin on bednets for the prevention of malaria. Food Chem Toxicol. 39: 407-422.

CARNEVALE, P. J., N'GUESSAN, R., AND DARRIET, F. 1998. Long-lasting anti-mosquito efficacy of a commercially impregnated bed net. Trans. R. Soc. Trop. Med. Hyg. 93: 379-380.

CONWAY, H. E., AND FORRESTER, T. 2007. Comparison of Mexican fruit fly (Diptera: Tehpritidae) capture between McPhail traps with torula and Multilure traps with Biolures in South Texas. Florida Entomol. 90(3): 579-580.

CYTRYNOWICZ, M., MORGANTE, J. S., AND DE SOUZA, H. M. L. 1982. Visual response of South American fruit flies, *Anastrepha fraterculus*, and Mediterranean fruit flies, *Ceratitis capitata*, to colored rectangles and spheres. Environ. Entomol. 11: 1202-1210.

DE LOS SANTOS RAMOS, M., HERNÁNDEZ, R., CERDÁ, J.M., NIEVES, F., TORRES, J. A., BELLO A., AND FRANCO, D. 2011. An environmentally friendly alternative (MS2®-CeraTrap®) for control of fruit flies in Mexico. J. Food Agric. Environ. 9(3-4): 926-927.

ECONOMOPOULOS, A. P. 1989. Use of traps based on color and/or shape *In* A. S. Robinson and G. Hooper [eds.], Fruit flies: Their biology, natural enemies and control. Vol. 3B. Elsevier Science Publishers, Amsterdam, The Netherlands. 447 pp.

EL SAYED, A. M., SUCKLING, D. M., WEARING C. H., AND BYERS, J. A. 2006. Potential of mass trapping for long term pest management and eradication of invasive species. J. Econ. Entomol. 99: 1550-1564.

EL SAYED, A. M., SUCKLING, D. M., BYERS, J. A., JANG E. B., AND WEARING. C. H. 2009. Potential of "lure and kill" in long-term pest management and eradication of invasive species. J. Econ. Entomol. 103(3): 815-835.

EPSKY, N. D., HEATH, R. R., GUZMAN, A., AND MEYER, W. L. 1995. Visual cue and chemical interactions in a dry trap with food-based synthetic attractants for *Ceratitis capitata* and *Anastrepha ludens* (Diptera: Tephritidae). Environ. Entomol. 24(6): 1387-1395.

EPSKY, N. D., HENDRICHS, J., KATSOYANNOS, B. I., VÁSQUEZ, L. A., ROS, J. P., ZÜMREOGLU, A., PEREIRA, R., BAKRI, A., SEEWOORUTHUN, S. I., AND HEATH, R. R. 1999. Field evaluation of female-targeted trapping systems for *Ceratitis capitata* (Diptera: Tephritidae) in seven countries. J. Econ. Entomol. 92: 156-164.

HEATH, R. R., EPSKY, N. D., GUZMAN, A., DUEBEN, B. D., MANUKIAN, A., AND MEYER, W. H. 1995. Development of a dry plastic insect trap with food-based synthetic attractants for the Mediterranean and Mexican fruit flies (Diptera: Tephritidae). J. Econ. Entomol. 88: 1307-1315.

HEATH, R. R., EPSKY, N. D., DUEBEN, B. D., MANUKIAN, A., RIZZO, J., AND JERONIMO, F. 1997. Adding methyl-substituted ammonia derivatives to a food-based synthetic attractant on capture of Mediterranean and Mexican fruit flies (Diptera: Tephritidae). J. Econ. Entomol. 90(6): 1584-1589.

HOUSTON, W. W. 1981. Fluctuations in numbers and the significance of the sex ratio of the Mexican fruit fly, *Anastrepha ludens* caught in McPhail traps. Entomol. Exp. Appl. 30: 140-150.

KHOOBDEL, M., SHAYEGHI, M., LADONNI, H., RASSI, Y., VATANDOOST, H., AND ALIPOUR, H. K. 2005. The efficacy species of permethrin treated military uniforms as a personal protection against *Culex pipiens*. Intl. J. Environ. Sci. Technol. 2(2): 161-167

LADONI, H., MOTABAR, M., AND IRANPOUR, M. 1994. Residual effect of lambdacyhalothrin (icon 10% WP) on different surfaces in South of Iran. Iran J. Public Health; 23: 1-4.

LASA, R., VELÁZQUEZ, O. E., ORTEGA, R., AND ACOSTA, E. 2013. Efficacy of commercial traps and food odor attractants for monitoring and mass trapping the Mexican fruit fly *Anastrepha ludens*. J. Econ. Entomol. (Submitted)

MARTÍNEZ, A. J., SALINAS, E. J., AND RENDÓN, P. 2007. Capture of *Anastrepha* species (Diptera: Tephritidae) with Multilure traps and BioLure attractants in Guatemala. Florida Entomol. 90(1): 258-263.

MARTÍNEZ-FERRER, M. T., CAMPOS, J. M., AND FIBLA, J. M. 2010. Field efficacy of *Ceratitis capitata* (Diptera: Tephritidae) mass trapping technique on clementine groves in Spain. J. Appl. Entomol. 136: 181-190.

NAVARRO-LLOPIS, V., ALFARO, F., DOMÍNGUEZ, J., SANCHÍS, J., AND PRIMO, J. 2008. Evaluation of traps and lures for mass trapping of Mediterranean fruit fly in citrus groves. J. Econ. Entomol. 101(1): 126-131.

NAVARRO-LLOPIS, V., PRIMO, J., AND VACAS, S. 2013. Efficacy of attract and kill devices for the control of *Ceratitis capitata*. Pest Manag. Sci. 69(4): 478-482.

PROKOPY, R. J. 1968. Visual responses of apple maggot flies, *Rhagoletis pomonella*: orchard studies. Entomol. Exp. Appl. 11: 403-422.

PIÑERO, J., ALUJA, M., EQUIHUA, M., AND OJEDA, M. M. 2002. Feeding history, age and sex influence the response of four economically important *Anastrepha* species (Diptera: Tephritidae) to human urine and hydrolyzed protein. Folia Entomol. Mex. 41: 283-298.

ROBACKER, D. C. 1992. Effects of shape and size of colored traps on attractiveness to irradiated, laboratory-strain Mexican fruit flies (Diptera: Tephritidae). Florida Entomol. 75: 230-240.

ROBACKER, D. C., AND RODRIGUEZ, M. E. 2004. A simple and effective cylindrical sticky trap for fruit flies (Diptera: Tephritidae). Florida Entomol. 87(4): 492-495.

RUBIO-PALIS, Y., AND GUERRA, L. A. 2003. Evaluación del poder residual del insecticida deltametrina en telas de mosquiteros. Entomotropica. 18(1): 63-68.

SIVINSKI, J. 1990. Colored spherical traps for capture of Caribbean fruit fly, *Anastrepha suspensa*. Florida Entomol. 73: 123-128.

WHO 2001. WHO Recommended insecticides for indoor residual spraying against malaria vectors. Geneva: World Health Organization.

WILLIAMS, P., SEMPLE, R. L., AND AMOS, T. G. 1983. Relative toxicity and persistence of three pyrethroid insecticides on concrete, wood and iron surfaces for control of grain insects. J. App. Entomol. 15: 7-10.

WRIGHT, S. E, LESKEY, T. C., JACOME, I., PIÑERO. J. C., AND PROKOPY, R. J. 2012. Integration of insecticidal, phagostimulatory, and visual elements of an attract and kill system for apple maggot fly (Diptera: Tephritidae). J. Econ. Entomol. 105: 1548-1556.