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Trap design for lovebugs, *Plecia nearctica* (Diptera: Bibionidae)

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Abstract

The lovebug, *Plecia nearctica* Hardy (Diptera: Bibionidae), is an invasive nuisance insect in Florida, USA. We previously showed that the floral compound phenylacetaldehyde (PAA) and yellow color were preferred olfactory and visual stimuli for capturing adult lovebugs. However, suitable designs for a trap have not been investigated. Here, we evaluated 3 basic types of insect traps (sticky, funnel, and interception) for their effectiveness in collecting adult lovebugs under field conditions in central and southern Florida. All traps were yellow or painted yellow and baited with PAA, which was highly attractive to both sexes. Yellow sticky cards orientated vertically were effective, but they quickly filled with lovebugs and were thus unsuitable for extended periods. Of the other commercial traps tested, the Universal moth (Unitrap), Japanese beetle, and modified Lindgren traps were effective, whereas the Delta, Ball (McPhail), boll weevil, fly (baited cup), and stink bug traps were relatively ineffective. Overall, the Unitrap was favored because it potentially can capture many thousands of lovebugs with a low proportion of non-target species (i.e., ≤ 6% of total insects collected), is reuseable for multiple seasons, and potentially can be improved by the addition of fluon or similar non-stick material to the entrance. The lure (polypropylene vial containing 0.75 mL PAA) was attractive to lovebugs for at least 2 wk under field conditions. The position of the lure (inside versus outside the trap) did not statistically affect the effectiveness of the Unitrap. The strategic deployment of lovebug traps is discussed.

Key Words: phenylacetaldehyde; Universal moth trap; attractant; polytetrafluoroethylene; Fluon®

Resumen

El insecto del amor, *Plecia nearctica* Hardy (Diptera: Bibionidae), es un molesto insecto invasivo en Florida, EE.UU. Previamente mostramos que el compuesto floral fenilacetaldehido (FAA) y el color amarillo fueron preferidos tanto olfativamente como por su estimulo visual para la captura de insectos del amor adultos. Sin embargo, diseños eficientes de trampas no han sido investigados. En este trabajo evaluamos tres tipos básicos de trampas (pegajosas, de embudo, y de intercepción) por su efectividad en las colectas de insectos del amor bajo condiciones de campo en la centro y sureste Florida. Todas las trampas fueron amarillas o pintadas de este color y cebadas con FAA el cual fue altamente atractivo para ambos sexos. Tarjetas amarillas pegajosas orientadas verticalmente fueron efectivas, pero fácilmente saturadas con los insectos del amor por consiguiente ineficientes por largos periodos de tiempo. De las otras trampas comerciales evaluadas, la universal para palomillas (Unitrap), para el escarabajo japonés y la Lindgren modificada fueron efectivas, mientras que la Delta, la Ball (McPhail), para el picudo de la bellota, trampa para la mosca (copa cebada), y para la chinche apestosa fueron relativamente inefectivas. En general, la trampa Unitrap fue la más favorable siendo que esta puede potencialmente capturar varios miles de insectos del amor con una baja proporción de especies no objetivo (ej. ≤ 6% del total de insectos colectados), así mismo es reutilizable por múltiple temporadas, y puede ser potencialmente mejorada con la adición de teflón o materiales similares no pegajosos en la entrada de la trampa. El cebo (un vial de polipropileno conteniendo 0.75 mL de FAA) fue atractivo para los insectos del amor por al menos 2 semanas bajo condiciones de campo. La posición del cebo (dentro contra fuera de la trampa) no afectaron estadísticamente la efectividad de la trampa Unitrap. El despliegue estratégico de las trampas para los insectos del amor es discutido.

Palabras Clave: fenilacetaldehido; trampa universal para polillas; atrayente; politetrafluoroetileno; Fluon®

The lovebug, *Plecia nearctica* Hardy (Diptera: Bibionidae), is found in Costa Rica, Guatemala, Honduras, Mexico, and the southeastern USA, with a current distribution extending to all states bordering the Gulf of Mexico and to Georgia and South Carolina (Denmark et al. 2012). In these areas, this insect is well known for its biannual flight periods in the spring and fall, when large numbers of day-flying adults swarm and may become a nuisance to motorists by splattering on vehicles moving at highway speeds (Buschman 1976). More recently, Cherry & Raid (2000) reported a smaller 3rd flight peak during the winter in southern Florida, USA. Lovebugs apparently are attracted to automobile exhausts and localized heat sources (Whitesell 1974) and to light-colored structures and freshly-painted surfaces (Hetrick 1970) and may become an annoyance in the rural–urban fringe (Denmark et al. 2012). The larvae develop in habitats high in organic matter, such as pastures, oak hammocks, and other moist vegetated areas. Although primarily reported as decomposers or scavengers, larvae of *Plecia* sp. (likely *P. nearctica)* have been associated with root damage to centipede grass sod (Held & Gelhaus 2006).

Despite their nuisance status, the extensive breeding habitats of *P. nearctica* make control with insecticides uneconomical in most

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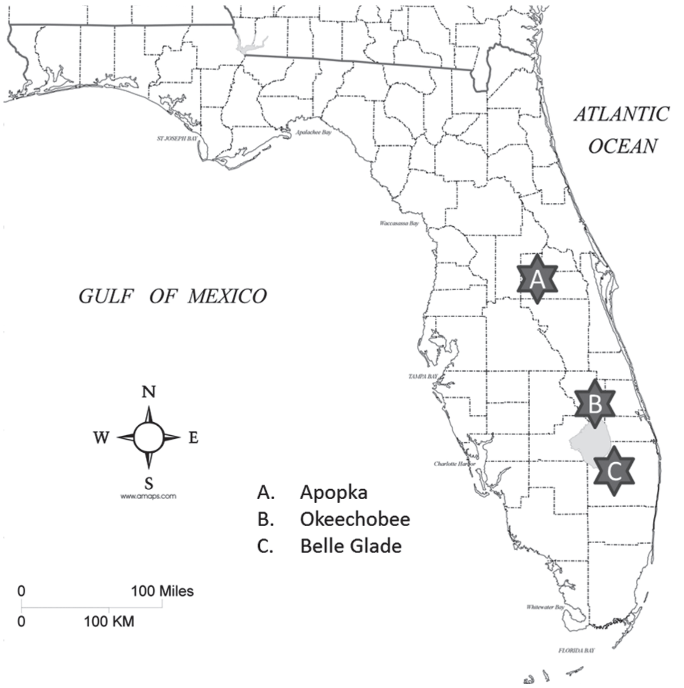

Fig. 1. Field locations for love bug, *Plecia nearctica*, trap testing in 2013 and 2014.

cases. Whereas cultural control methods such as removal of crop residues or improved drainage might reduce suitable breeding populations locally (D'Arcy-Burt & Blackshaw 1991), few options exist to control the adult stage. The development of an effective low-cost monitoring trap could be useful for both sampling and possibly reducing populations locally.

Although a sex pheromone has not been discovered, we previously reported that the floral compound phenylacetaldehyde (PAA) and yellow or white colors (Arthurs et al. 2012, 2013) were highly attractive to both sexes of adult *P. nearctica*. The next step is to optimize a trap design that would allow researchers and pest control specialists to capture large numbers of lovebugs during the flight season. Previous studies used yellow or white sticky cards for collecting lovebugs (Thornhill 1976; Cherry 1998; Arthurs et al. 2013). Other authors also used yellow pan (water) traps for collecting other bibionids in Europe (D'Arcy-Burt & Blackshaw 1987; Tomasovic 1992). Although effective, such traps require replacement or maintenance and are not convenient for routine use. The goal of the present study was to evaluate commercial and modified insect traps containing PAA lures for their suitability as lovebug traps.

Materials and Methods

FIELD LOCATIONS

Field studies were conducted over 2 yr in open flat pasture in 3 locations, i.e., in central Florida (Apopka) on bahiagrass, *Paspalum notatum* Flüggé (Poales: Poaceae), in southern Florida (Okeechobee) on bahiagrass with scrub palmetto, *Sabal* spp. (Arecales: Arecaceae), and further south below Lake Okeechobee near the Everglades (Belle Glade) on St. Augustinegrass, *Stenotaphrum secundatum* (Walter) Kuntze (Poales: Poaceae) (Fig. 1). Studies were conducted when adult lovebugs were abundant in May and Sep, during the main spring and fall flights, respectively.

EVALUATION OF COMMERCIAL TRAPS

In 2013, we evaluated various traps consisting of 3 basic types (i.e., sticky, funnel, and interception) for lovebug attractiveness (Table 1; Fig. 2). Each trap was baited with a lure consisting of 0.75 mL PAA (Fisher Scientific Co., Fair Lawn, New Jersey, USA) dispensed inside a 1.5 cm diameter hollow polyethylene stopper (Kimble, Vineland, New Jersey, USA) that was attached to the trap or trap entrance. To standardize color, the collecting surface of all traps was yellow; if necessary, traps were painted yellow using a non-toxic aerosol spray. All traps were hung vertically at 1 m height from a polyvinyl chloride (PVC) pole at 20 m spacing within treatment blocks and with blocks separated by at least 100 m. Traps A–F were evaluated at each location in the spring, whereas traps G–I were assessed at Apopka in the fall. Studies were a complete randomized block design with 5 replicates. An insecticidal strip (Hercon® Vaportape II containing 10% 2,2-dichlorovinyl dimethyl phosphate) was placed inside non-sticky traps to kill insects inside traps. Insects were collected after 24 to 72 h, depending on test location and insect abundance. Tests were terminated if sticky traps became covered with lovebugs. The sex ratio of lovebugs was determined (Apopka only) as described previously (Cherry 1998), and non-target insects were also counted.

UNITRAP MODIFICATION

Based on spring tests, we determined that the Unitrap (trap D) was most useful having the potential to be deployed for long time periods while capturing large numbers of lovebugs. Two modifications were tested to determine if the efficiency of this trap could be improved. First, our observations indicated that many lovebugs did not fall through the entrance funnel trap while visiting the traps. Hence, a thin layer of low resistance Fluon® paint (Insect-a-Slip, BioQuip, Compton, California, USA) was applied to the funnel entrance. Second, vanes comprising 2 vertical perpendicular collecting baffles above the entrance (i.e., similar to the Japanese beetle trap A) were tested

Table 1. Trap types used in lovebug tests (spring 2013).

Name	Type	Original target	Manufacturer	Fig. 2
Japanese beetle	Interception	Scarab beetles	Safer® Brand model #70102, Lititz, Pennsylvania	A
Ball AR934A	Funnel	Fruit flies, yellow jackets	ISCA Technologies, Riverside, California	B
Panel	Sticky	Aphids, thrips, etc.	Pestrap™, Earth City, Missouri	C
Universal moth (Unitrap)	Funnel	Moths	Great Lakes IPM, Vestaburg, Michigan	D
Delta Pherocon IIID	Sticky	Moths	Trécé, Inc., Adair, Oklahoma	E
Lindgren-modified[1]	Interception	Bark beetles	n/a	F
Stink bug trap[2]	Funnel	*Euschistis* spp.	Great Lakes IPM Inc.	G
Boll weevil trap[2]	Funnel	Cotton boll weevil	Great Lakes IPM Inc.	H
Fly trap[2]	Entrance holes in lid	Flies	Victor®, www.victorpest.com	I

[1]Homemade version with 2 L soda bottles.
[2]Painted yellow from manufacturer product.

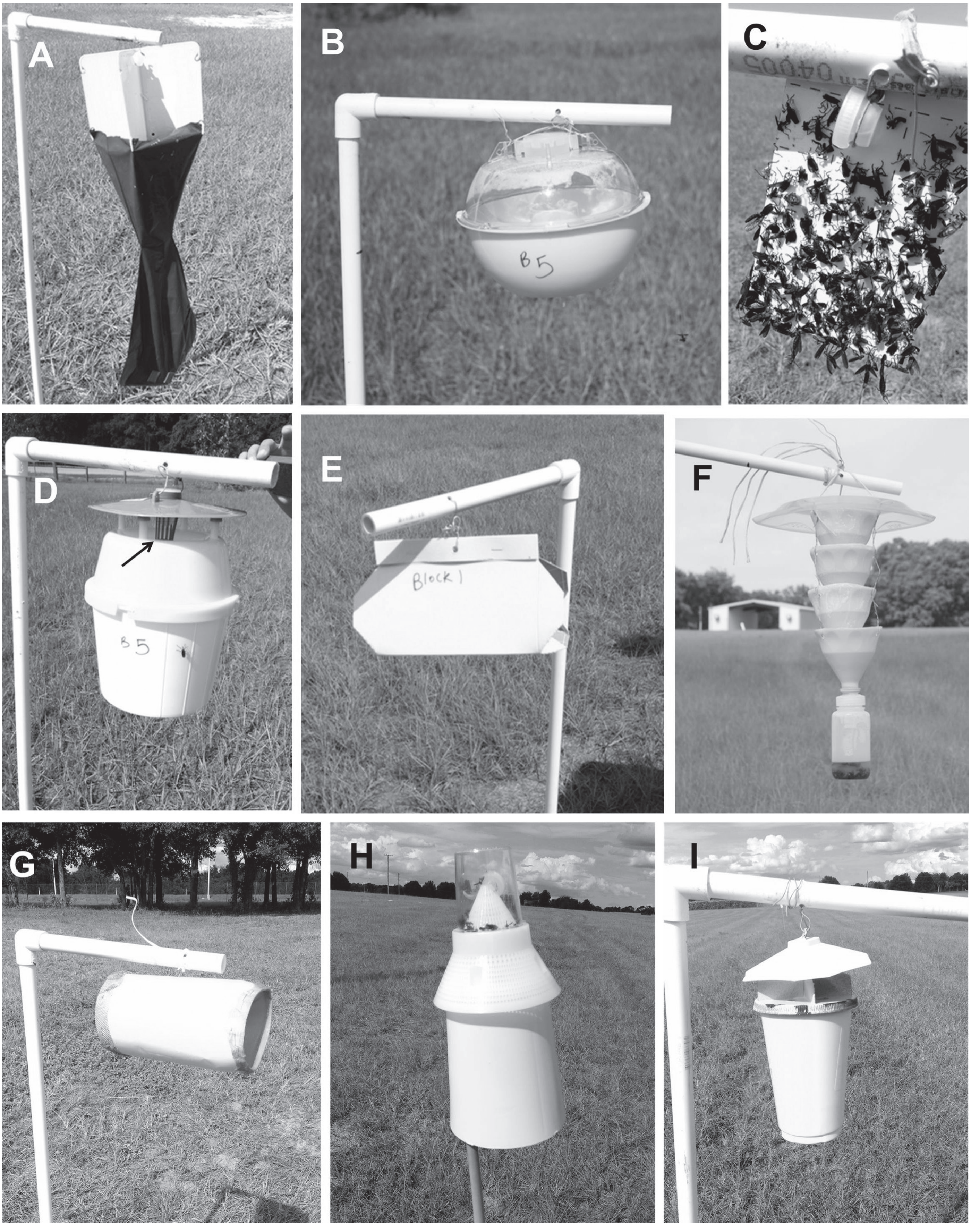

Fig. 2. Commercial or modified insect traps baited with phenylacetaldehyde and assessed for lovebug attractiveness in 2013 field tests (see Table 1).

to determine if they improved trap efficiency. The fluon study was a paired design with 5 replicates and was conducted in 2013 during the spring and fall (Apopka) and fall (Okeechobee). Each pair consisted of 1 standard (unmodified) trap and 1 fluon-modified trap hung at 1 m and located at 20 m spacing with ≥ 100 m between pairs. The trap with added vanes was included as an additional treatment in the fall test at Apopka. Insects were collected after 24 to 72 h, and the sex ratio and non-target arthropods were determined at Apopka.

RESIDUAL ACTIVITY OF PAA LURE

To determine if PAA dispensed in a polyethylene vial is a sufficient lure for the typical main 3 to 4 wk lovebug flight period, the residual attractiveness of this lure was evaluated under field conditions in Okeechobee during fall 2013. Five pairs of Unitraps were placed on PVC poles at 1 m height with 20 m spacing, with each pair separated by at least 50 m. At each location, 1 randomly chosen trap per pair was baited with 0.75 mL PAA; the other remained unbaited for comparison. Insecticide strips were used to kill collected insects. Traps were initially set on 9 Sep and lovebugs collected after 24 h. The process was repeated after 4, 7, 14, and 21 d. On each occasion, the traps were first emptied and collections made after an additional 24 h. All collected insects were frozen for subsequent counting in the laboratory. The lure was not replaced during the experiment. Comparisons between paired baited and unbaited traps were used to determine the attractiveness of the aged lure at different time intervals.

EFFECT OF LURE POSITION

An additional study in 2014 evaluated the effect of lure position with respect to the Unitrap. Lures were positioned outside in the supplied green basket positioned above the funnel (Fig. 2D arrowed) or else inside the collecting bucket. An additional trap, broadly similar to the Unitrap but containing small holes in the collecting funnel and about 30% smaller, was included (Better World Manufacturing, Fresno, California, USA; Fig. 3A). The holes theoretically improve odor dissipation from lure that is designed to be placed inside the trap, favoring insect movement down the funnel into the collecting bucket. The clear collecting bucket of the new trap was painted white (similar to the Unitrap) to increase its attractiveness. Tests were conducted in the fall at Apopka and Belle Glade. The study was a random block design with 5 replicates and traps hung on PVC poles at 1 m as previously described.

DATA ANALYSES

Differences in lovebugs captured in different traps at each location were determined by 1-way or 2-way ANOVA and mean separations conducted using the least significant difference (LSD) test (SAS Institute 2012). Independent *t*-tests were used to compare the effect of lure position within a trap type. Counts were transformed via log(n+1) if needed to normalize data. Chi square analysis with Yates correction was used to determine if the sex ratio of lovebugs differed significantly among the various treatments. Linear regression was used to model the residual attractiveness of PAA lures and unbaited traps for lovebugs over time.

Results

EVALUATION OF COMMERCIAL-TYPE TRAPS

In spring tests, 12,139 lovebugs and 805 other insects (i.e., approx. 6% of total) were collected among the different traps, suggesting that

Fig. 3. Better World funnel trap with collecting bucket painted white and with upper holes in entrance funnels visible (arrowed) (A); inside of Unitrap containing several thousand lovebugs (B).

most traps (when baited with PAA) were relatively specific for lovebugs. The effect of trap type was significant at all locations (Table 2). Overall, the sticky panel trap caught the most lovebugs, although we noted that this trap became completely filled with insects within 24 h under high density, and hence would not be suitable for extended periods. Of the other traps, the Unitrap, Japanese beetle, and modified Lindgren traps were effective and caught statistically similar numbers of lovebugs at each location. The Delta and Ball traps caught few lovebugs. We observed that lovebugs did not readily enter these traps, with most remaining on the outside of the traps. The boll weevil trap, fly trap (Victor), and stink bug trap were less effective when compared with the Unitrap in the fall (Table 3). Overall, lovebugs sex ratio was even (52% female at Apopka). There was no statistical association between the sex of lovebug and trap type in the spring (χ^2 = 2.6, df = 5, P = 0.77). However, in the fall test using different trap types, a higher proportion of female lovebugs were captured in fly traps (63% female) compared with other traps (χ^2 = 11.0, df = 2, P < 0.01) at Apopka for unknown reasons.

Non-target insects were also significantly affected by trap type in the spring (pooled across sites) ($F_{5,84}$ = 7.3, P < 0.0001) and fall (Apopka) ($F_{3,16}$ = 36.6, P < 0.0001). Highest catch of non-target insects was observed in the Japanese beetle trap (34% of total) followed by the Lindgren trap (30% of total). These insects mostly comprised incidental beetles of the Cantharidae and Chrysomelidae and moths of the Noctuidae, which may have been attracted by the PAA (Meagher 2001, 2002).

UNITRAP MODIFICATION

In 3 tests, 22,659 lovebugs and 468 other insects (i.e., 2.1% of total) were collected. Traps with fluon caught approx. twice as many lovebugs as unmodified traps, both during the late spring after peak flight (Apopka) and during peak flight periods in the fall (Table 4). Although the increased captures in fluon-modified traps was not statistically significant at each location separately, it was significant when data were pooled across locations ($F_{1,18}$ = 5.1, P < 0.05). Fewest lovebugs were captured in traps in which vanes were fitted (Table 4). There was no significant association between the sex of lovebugs caught and trap type in the spring (χ^2 = 0.07, df = 1, P = 0.44) and fall tests (χ^2 = 2.0, df = 2, P = 0.37) at Apopka. Trap modification did not statistically affect the numbers of non-target insects caught at Apopka in the spring ($F_{1,8}$ = 1.1, P = 0.33).

RESIDUAL ACTIVITY OF PAA LURE

In this study, 24,472 lovebugs were caught in PAA-baited traps over 3 wk, compared with 604 in unbaited traps. An attractiveness quotient (AQ) based on the ratio of lovebugs caught in baited traps compared with paired unbaited traps was calculated. The AQ accounted for differences in lovebug populations based on environmental conditions or other factors that might influence trap catches over time, because both baited and unbaited traps were affected equivalently. A linear function ln(AQ+1) showed a significant negative correlation (P < 0.01), with approx. 57% of the variance of the ratio of baited versus unbaited traps over time explained by the linear regression model (Fig. 4). Our data suggest that the PAA lure remained attractive for at least 2 wk under the described field conditions.

Table 2. Number of lovebugs captured in different traps (spring 2013).

Trap	Belle Glade (24 h)	Okeechobee (24 h)	Apopka (72 h)
Panel	324 ± 32 a	439 ± 44 a	126 ± 40 a
Unitrap	193 ± 65 a	136 ± 37 b	64 ± 12 a
Japanese beetle	344 ± 227 a	60 ± 8 b	61 ± 15 a
Lindgren-modified	240 ± 102 a	98 ± 22 b	94 ± 17 a
Delta Pherocon IIID	22 ± 10 b	22 ± 6 c	5 ± 2 b
Ball AR934A	3 ± 1 b	4 ± 1 d	4 ± 1 b

Data are mean ± SE from 5 replicates per location, test duration in parentheses. Means in a column followed by the same letter are not significantly different, 1-way ANOVA per location (LSD at P < 0.05).

Table 3. Adult lovebugs captured in different traps (fall 2013).

Trap	Apopka (72 h)
Unitrap	128 ± 46 a
Fly trap (Victor)	33 ± 15 b
Boll weevil trap	28 ± 6 b
Stink bug trap	0 ± 0 c

Data are mean ± SE from 5 replicates. Means followed by the same letter are not significantly different (LSD at P < 0.05).

EFFECT OF LURE POSITION

Overall, 22,431 lovebugs and 180 non-target insects (< 1% of total) were caught in this test. More lovebugs were caught in the Unitrap compared with the BetterWorld trap ($F_{1,16}$ = 130.7, P < 0.0001). However, within traps, in the Unitrap more lovebugs were collected with the lure positioned in the pheromone basket compared with inside the trap, although this difference was not statistically significant (Table 5). Conversely, in Better World traps significantly more lovebugs were caught with the lure placed inside the trap. There was also an interaction with trap type and lure location ($F_{1,16}$ = 16.7, P < 0.001), as the importance of the lure position varied between the 2 trap types. Lovebug populations remained very low in the tests at Belle Glade, for unknown reasons, which prevented statistical comparisons being conducted.

Discussion

Different trap types have not previously been compared for collecting *P. nearctica*. Our objective was to evaluate insect traps that are relatively inexpensive, commercially available, easily deployed, and effective over a 3 to 4 wk seasonal flight period with a PAA lure, while minimizing the collection of non-target insects. Among commercial traps, the yellow and white Unitrap used for collecting moths was effective, as it caught thousands of lovebugs with relatively few non-targets (i.e., ≤ 6% of total catch in our studies), is reuseable for multiple seasons, and can potentially be improved by the addition of fluon or similar non-stick material to the entrance. The lure (polypropylene vial containing liquid PAA) was attractive to lovebugs for at least 2 wk under field conditions. The attractiveness of the PAA lure likely declined by week 3, possibly due in part to declining numbers of lovebugs available for capture as the flight season declined. The residual activity of the

Table 4. Lovebugs caught in Unitraps with and without modification (fall 2013).

Treatment	Okeechobee fall (24 h)	Apopka spring (48 h)	Apopka fall (72 h)
Standard	687 ± 306 a	18 ± 3 a	590 ± 179 ab
+Fluon	1,520 ± 312 a	38 ± 9 a	1,194 ± 507 a
+Vanes	—	—	283 ± 106 b

Data are mean ± SE from 5 replicates per location; 1-way ANOVA not significant in any test.

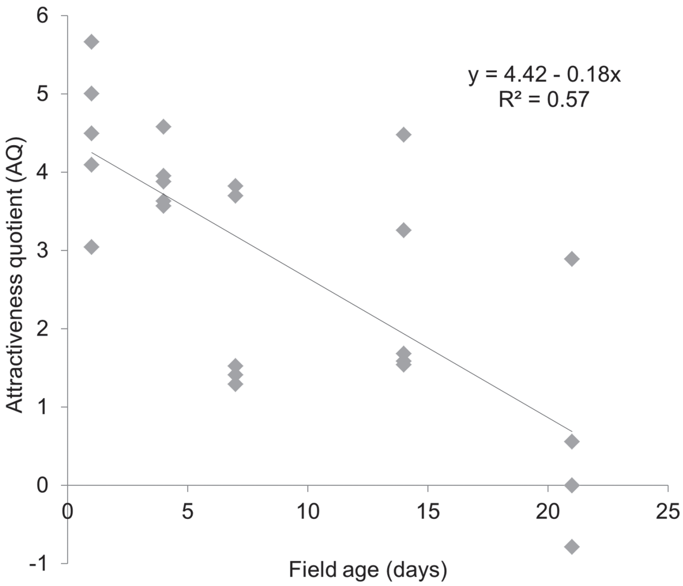

Fig. 4. Linear regression describing attractive quotient (AQ) of the phenylacetaldehyde baited Unitraps for capturing lovebugs over time, when compared with equivalent paired unbaited traps in field tests in Okeechobee, Florida.

volatile lure would presumably be influenced by wind speed, temperature, or other factors. Replacement of the lure after 2 wk if needed would help optimize trap catch during the lovebug flight season.

Several improvements for the Unitrap are proposed. Firstly, encapsulating PAA in a slow-release wax (Meagher 2002) or membrane for commercial deployment might be beneficial to provide a long-life lure and prevent the need for a volatile liquid. Further studies to confirm the attractiveness and optimize the release period of such solid lures are needed. Secondly, the use of a non-stick funnel entrance may increase trap efficiency. The fluon used in our tests was rather water soluble and unlikely to be long lasting under heavy rains. Adding a permanent non-stick surface such as polytetrafluoroethylene (PTFE) to the funnel entrance may provide a more efficient trap.

The utility of lovebug traps for control likely will depend on the situation. Although lovebug swarms are problematic for motorists, the use of traps alongside long stretches of roadways is unlikely to be practical in most cases. However, the selective deployment of traps in yards, gardens, gas stations, athletic fields, and other smaller areas where lovebugs become a nuisance may be beneficial. Because adult lovebugs emerge from pastures, hammocks, and other vegetated areas, a line of strategically placed traps at the urban fringe may intercept populations before they move into adjacent populated areas. However, this hypothesis remains to be tested. It is also unknown whether deployment of lovebug traps might result in increased numbers of insects due the “trap spillover” phenomenon that has been noted for other insects. Switzer et al. (2009) noted that traps placed to capture Japanese beetles, *Popillia japonica* (Newman) (Coleoptera: Rutelidae), in a soybean field attracted many beetles without capturing all of them, resulting in increased damage to surrounding plants.

Table 5. Lovebugs caught in 2 trap types with different positioning of the PAA lure (Apopka, fall 2014).

Lure position	Unitrap	Better World
Outside trap	2,336 ± 541 a	213 ± 42 a
Inside trap	1,470 ± 171 a	468 ± 40 b

Data are mean ± SE from 5 replicates. Means in a column followed by the same letter are not significantly different (independent sample *t*-test at $P < 0.05$).

Finally, because all our traps were placed 1 m high, the most effective height for trap deployment for lovebugs should also be investigated. Lovebug mating flights are generally reported at low altitudes, such as 1 to 3 m (Buschman 1976; authors’ observations). However, Leppla et al. (1974) noted male lovebugs hovering up to 12 m in the air looking for females, even on windy days.

We observed large differences in the numbers of lovebugs collected between locations and years in our studies. There are anecdotal reports that lovebug populations have declined substantially in North Central Florida, and possibly elsewhere, in recent years (Weston et al. 2011). Such differences in lovebug abundance may reflect changes in the suitability of larval breeding habitats, the combined action of predators and fungal pathogens as well as wind direction or other climatic variables influencing trapping efficiency (Hetrick 1970; Kish et al. 1974; Weston et al. 2011). We noted large numbers of birds, including swifts and cattle egrets, and dragonflies feeding extensively on adult lovebugs in some locations. However, quantitative studies into the effects of different environmental factors on lovebug populations are lacking. The use of traps would be useful in quantitative studies of mortality (or management) factors for this insect.

In summary, at this point our research has shown that the Unitrap in conjunction with PAA lure has several advantages over other tested traps for catching lovebugs for research and sampling purposes. Possible refinements for trap catches of lovebugs might be investigated in the future. This trap should also be investigated further for possible reduction of lovebug populations.

Acknowledgments

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