Trapping Pestiferous Fruit Flies (Diptera: Tephritidae): Additional Studies on the Performance of Solid *Bactrocera* Male Lures and Separate Insecticidal Strips Relative to Standard Liquid Lures

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Abstract. Detection of pestiferous *Bactrocera* fruit flies relies largely on traps baited with male-specific attractants. Surveillance programs in Florida and California use liquid methyl eugenol (ME, attractive to males of *B. dorsalis* (Hendel)) and liquid cue-lure (CL, attractive to males of *B. cucurbitae* (Coquillett)) mixed with the toxicant naled to bait traps. However, the application of the liquids requires considerable time and may subject personnel to health risks from inadvertent exposure to the lure and the insecticide. Recent studies have shown that solid dispensers containing a toxicant perform as well or better than liquid lures, but the combination of lure and toxicant in the same solid dispenser faces registration problems. Fewer studies have assessed the efficacy of solid, and separate, lures and toxicants, but existing data are promising. Here, we present the results of two independent studies that further assess the effectiveness of solid ME and CL lures and their associated, but separate, insecticidal strips. The first study, conducted exclusively in Hawaii over a 12 week period, found that captures of *B. dorsalis* or *B. cucurbitae* males were similar between traps baited with the standard liquid formulation and traps baited with solid lure dispensers and either 1 or 2 insecticidal strips. In the second study, solid lure dispensers and associated insecticide strips were weathered for 6 or 12 weeks under summer conditions in Arizona and Florida, where high temperatures were presumed to result in high volatility and thus provide a rigorous test of field longevity. Aged materials were shipped to Hawaii for testing against fresh (non-weathered) lures and insecticidal strips in wild populations. The results were fairly consistent between Arizona- and Florida-weathered devices and indicated that (i) solid ME dispensers were effective for 6 weeks but lost significant attractancy at 12 weeks and (ii) CL solid lures and the insecticidal strips were effective for at least 12 weeks. Collectively, these findings provide additional evidence that surveillance programs could switch to solid lures and toxicants and maintain a high level of detection sensitivity.

Introduction

The genus *Bactrocera* (Diptera: Tephritidae) contains approximately 500 species occurring primarily in tropical Asia (Drew and Hancock 2000). Of these, about 70 species are serious pests that attack a wide range of commercially important vegetables and fruits (White and Elson-Harris 1992). Two of these species, the oriental fruit fly, *B. dorsalis* (Hendel) and the melon fly, *B. cucurbitae* (Coquillett), are invasive threats to US agriculture, and southern states, such as California, Florida, and Texas, maintain continuous

trapping programs to detect incipient infestations (IPRFFSP 2006). Detection relies chiefly on male-specific attractants, namely methyl eugenol (hereafter ME; 4-allyl-1, 2-dimethoxybenzene-carboxylate) for *B. dorsalis* and cue-lure (hereafter CL;4-(*p*-acetoxyphenyl)-2-butanone) for *B. cucurbitae*, and in present practice, these male lures (containing the insecticide naled, 1,2-dibromo-2,2-dichloroethyl dimethyl phosphate) are applied as liquids to cotton wicks, which are then placed in traps.

The application of liquid lures, however, is time-consuming (Vargas et al. 2009) and entails health risks arising from inadvertent contact with both the lures and the toxicant (National Toxicology Program 2000). As a result, there is considerable interest in the development and implementation of solid dispensers for *Bactrocera* detection that minimize handling time and exposure risk. There are a number of published studies (see Tan et al. 2014 for references) demonstrating that solid polymeric ME- or CL-containing plugs or wafers are at least as effective as the standard liquid formulations. In most cases, however, the solid dispensers tested contained both the male lure and a toxicant, and such "combination" products are not approved for USDA-APHIS fruit fly surveys (J. Crowe, pers. comm.). This has prompted additional fieldwork assessing the effectiveness of traps baited with solid male lures and separate insecticidal (DDVP, 2,2-dichlorovinyl dimethyl phosphate) strips. The results obtained thus far are encouraging and show that, even with separate presentation of male lure and insecticide, traps with solid dispensers are at least as effective as the standard liquid formulations (Jang et al. 2013; Shelly 2013).

In addition to documenting the effectiveness of solid *Bactrocera* male lures, data from Shelly (2013) indicated that DDVP was an effective killing agent when presented in doses much lower than previously tested. In the Hawaii Fruit Fly Area-Wide Pest Management Program (Mau et al. 2007; Vargas et al. 2008), bucket traps containing a male lure and a Vaportape II strip (2.5 x 10 cm, 2 mm thick, 0.58 g DDVP, Hercon Environmental, Emigsville, PA) were employed in detection efforts. However, Jang (2010) and Jang et al. (2013) showed that this strip initially repelled flies and suppressed captures, presumably because of the strong outgassing of DDVP. Shelly (2013) manipulated DDVP dose in traps while maintaining uniform doses of male lure and found that DDVP strips (2.54 cm^2 squares, 2.0 mm thick, Plato Industries Inc., Houston, TX) containing only 0.09 g of DDVP were as effective as the standard naled dose in liquid lures after 6 weeks of field weathering. If further validated, the use of these small DDVP strips would result, not only in reduced insecticide use, but also considerable cost saving.

The present study describes two separate field experiments undertaken to further evaluate the performance of solid *Bactocera* male lures along with the 2.54 cm square DDVP strips (i) over a longer weathering interval (12 weeks) in Hawaii and (ii) after weathering under hot summer conditions in two mainland US locations. For the latter experiment, solid lures and toxicants were weathered for 6 or 12 weeks in Nogales, Arizona, or Sarasota, Florida, then shipped to Hawaii, and tested against both fresh liquid formulations and fresh solid lure and toxicant devices. The two weathering locations, selected because of their high summer temperatures (see below), presumably resulted in accelerated release rates of the active ingredients from the solid devices (Domínguez-Ruiz et al. 2008) and thus provided conservative estimates of the effective field longevity of both the solid

lure and the toxicant. Note that Jang et al. (2013) used this same basic protocol—weathering on the mainland US, followed by testing in Hawaii—but investigated combination dispensers containing both lure and toxicant combination. As a result, the effects of ageing of the male lure versus the toxicant on trap catch could not be distinguished in that study.

Materials and Methods

Methods (as well as Results) are described separately for the two experiments, hereafter termed the 'Hawaii weathering' and 'Mainland weathering' experiments, respectively.

Hawaii weathering. *Study site*. Trapping was conducted from February to May, 2014, in Waimanalo, Oahu, a lowland area (< 30 m elevation) of mixed agricultural, nursery, and residential lots. Weather data for the 12-week period were obtained on-line (http://wunderground.com) for the Kaneohe Marine Corps Base, approximately 10 km from the study area.

Traps, lures, and toxicants. Jackson traps (Better World Mfg., Fresno, CA) were used exclusively. These traps were triangular in shape, white in color, and made of thick, waxed paper (12.7 x 9.5 x 8.4 cm, l:w:h). A removable insert, made of the same waxed paper as the trap body and coated with "stickum," was placed on the bottom of the trap to catch flies. Traps were suspended from branches of non-host trees (primarily *Leucaena leucocephala* (Lam.) de Wit) using a metal hanger, with a straight portion positioned under the "roof" along the apex of the trap.

Liquid lures (Farma Tech International, North Bend, WA) were applied to cotton wicks (2.5 cm in length, 2.0 cm in diameter), which were placed in plastic, perforated baskets. The baskets were fastened to the metal hanger and suspended in the middle of the trap directly above the sticky insert. Six ml of ME (1% naled) or 6 ml of CL (5% naled) were used per wick. Wicks contained either ME or CL; the two lures were never applied together as a blend. Two types of solid dispensers were used, namely plugs (Scentry Biologicals Inc. Billings, MT) and wafers (Farma Tech International). [The use of two different types of solid dispensers from two different vendors in this experiment (and in the following experiment as well) was a programmatic decision]. Plugs were cylindrical (2.5 x 1.5 cm; length:diameter), and wafers were rectangular (7.5 x 5.0 cm, 0.2 cm thickness). Both dispenser types contained 6 g of a single lure (ME or CL), and as the specific gravity of these lures is approximately 1.0, the amount of lure in the solid dispensers was approximately the same as that contained in the liquid formulation. In the traps, plugs were held in two plastic baskets fastened together mouth-to-mouth (basket covers were removed beforehand) with wire and suspended from the metal hanger (Fig. 1A). The wafers were suspended in the Jackson traps by inserting a "twist tie" through a pre-made hole along one of the long sides of the dispenser, and wrapping this around the hanger (Fig. 1B). All traps baited with solid male lures used 1 or 2 (see below) of the aforementioned 2.54 cm square DDVP strips as the killing agent. In traps containing a CL plug, the strip(s) was placed in the same perforated baskets holding the CL plug (Fig. 1A). In traps containing an ME wafer, the strip(s) was placed in a perforated basket (from which the cover had been removed), and the basket was then stapled directly on the wafer (Fig. 1B).

Trapping protocol. Traps were placed at 60 stations for each sampling interval, and each station contained two Jackson traps, one baited with ME and the other with CL. There were 5 different station types (each replicated 12 times) based on the lure dispensers and toxicants used, namely:

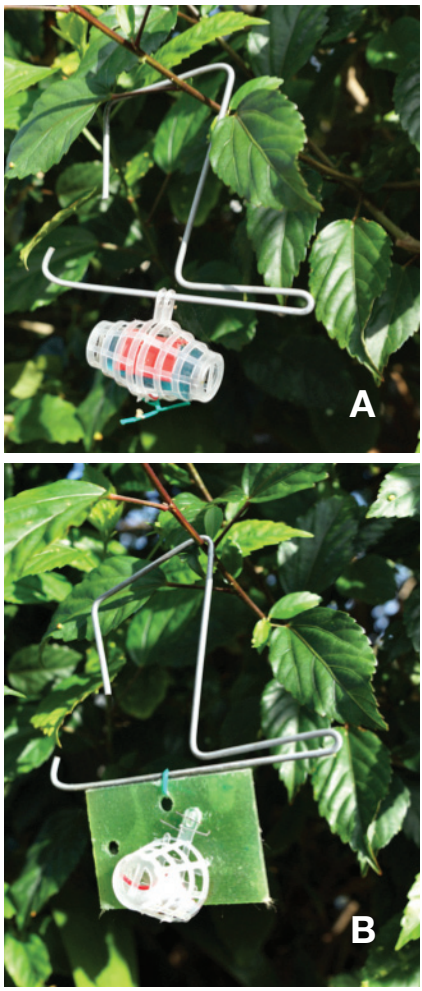

Figure 1. (A) CL plug contained in two face-to-face perforated baskets along with Plato strip (red object). (B) ME wafer with plastic basket holding DDVP strip affixed. Photos show the lures and DDVP strips only, and when deployed in the field, these were housed in Jackson traps.

(i) ME liquid and CL liquid each mixed with naled, (ii) ME plug and CL plug each with 1 DDVP strip, (iii) ME plug and CL plug each with 2 DDVP strips, (iv) ME wafer and CL wafer each with 1 DDVP strip, and (v) ME wafer and CL wafer each with 2 DDVP strips. Thus, during a given sampling interval, there were 120 traps in total, 60 ME-baited traps (12 stations X 5 lure/toxicant treatments) and 60 CL-baited traps.

Trapping was conducted when lures/toxicants were aged 0 (fresh), 6, 8, 10, and 12 weeks. During each sampling interval, traps were operated for 24 h. As noted above, traps were placed on non-host trees between 1–3 m above ground in shaded locations. At a particular station, the ME and CL baited traps were separated by a minimum of 2–3 m to avoid possible interference (Vargas et al. 2000). Trapping stations were separated by a minimum of 50 m. Upon collection, traps were returned to the laboratory, the sticky inserts were removed, the flies were counted, and the traps (minus the insert) were hung in a shaded area outside the laboratory for ageing. All treatments, including the wicks containing standard liquid mixtures, were aged in this experiment.

Data analysis. For each species, captures were compared among the different lures/toxicant combinations independently for each ageing period using a 1-way ANOVA. In all cases, the raw data or $\log_{10}$ transformed data met the parametric assumptions of normality and homoscedasticity. Where significant variation was detected, Tukey's multiple comparisons test was used to identify pair wise differences. Captures were not compared across different ageing intervals, since without systematic monitoring of wild populations, we could not ascribe temporal variation in captures to changes in fly abundance or the potency of the lures/toxicants.

Mainland weathering. *Study site*. Weathering of lures and toxicants was conducted in Nogales, AZ, and Sarasota, FL, and in both states occurred within established areas for fruit fly monitoring.

Climatological data were obtained from the National Climatic Data Center (NCDC) and were derived from measurements taken at the Nogales International Airport, Nogales, AZ, and the Sarasota-Bradenton International Airport, Sarasota, FL.

Traps, lures, and toxicants. Jackson traps were used exclusively for weathering in Arizona and Florida and testing in Hawaii. The materials and procedures associated with liquid ME and CL and the ME wafers were identical to those described above. For CL, we used cylindrical plugs (2.5 x 1.5 cm) containing 3 g of the lure (Scentry Biologicals Inc., Billings, MT); Shelly(unpublished data) showed that traps baited with plugs with 3 g CL captured comparable numbers of male melon flies as traps baited with 6 ml of liquid CL or plugs with 6 g CL. The CL plugs were placed in plastic, perforated baskets, which were fastened to the metal hanger and suspended in the middle of the Jackson trap. Traps were baited with either ME or CL, never both. The same 2.54 cm square DDVP strips mentioned above were used in the weathering and testing of the solid lure dispensers, but in this experiment only 1 DDVP strip was used per trap. As above, a plastic basket containing the DDVP strip was stapled directly on to the ME wafers. For traps with CL plugs, the DDVP strip was placed in a basket that was suspended adjacent to the lure-holding basket.

Weathering procedures. In both Arizona and Florida, two sets each of 15 ME wafers and 15 CL plugs were placed in the field, one set being aged for 6 weeks, which is the standard servicing interval (i.e., interval between replacement of the cotton wick containing the liquid lure/toxicant formulation, IPRFFSP 2006) for *Bactrocera* detection traps, and the other for 12 weeks. Thus, investigators in each location weathered and then shipped 60 solid dispensers (and their associated DDVP strips) to Hawaii for eventual testing: 15 ME wafers and 15 CL plugs weathered 6 weeks and 15 ME wafers and 15 CL plugs weathered 12 weeks. All solid dispensers and DDVP strips were held in Jackson traps (lacking sticky inserts) that were placed in trees (primarily, but not exclusively, host plants) at a height of 1.5–2.0 m above ground. In Arizona, the first set was placed in the field on June 16–17, 2014, and all traps were collected on September 10, 2014. In Florida, the first set was placed in the field on June 24–25, 2014, and all traps were collected between September 16–18, 2014. The second set of traps was placed on the same (or nearby) trees as the first of traps, which were left in place and not removed. All traps were removed 6 weeks following the placement of the second set of traps.

Either on the day of collection or one day later, the lures and DDVP strips were wrapped in aluminum foil and placed in appropriately labelled sealable plastic bags. All materials were then shipped via express courier to Hawaii, with 2–3 days required for delivery.

Field testing in Hawaii. Trapping was conducted at two locations on Oahu, a coffee (*Coffea arabica* L.) field near Haleiwa with high numbers of *B. dorsalis* and Aloun Farm near Kapolei with a large population of *B. cucurbitae*. The two sites, separated by 25 km, are low elevation (< 200 m elevation) and are similar climatically. During the testing period, the daily minimum, maximum, and average temperatures were 19.6°C, 28.3°C, and 23.8°C, respectively, at Haleiwa and 21.3°C, 32.0°C, and 26.2°C, respectively, at Kapolei (weatherwarehouse.com). The skies were generally clear or partly cloudy, and total rainfall was < 0.5 cm at both locations.

Weathered lures and DDVP strips were tested within 1–5 d of their arrival to Hawaii. At each site, lures and their associated DDVP strips were tested separately

in two successive 24 h periods. As noted above, weathering was staggered between Arizona and Florida, and correspondingly the Arizona materials were tested one week before the Florida materials (September 15–18 and September 23–26, respectively). At both sites and for both lure and toxicant assessment, we placed 15 traps per treatment (see below) in the field. Traps at both sites were separated by a minimum of 50 m, with traps at the Haleiwa site being placed approximately 1 m above ground on coffee plants (a host plant of *B. dorsalis*) and those at the Kapolei site being placed 1.5–2 m above ground in a citrus grove surrounded by large commercial fields devoted to production of various cucurbits, i.e., squashes and melons.

In testing lures, the following treatments were used: (i) fresh liquid ME or CL (containing naled as noted above) on a cotton wick, (ii) fresh ME wafer or CL plug with fresh DDVP strip, (iii) 6-week-aged ME wafer or CL plug with fresh DDVP strip, and (iv) 12-week-aged ME wafer or CL plug with fresh DDVP strip. Thus, in all treatments the toxicant was fresh, while the lures were either fresh (no weathering) or had been weathered 6 or 12 weeks. The fresh DDVP strips used in Hawaii used were the same type and were positioned in the same manner as the DDVP strips weathered in Arizona and Florida. Traps (n = 4 treatments X 15 traps/treatment = 60 total traps) were collected 24 h after deployment, and the numbers of *Bactrocera* males captured were tallied for each trap.

One day after the lure assay, a second set of traps was deployed to examine the effects of weathering on the effectiveness of the DDVP strips. The following treatments were used: (i) fresh liquid ME or CL (containing naled as noted above) on a cotton wick, (ii) fresh ME wafer or CL plug with fresh DDVP strip, (iii) fresh liquid ME or CL with 6-week-aged DDVP strip, and (iv) fresh liquid ME or CL with 12-week-aged DDVP strip. Thus, in all treatments the lure was fresh, while the DDVP strips were either fresh (no weathering) or had been weathered 6 or 12 weeks.

Data analysis. For both *Bactrocera* species, we used one-way ANOVA (with $\log_{10}$ transformed data) to examine potential differences in trap capture among treatments related to lure and toxicant effectiveness, respectively. Transformed data met the parametric assumptions of normality and homoscedasticity in all cases except one (assessment of toxicant weathering in Florida on capture of *B. dorsalis*), and in this instance the Kruskal-Wallis test, a non-parametric analogue of one-way ANOVA, was employed. Where significant variation was detected, Tukey's multiple comparisons test was used to identify pair wise differences.

Results

Hawaii weathering. *Climatological data*. In Waimanalo, temperatures were moderate, humidity was generally high, and rainfall was low during the study period (Table 1).

Bactrocera dorsalis. Variation in captures was not significant among the 5 different lure/toxicant treatments for weathering intervals of 6, 8, 10, or 12 weeks (Table 2). For fresh treatments (0 weeks ageing), traps containing an ME wafer and 1 DDVP strip captured significantly more *B. dorsalis* males than traps baited with an ME plug and 1 DDVP strip, while no other comparisons revealed significant differences.

Bactrocera cucurbitae. Captures of *B. cucurbitae* males did not vary significantly among treatments for any of the ageing intervals tested (Table 2).

Mainland weathering. *Climatological data*. With respect to temperature, the average daily maximum temperature

Table 1. Climatological data for Waimanalo, HI, over the 12 weeks of lure and toxicant weathering/testing from February to May, 2014 (Hawaii weathering experiment), and for Nogales, AZ, and Sarasota, FL, over the 12 weeks of lure and toxicant weathering from June to September, 2014 (Mainland weathering experiment). All values, except those for rainfall, are daily averages based on hourly measurements. Rainfall represents total amount of precipitation over the 12-week periods.

	Waimanalo Feb–May	Nogales June–Sept	Sarasota June–Sept
Parameter			
Temperature (°C)			
Minimum	21.2	18.5	24.4
Maximum	26.9	33.5	33.5
Average	24.1	26.1	29.1
Relative humidity (%)	68.1	52.0	71.7
Rainfall (cm)	7.2	31.3	22.3
Wind speed (km/h)	----	7.8	10.9

Table 2. Captures of *Bactrocera dorsalis* and *B. cucurbitae* males in traps baited with liquid male lures (with naled) or solid polymeric wafers or plugs (with either 1 or 2 DDVP strips). See text for details regarding the different lure/insecticide treatments. Lure/toxicant combinations were tested when aged 0 (fresh), 6, 8, 10, and 12 weeks. Values are averages ± SE; n = 12 traps per lure/toxicant combination per ageing interval.

	Age (weeks)				
Lure dispenser/toxicant	**0**	**6**	**8**	**10**	**12**
Bactrocera dorsalis					
Liquid/naled	149 (33)[ab]	75 (18)	38 (15)	44 (13)	23 (4)
Wafer/1 DDVP strip	254 (45)[a]	116 (24)	58 (18)	41 (15)	21 (3)
Wafer/2 DDVP strips	237 (50)[ab]	128 (27)	49 (12)	58 (13)	24 (3)
Plug/1 DDVP strip	113 (23)[b]	90 (22)	37 (20)	56 (18)	15 (4)
Plug/2 DDVP strips	132 (25)[ab]	85 (24)	36 (14)	54 (24)	23 (4)
F value[1]	3.72	1.23	1.64	0.35	0.08
Significance[2]	P = 0.01	ns	ns	ns	ns
Bactrocera cucurbitae					
Liquid/naled	5 (2)	18 (8)	4 (1)	9 (3)	6 (2)
Wafer/1 DDVP strip	8 (4)	11 (5)	8 (3)	10 (5)	10 (3)
Wafer/2 DDVP strips	7 (2)	11 (4)	4 (1)	5 (1)	5 (1)
Plug/1 DDVP strip	5 (1)	7 (1)	4 (1)	9 (3)	5 (2)
Plug/2 DDVP strips	8 (3)	8 (2)	4 (1)	10 (3)	6 (2)
F value	0.33	0.27	0.58	0.61	1.44
Significance	ns	ns	ns	ns	ns

[1]Each weathering age was analyzed separately using 1-way ANOVA (i.e., the test compared values within columns, not across rows). Non-significant F values (P > 0.05) are designated ns; for the single significant F value, means sharing a letter were not significantly different.

was identical in two locations over their respective sampling intervals, but average daily minimum temperatures were noticeably lower in Nogales than Sarasota (Table 1). Consequently, the daily average temperature was slightly higher in Sarasota than Nogales. Not surprisingly, Sarasota was generally more humid than Nogales, although owing to intense summer storms, total rainfall during the sampling interval was greater in Nogales than Sarasota (Table 1). Average winds were light and not appreciably different between the two locations.

Bactrocera dorsalis. The effects of weathering on the solid ME dispensers differed slightly between Arizona and Florida. For traps containing ME wafers aged in Arizona, those with 12-week-aged wafers captured significantly fewer *B. dorsalis* males than the other treatments, among which there were no statistically significant differences (Fig. 2). For traps containing ME wafers aged in Florida, traps with the 12-week-aged ME wafers likewise captured fewer *B. dorsalis* males than traps baited with fresh ME (liquid or wafer; Fig. 2). For the Florida lures, however, there was no significant difference in catch between traps baited with 6-week- and 12-week-aged lures. For both the Arizona and Florida lures, traps with fresh ME wafers captured more *B. dorsalis* males than fresh liquid ME, but the difference was significant only for the Florida samples. Overall, higher numbers of *B. dorsalis* males were captured during testing of the Arizona-weathered lures than the Florida-weathered lures, most likely reflecting temporal variation in the abundance of wild flies.

As with the ME lures, the effectiveness of the DDVP strips in ME baited traps varied between Arizona and Florida. For the Arizona materials, traps containing 12-week-aged DDVP strips captured significantly fewer *B. dorsalis* males than fresh naled (with fresh liquid ME) or fresh DDVP strips (with fresh ME wafers) (Fig. 3). Captures in traps baited with 6-week-aged DDVP strips were intermediate between fresh toxicants and 12-week-aged DDVP strips and did not differ significantly from the other treatments. In contrast, for the Florida toxicants, there were no significant differences among any of the treatments (Fig. 3).

Bactrocera cucurbitae. There were no significant differences detected among any of the treatments for the lure tests (Fig. 4) or the toxicant tests (Fig. 5) for either the Arizona- or Florida-weathered materials. As noted for *B. dorsalis*, higher numbers of *B. cucurbitae* males were captured during testing of the Arizona materials than the Florida materials, and this presumably reflects temporal differences in fly abundance.

Discussion

The two experiments described here offer additional evidence that separate presentation of solid *Bactrocera* male lures and DDVP strips yields similar numbers of captures as the standard liquid formulations currently in use. The first experiment showed that, even after 12 weeks of weathering in Hawaii (for all lure/toxicant treatments), solid lures and toxicants resulted in trap captures of male *B. dorsalis* and *B. cucurbitae* comparable to those noted with the liquid lure/toxicant mixture. This result was obtained regardless of whether 1 or 2 DDVP strips were placed with the solid lure, suggesting that only a small amount of DDVP (0.09 g per strip) is sufficient for fruit fly detection using Jackson traps.

As noted, the field site in Hawaii had moderate temperatures, consequently a second experiment was undertaken to gauge the effectiveness of solid lures and toxicant strips after weathering in hotter locations in the continental US.

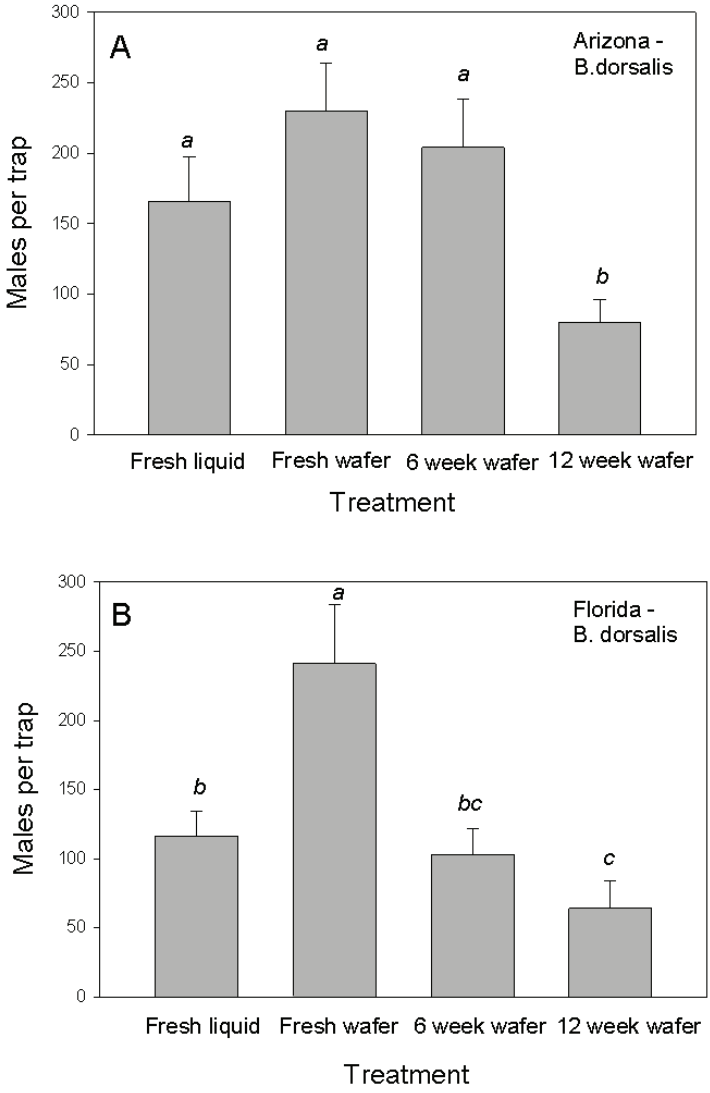

Figure 2. Captures of *Bactrocera dorsalis* males in traps baited with ME lures of variable age. Data for wafers weathered in Arizona and Florida are given in top and bottom plots, respectively. While lure age varied among treatments, the toxicant was fresh (no weathering) in all treatments. Liquid was applied to a cotton wick; in all other cases ME was presented in a polymeric wafer. Height of bar represents mean number of males captured per trap (n = 15 traps per treatment) in a 24-h period; error bars are ± 1 SE. Significant variation existed among treatments for both Arizona ($F = 10.5$, $P < 0.001$) and Florida ($F = 11.0$, $P < 0.001$); bars sharing a letter did not differ significantly ($P > 0.05$).

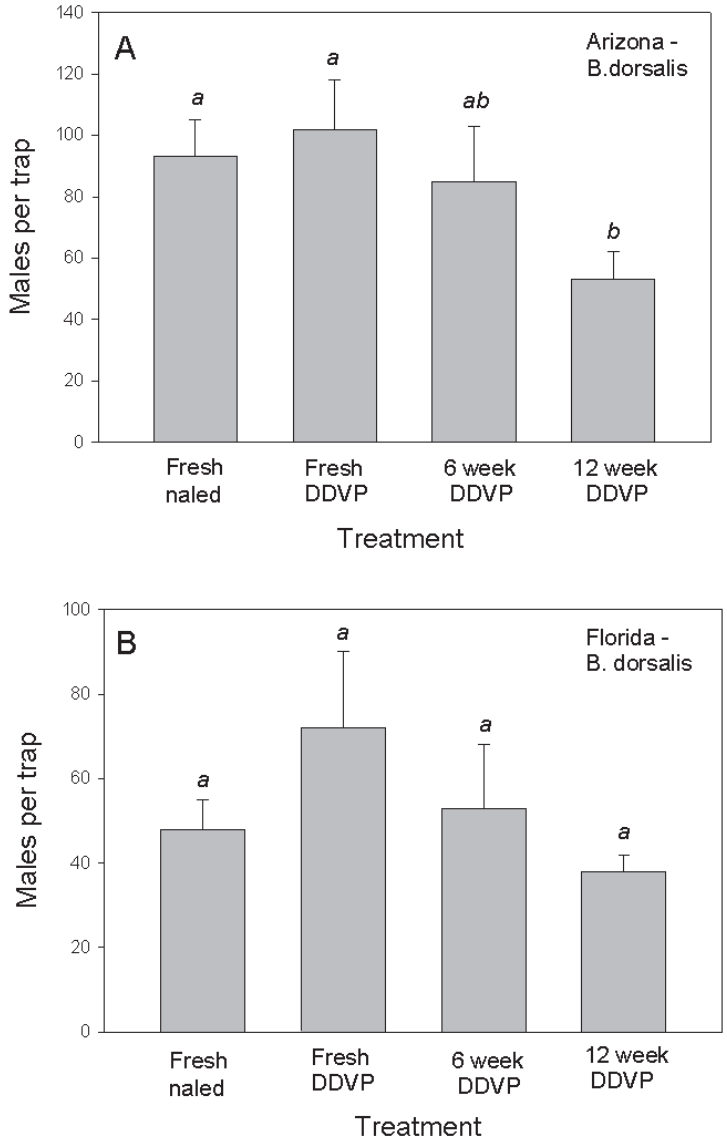

Figure 3. Captures of *Bactrocera dorsalis* males in traps baited with toxicants of variable age. Data for DDVP strips weathered in Arizona and Florida are given in top and bottom plots, respectively. While toxicant age varied among treatments, the lure was fresh (no weathering) in all treatments. All traps were baited with fresh liquid ME, except the Fresh DDVP treatment which employed a fresh ME wafer. Height of bar represents mean number of males captured per trap (n = 15 traps per treatment) in a 24-h period; error bars are ± 1 SE. Significant variation existed among treatments for Arizona ($F = 3.7$, $P = 0.02$) but not for Florida ($H = 1.8$, $P = 0.61$); bars sharing a letter did not differ significantly ($P > 0.05$).

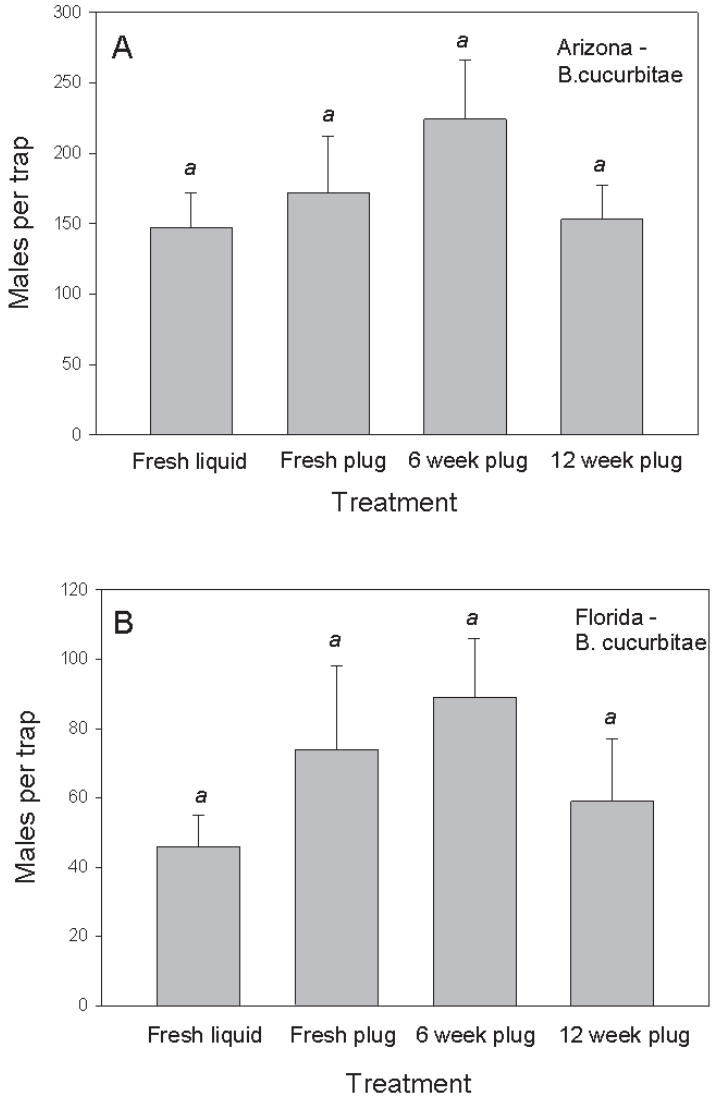

Figure 4. Captures of *Bactrocera cucurbitae* males in traps baited with CL lures of variable age. Data for CL plugs weathered in Arizona and Florida are given in top and bottom plots, respectively. While lure age varied among treatments, the toxicant was fresh (no weathering) in all treatments. Liquid was applied to a cotton wick; in all other cases CL was presented in a polymeric plug. Height of bar represents mean number of males captured per trap (n = 15 traps per treatment) in a 24-h period; error bars are ± 1 SE. No significant variation existed among treatments for either Arizona ($F = 0.5$, $P = 0.65$) or Florida ($F = 1.9$, $P = 0.15$). Bars sharing a letter did not differ significantly ($P > 0.05$).

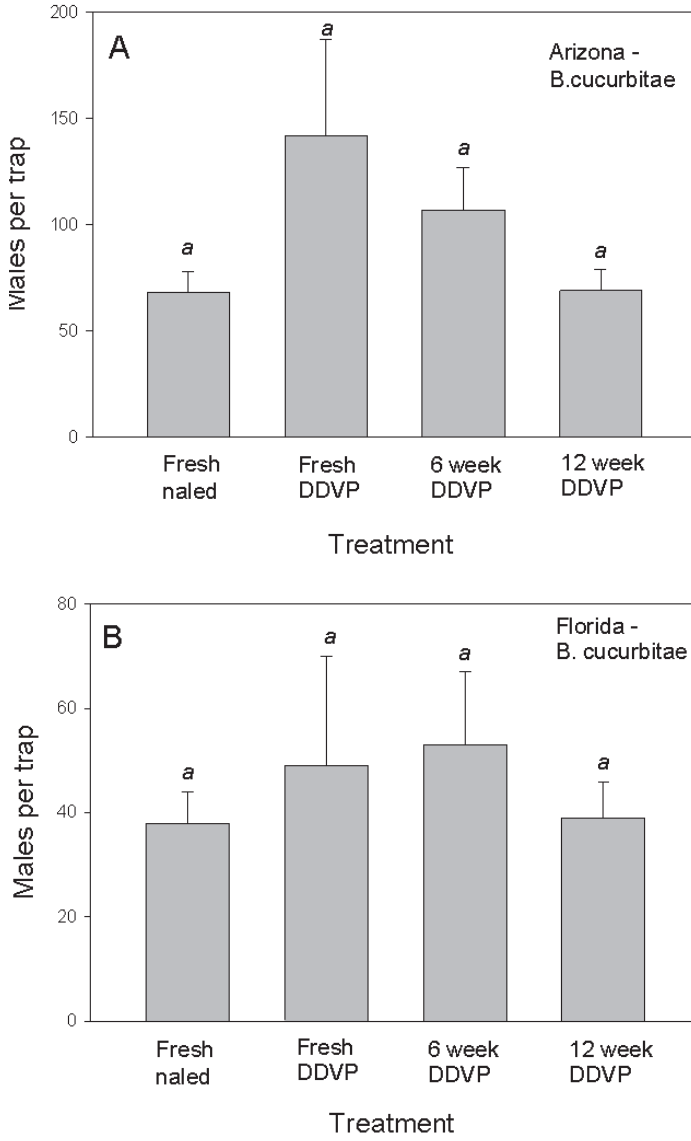

Figure 5. Captures of *Bactrocera cucurbitae* males in traps baited with toxicants of variable age. Data for DDVP strips weathered in Arizona and Florida are given in top and bottom plots, respectively. While toxicant age varied among treatments, the lure was fresh (no weathering) in all treatments. All traps were baited with fresh liquid CL, except the Fresh DDVP treatment which employed a fresh CL plug. Height of bar represents mean number of males captured per trap (n = 15 traps per treatment) in a 24-h period; error bars are ± 1 SE. No significant variation existed among treatments for either Arizona ($F = 2.5$, $P = 0.07$) or Florida ($F = 0.5$, $P = 0.66$). Bars sharing a letter did not differ significantly ($P > 0.05$).

Assessment, which was made in Hawaii, indicated that Jackson traps baited with solid lures and DDVP strips aged 6 weeks (the replacement interval used in ongoing detection programs) in Arizona or Florida captured similar numbers of male *B. dorsalis* and *B. cucurbitae* as fresh liquid lure/naled mixtures. After 12 weeks of weathering, the CL plugs and the DDVP strips weathered in either location were as effective as fresh liquid formulations. However, presumably owing to the higher volatility of ME (Vargas et al. 2015), the ME wafers from both Arizona and Florida lost significant attractancy after 6 weeks of weathering. Thus, if adopted for use under hot summer conditions, ME wafers may need replacement every 6 weeks. More precise determination of the effective duration of ME wafers (i.e., more exact than at least 6 weeks but less than 12 weeks) awaits further testing.

A potential criticism of our study was the short sampling period (24 h) used in both experiments. However, we do not consider this problematic for several reasons. In most cases, the target populations were large, resulting in high capture rates (usually > 50 males/d/trap) and comparisons based on relatively large counts. The exception was capture of *B. cucurbitae* in Waimanalo in the first experiment, which averaged between 4 and 11 males/d/trap. While catch was relatively low, most traps captured some flies (250/300 = 83% over all treatments and all sampling intervals), and comparisons were not based on samples consisting largely of zeros with just a few positive values. Also, the observation that the results for this species were similar between the two experiments (i.e., solid lures/toxicants were as effective as the liquid CL/naled mixture over 12 weeks) suggests that the relatively low captures in Waimanalo did not a biased outcome. In addition, and particularly in regard to the first experiment, as statistical comparisons were made among treatments for a given weathering interval, rather than among different intervals, all the trap captures being derived from traps subject to the same environmental conditions. As a result, there was no need to operate traps for long periods in order to adequately represent the environmental conditions between, for example, different months. Finally, and particularly in regard to the second experiment, given manpower constraints, 24-h sampling periods allowed for rapid testing of the materials received from mainland, thus avoiding potential complications arising from lengthy holding of these materials prior to field assays.

Based on the present findings, follow-up tests are underway to more precisely identify the effective longevity of ME wafers by evaluating their performance after 8 or 10 weeks of field weathering and CL plugs by assessing their performance after 14, 16 or 20 weeks of field weathering. This information will potentially allow for lengthening the inter-service interval of detection traps without concomitant loss of trapping sensitivity and thus allow substantial cost savings for fruit fly monitoring programs.

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