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# EVALUATION OF CUE-LURE AND METHYL EUGENOL SOLID LURE AND INSECTICIDE DISPENSERS FOR FRUIT FLY (DIPTERA: TEPHRITIDAE) MONITORING AND CONTROL IN TAHITI

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ABSTRACT

Performance of solid male lure (cuelure (C-L)/raspberry ketone (RK) against *Bactrocera tryoni* (Froggatt), and methyl eugenol (ME) against oriental fruit fly, *B. dorsalis* (Hendel)) both formulated with insecticide, were evaluated in Tahiti Island (French Polynesia), as alternatives to current monitoring and control systems using liquid formulations of attractant and organophosphate insecticides. Captures of *B. tryoni* in traps with BactroMAT C-L stations, Mallet C-L, Mallet MC wafers (containing both ME and RK), and Specialized Pheromone and Lure Application Technology (SPLAT) C-L were as high as with the standard liquid C-L formulation until 8 weeks, but thereafter the effectiveness of Mallet C-L baited traps declined. Captures of *B. dorsalis* with Mallet ME wafers outperformed any other ME formulation. Traps baited with ME and RK combined in a single Mallet MC wafer captured as many *B. tryoni* and *B. dorsalis* as traps baited with a single liquid lure. This suggested that solid Mallet dispensers with RK are longer lasting than those with C-L. For control applications, the weathered SPLAT-MAT-ME-spinosad lure and kill formulation was equal to fresh material for up to 4 weeks. SPLAT C-L was more persistent than weathered SPLAT-MAT-ME under Tahitian climatic conditions, which suggested that SPLAT-MAT-ME may need to be reapplied at shorter intervals and in greater amounts for suppression of *B. dorsalis* than is required to suppress *B. tryoni* with SPLAT-MAT-C-L. Mallet ME and MC wafers and SPLAT-MAT-ME/C-L were more convenient and safer to handle than standard liquid insecticide formulations, and should be considered for monitoring and control programs in Pacific island nations. The Mallet MC wafer could be used in a single trap in place of two separate traps for detection of both ME and C-L responding fruit fly species, and thereby reduce trap and labor costs. In addition to the SPLAT-MAT-ME or C-L for control, the Mallet MC wafer in a single trap should be tested further in Florida fruit fly programs.

Key Words: Integrated Pest Management, oriental fruit fly, Queensland fruit fly, malathion

RESUMEN

La efectividad de atrayentes sólidos (cueluro (C-L) / ketona de frambuesa (RK) para *Bactrocera tryoni* (Froggatt)), y metil eugenol (ME) para la mosca oriental, *B. dorsalis* (Hendel)) y varias formulaciones de insecticidas, fue evaluada en la isla de Tahití (Polinesia Francesa) como alternativas para sistemas de monitoreo y control que actualmente utilizan atrayentes líquidos e insecticidas organofosforados. Las capturas de *B. tryoni* en trampas cebadas con estaciones BactroMAT C-L, Mallet C-L, cebos sólidos Mallet MC (conteniendo tanto ME como RK), y SPLAT C-L fueron tan altas como la formulación líquida estándar C-L hasta por 8 semanas, posteriormente hubo un decremento en la efectividad de Mallet C-L. Las capturas de *B. dorsalis* en trampas cebadas con Mallet ME wafers fueron superiores a cualquier otra formulación conteniendo ME. La combinación de ME y RK en un mismo cebo sólido Mallet MC no redujo las capturas de *B. tryoni* y *B. dorsalis* en comparación con trampas cebadas con individual atrayentes, lo que sugiere que la formulación sólida Mallet con RK dura más que formulaciones con C-L. Con fines de control, SPLAT-MAT-ME-spinosad expuesto a condiciones ambientales fue tan atractivo como el material fresco por un periodo de hasta 4 semanas. SPLAT C-L mostró ser más persistente que SPLAT ME expuesto a las condiciones ambientales de Thaití, lo que sugiere que SPLAT ME probablemente debe ser re-aplicado a intervalos más cortos y en cantidades mayores para suprimir *B. dorsalis*. Los cebos sólidos Mallet ME y MC y SPLAT-MAT-ME/C-L son más convenientes y seguros para manejar que las formulaciones líquidas estándar que contienen insecticidas organofosforados y deben ser consideradas para programas de monitoreo y control en naciones de las islas del Pacífico. La formulación sólida Mallet MC puede ser utilizada en una misma trampa en lugar de dos trampas separadas para la detección de especies de moscas que responden tanto a ME como a C-L, reduciendo costos asociados con el costo de trampas y labor y, en adición a SPLAT-MAT-ME ó C-L con fines de control, debe ser evaluada en programas de moscas de la fruta en Florida.

Translation provided by the authors

Early eradication of invasive fruit flies (Diptera: Tephritidae) depends largely on the deployment of both effective and safe detection and control systems. Current methods utilized throughout Pacific Island Nations, Australia and the US mainland for rapid detection of accidental introductions of species of Dacinae (comprised of the two major genera, *Bactrocera* Macquart and *Dacus* Fabricius) (White & Elson-Harris 1992) require the deployment of large numbers of traps baited with highly attractive male-specific lures. For example, methyl eugenol (ME) (4-allyl-1, 2-dimethoxybenzene-carboxylate) is used for detection of oriental fruit fly, *Bactrocera dorsalis* (Hendel), and the Pacific fruit fly, *B. xanthodes* (Broun), and cue-lure (C-L) [4-(*p*-acetoxyphenyl)-2-butanone] is used for *B. kirki* (Froggatt), melon fly, *B. cucurbitae* (Coquillett), and the Queensland fruit fly, *B. tryoni* (Froggatt). All these species, except melon fly, have been introduced to French Polynesia and have become severe pests of tropical fruits (Leblanc & Putoa 2000; Vargas et al. 2007). C-L has never been isolated as a natural product, but is rapidly hydrolyzed to form raspberry ketone (RK) (Metcalf & Metcalf 1992).

One important safety concern of large trapping systems is that detection traps are currently deployed in association with liquid formulations of toxic organophosphate insecticides such as malathion and naled (Vargas et al. 2010a).This, coupled with concerns for use of organophosphate insecticides in sensitive (e.g., residential) areas, has raised serious environmental/human health concerns and has also resulted in strong reluctance of some workers to use them. Safer alternatives to the use of organophosphate insecticides for fruit fly monitoring and control have been developed by the Hawaii Fruit Fly Area-Wide Pest Management (AWPM) program, funded by the U.S. Department of Agriculture, Agricultural Research Service (USDA-ARS). The AWPM program successfully integrated environmentally friendly integrated pest management (IPM) technologies into a comprehensive fruit fly management package that has proven to be economically viable, environmentally compatible, and sustainable (Vargas et al. 2008a) with an important level of grower adoption (Mau et al. 2007). Some novel IPM technologies include applications of GF-120 NF Naturalyte protein bait as foliar sprays (Prokopy et al. 2003, Piñero et al. 2009a) or in bait stations (Piñero et al. 2009b), and the use of SPLAT (Specialized Pheromone and Lure Application Technology) Male Annihilation Treatment (MAT) containing either ME or C-L (Vargas et al. 2008b, 2009a, 2010b). Both GF-120 and SPLAT MAT-ME contain the reduced risk insecticide, spinosad, and were researched, developed and registered in Hawaii for areawide suppression of fruit flies (Mau et al. 2007, Vargas et al. 2008a). SPLAT™ is a waxy formulation of biologically inert materials used to control the release of semiochemicals with or without pesticides. Previous research in Hawaii has shown that the SPLAT matrix emits ME or C-L at effective pest suppression levels for a time interval ranging from 4-8 wk (Vargas et al. 2009a, 2010b). Similarly, solid lure-insecticide dispensers have been developed and successfully evaluated for monitoring and male annihilation traps (Vargas et al. 2009b, 2010a) allowing for the elimination of liquid lures and insecticides.

The present study compares the performance of ME and C-L monitoring traps with novel solid lure and insecticide formulations at capturing *B. tryoni* and *B. dorsalis* on Tahiti Island, in French Polynesia. In addition, a recently developed solid lure wafer containing both ME and RK (Mallet MC) was evaluated against individual ME and C-L wafers. Finally, SPLAT ME and SPLAT C-L were weathered and compared with fresh material for attractiveness to fruit flies.

## Materials and Methods

Evaluations were conducted on Tahiti Island, French Polynesia, in areas where populations of both *B. tryoni* and *B. dorsalis* occur. The standard monitoring/detection system in French Polynesia consists of a modified version of the Steiner trap (Steiner 1957) (hereafter referred to as "Tahitian trap") baited with either liquid ME or C-L in association with malathion. The trap consists of a plastic 1-L container (7.0 cm radius and 12.5 cm ht) (Platiserd, Papeete, Tahiti FP) with four 1.5 cm-diam holes and suspended in a horizontal position by a tie wire. For detection of new invasive species of fruit flies, traps are often deployed around the airport and harbors at Papeete, as well as other high-risk locations. For each of the experiments described below lures were deployed in Tahitian traps.

Experiment 1. Comparison of Captures with Different Solid Lure Dispensers.

Five C-L treatments (against *B. tryoni*) and ME treatments (against *B. dorsalis*) were evaluated in Tahitian traps at Papara (3 sites) and Papeete (1 site). Traps were deployed on 19 Jan 2009, and emptied weekly until 11 May 2009, for a total of 16 collections.

The 5 C-L treatments evaluated were (1) C-L solution (International Pheromone System, South Wirral, UK) with malathion 50% EC (Venture Export Ltd., Auckland, NZ) on 2 cotton wicks (Henry Schein Inc., Melville, NY) (1-cm-diam × 3.5 cm long) (4 g lure + 1 g malathion per trap) (= standard C-L detection trap in French Polynesia); (2) BASF BactroMAT C-L fruit fly station, made of recycled cardboard (5.8 × 3.6 × 0.5 cm) (Venture Export) (0.5 g lure + 0.024 g fipronil per trap); (3) Farma Tech Mallet C-L wafer (5.5 × 3 × 0.32 cm) (Farma Tech, North Bend, WA) (1.3 g lure + 0.18 g DVVP per trap); (4) Farma Tech Mallet MC wafer (5.5 × 3 × 0.32 cm) (1.9 g raspberry ketone + 2.8 g methyl eugenol + 1.9 g benzyl acetate + 0.43 g DVVP per trap); and (5) SPLAT C-L (ISCA Technologies, Riverside, CA) (0.8 g lure + 0.08 g spinosad per trap), smeared on a 4-cm-diam wooden disk. The disk had a small hole through which a twist tie was inserted and attached inside the trap.

The 5 ME treatments evaluated were: (1) ME solution (Farma Tech) with malathion 50% EC on 2 cotton wicks (4 g lure + 1 g malathion per trap) (= standard ME detection trap in French Polynesia); (2) BASF BactroMAT ME fruit fly station (Venture Export) (4 g lure + 0.024 g fipronil per trap); (3) Farma Tech Mallet ME wafer (7.7 × 5 × 0.32 cm) (4.7 g lure + 0.28 g DVVP per trap); (4) Farma Tech Mallet MC (as described above); and (5) SPLAT ME (ISCA Technologies) (2.04 g lure + 0.08 g spinosad per trap), on a wooden disc, as described above.

Experiment 2. Comparison of Captures in Traps with Single and Multiple Lures.

Five C-L or ME treatments were further evaluated at the same study sites as in experiment 1, with traps set on 5 Oct 2009, and emptied weekly until 25 Jan 2010 (16 collections). Treatments (details under experiment 1) were placed inside Tahitian traps as follows: (1) C-L solution on cotton wicks; (2) ME solution on cotton wicks; (3) Mallet ME wafer; (4) Mallet C-L wafer; and (5) Mallet MC wafer. The Mallet MC collected both *B. dorsalis* and *B. tryoni*, and their trapping data were separately analyzed with the single lure wick and Mallet treatment traps baited with lure. To further confirm the superiority of the ME wafer observed in experiments 1 and 2, the ME component of experiment 2 (treatments 2, 3 and 5 above) was replicated at the same 4 sites, with traps set on 1 Mar 2010 and emptied weekly until 7 Jun (14 collections).

Experiment 3. Comparison of Weathered and Fresh SPLAT ME and SPLAT C-L.

A M10 metered gun (#4 setting) (ISCA Technologies, Riverside, CA) was used to apply approximately 3.3 g of freshly formulated SPLAT C-L and SPLAT ME (the same formulations used in experiment 1) to the surface of wooden tongue depressors (1 × 2.5 cm) (Puritan Medical Products Co. LLC, Guilford, ME). Depressors were hung in shaded locations in the lower branches of various trees at Papara, Tahiti and exposed to direct sunlight, wind and rain for up to 14 wk. At 1-wk intervals, 4 C-L and 4 ME stations were removed at random from the 'weathering tree' and their performance was compared with that of fresh material. Dispensers were placed inside separate Tahitian traps and fruit fly captures recorded after one wk of trapping. Studies were conducted from 25 Feb to 26 May 2010 (12 collections). Trapping using fresh and weathered SPLAT was done in the Mataiea (C-L tests) and Papara (ME tests). Mean (±SEM) max/min temperatures and rainfall for the weathering site in Papara were 31.9 ± 0.15°C, 22.9 ± 0.20°C, and 4.88 ± 1.35 mm, respectively.

Data collection and analysis.

For each of the experiments described above, ME and C-L traps were placed (20 m apart) randomly throughout the study sites in various fruit trees, such as common guava *Psidium guajava* L., mapé or Tahitian chestnut, *Inocarpus fagifer* Parkinson (Fosberg), mango, *Mangifera indica* L., tropical almond, *Terminalia catappa* L., and pomelo, *Citrus maxima* (Burm.) Merr. Traps were emptied once every wk and all flies captured were counted and recorded. To compensate for position effects, traps within an area were rotated clockwise by one position every wk.

Trap capture data for *B. dorsalis* or *B. tryoni*, expressed as an index (number of males per trap per wk) were transformed [log(x+1)] to stabilize the variance, and subjected to analysis of variance with lure treatment as the fixed variable, trapping site as the random variable, and weekly service date as a repeated measure (Proc GLIMMIX, SAS Institute 2009). Means were separated with a Fisher's Least Significant Difference (LSD) test at the $P = 0.05$ level (SAS Institute 2009). Untransformed data are presented in both figures and tables.

## Results

### Experiment 1. Comparison of Captures with Different Solid Lure Dispensers.

Captures of *B. tryoni* over a 16 wk period differed significantly by treatment and wk, and the treatment × wk interaction was almost significant ($P = 0.0590$). For this reason, captures were summarized by wk (Table 1). For the first 8 wk there were no notable differences among treatments. Subsequently, there were numerical differences with a generally lower performance of Mallet C-L, and frequently higher captures in SPLAT C-L and wick traps. Treatment and wk effects were significant for captures of *B. dorsalis*, but not their interaction. Therefore the data for the ME test are presented combining all wk (Table 2). Overall, the numbers of *B. dorsalis* captured in traps with Mallet ME wafers were consistently greater than in traps baited with any other dispenser, and in every individual week except wk 1 and wk 16. Captures in BactroMAT ME traps quickly dropped to very low numbers after 4 wk, and overall were significantly lower than with all other ME formulations, except the wick.

### Experiment 2. Comparison of Captures in Traps with Single and Multiple Lures.

Captures of *B. tryoni* in CL-baited traps did not differ significantly among treatments for the 16-wk period, but differed significantly by wk, and their interaction was not significant (Table 3). In the ME assessment, captures of *B. dorsalis* in ME-baited traps differed significantly by wk but not by treatment in the first replicate, and by treatment but not by wk in the second replicate; with no significant interaction in either replicate (Table 3). As observed in experiment 1, Mallet ME consistently outperformed all the other dispensers in the second replicate of the ME test. Mallet ME captures were also higher in the first replicate, though not statistically significant, due to the high variation in the data set. When data from the two replicates were pooled, both treatment ($F = 10.20$; $df = 2, 18$; $P = 0.0011$) and week ($F = 2.50$; $df = 15, 250$; $P = 0.0019$) effects became significant, with no significant interaction ($F = 0.79$; $df = 30, 255$; $P = 0.7745$), and the Mallet ME (348.9 ± 52.3 flies per trap per day) significantly outperformed the two other lure dispensers (MC: 99.5 ± 17.9; wick: 102.6 ± 11.3).

### Experiment 3. Comparison of Weathered and Fresh SPLAT.

Captures of *B. tryoni* in SPLAT C-L traps over the 14 wk differed significantly by treatment and wk, but their interaction was not significant (Fig. 1). Overall mean (±SEM) captures were 41.04 ± 6.51 flies/trap/week for fresh and 18.86 ±

Table 1. Captures (mean ± SEM flies/trap/week) of male *B. tryoni* in Tahitian traps maintained at Papara and Papeete (Tahiti Island, FP), and serviced weekly from 26 Jan to 11 May 2009.

| Week | BactroMAT C-L (fipronil) | Mallet C-L (DVVP) | Mallet MC (DVVP) | SPLAT C L (spinosad) | C-L wick (malathion) |
|---|---|---|---|---|---|
| 1 | 74.0 ± 12.4 | 91.0 ± 44.4 | 12.5 ± 4.7 | 57.0 ± 24.5 | 89.0 ± 20.2 |
| 2 | 56.5 ± 22.1 | 64.0 ± 41.3 | 59.0 ± 42.5 | 38.8 ± 29.4 | 23.8 ± 17.0 |
| 3 | 36.8 ± 22.5 | 57.0 ± 20.3 | 22.0 ± 13.4 | 57.5 ± 14.7 | 32.3 ± 16.4 |
| 4 | 62.5 ± 46.4 | 29.0 ± 15.7 | 64.5 ± 30.8 | 72.3 ± 54.1 | 18.5 ± 16.5 |
| 5 | 44.3 ± 27.7 | 55.0 ± 26.3 | 22.8 ± 13.1 | 52.5 ± 34.3 | 26.5 ±14.2 |
| 6 | 36.8 ± 14.0 | 32.0 ± 13.3 | 27.3 ± 5.2 | 54.8 ± 23.5 | 34.3 ± 11.3 |
| 7 | 36.5 ± 14.4 | 16.7 ± 10.8 | 22.5 ± 8.6 | 48.8 ± 18.9 | 37.0 ± 8.4 |
| 8 | 34.8 ± 10.8 | 26.0 ± 17.6 | 29.5 ± 14.3 | 53.5 ± 15.5 | 35.7 ± 19.2 |
| 9 | 24.0 ± 3.8 | 16.3 ± 9.8 | 31.5 ± 10.5 | 44.8 ± 13.7 | 50.0 ± 3.6 |
| 10 | 37.8 ± 8.5 | 31.7 ±14.9 | 37.8 ± 14.0 | 65.0 ± 33.8 | 57.5 ± 12.2 |
| 11 | 39.0 ± 14.8 | 7.0 ± 3.5 | 28.8 ± 10.7 | 64.3 ± 24.0 | 72.7 ± 8.1 |
| 12 | 30.8 ± 6.5 | 3.3 ± 1.8 | 14.8 ± 7.4 | 26.8 ± 16.9 | 35.7 ± 5.6 |
| 13 | 19.0 ± 7.4 | 1.0 ± 1.0 | 23.5 ± 11.0 | 21.0 ± 8.9 | 44.3 ± 13.9 |
| 14 | 42.5 ± 11.0 | 11.0 ± 5.9 | 46.3 ± 22.7 | 51.8 ± 38.1 | 54.0 ± 28.1 |
| 15 | 30.5 ± 11.7 | 4.3 ± 2.3 | 27.8 ± 21.2 | 41.5 ± 16.5 | 27.3 ± 3.8 |
| 16 | 20.5 ± 7.3 | 3.0 ± 1.0 | 22.3± 12.4 | 30.8 ± 14.9 | 24.0 ± 5.6 |

PROC GLMMIX (SAS Institute 2009). Treatment: $F = 3.86$; $df = 4, 39.1$; $P = 0.0098$; Week: $F = 2.67$; $df = 15, 190$; $P = 0.0010$; Treatment × Week: $F = 1.37$; $df = 60, 179$; $P = 0.0590$.

TABLE 2. CAPTURES (MEAN ± SEM FLIES/TRAP/WEEK) OF MALE *B. DORSALIS* IN TAHITIAN TRAPS MAINTAINED AT PAPARA AND PAPEETE (TAHITI ISLAND, FP), AND SERVICED WEEKLY FROM 26 JANUARY TO 11 MAY 2009.

| BactroMAT ME (fipronil) | Mallet ME (DVVP) | Mallet MC (DVVP) | SPLAT ME (spinosad) | ME wick (malathion) |
|---|---|---|---|---|
| 94.5 ± 25.0 c | 614.1 ± 106.6 a | 182.4 ± 39.6 b | 180.1 ± 40.5 b | 134.7 ± 27.3 bc |

Values in each row followed by the same letters are not significantly different at the $P = 0.05$ level, PROC GLMMIX (SAS, 1999). Treatment: $F = 6.68$; $df = 4, 22.2$; $P = 0.0011$; Week: $F = 6.61$; $df = 15, 211$; $P < 0.0001$; Treatment × Week: $F = 1.11$; $df = 60, 200$; $P = 0.2878$.

TABLE 3. TRAP CAPTURES (MEAN ± SEM FLIES/TRAP/WEEK) OF MALE *B. TRYONI* AND *B. DORSALIS* IN TAHITIAN TRAPS SERVICED WEEKLY FROM 12 OCT 2009 TO 25 JAN 2010 (*B. TRYONI* AND *B. DORSALIS* REPLICATE 1) OR 8 MAR TO 7 JUN 2010 (*B. DORSALIS* REPLICATE 2), IN A DETECTION GRID MAINTAINED AT PAPARA OR PAPEETE (TAHITI ISLAND, FP).

| Species | Mallet C-L or ME (DVVP) | Mallet MC (DVVP) | C-L or ME wick (malathion) |
|---|---|---|---|
| *B. tryoni* | 130.9 ± 28.6 a | 111.6 ± 16.2 a | 185.0 ± 30.4 a |
| *B. dorsalis* (replicate 1) | 210.0 ± 34.1 a | 78.1 ± 16.3 a | 81.3 ± 11.3 a |
| *B. dorsalis* (replicate 2) | 513.5 ± 103.0 a | 124.9 ± 33.9 b | 127.8 ± 20.5 b |

Values in each row followed by the same letters are not significantly different at the $P = 0.05$ level for the main effect, PROC GLMMIX (SAS 2009). *B. tryoni*: Treatment: $F = 0.58$; $df = 2, 11.9$; $P = 0.5772$; week: $F = 2.98$; $df = 15, 120$; $P = 0.0005$; treatment × week interaction: $F = 1.00$; $df = 30, 117$; $P = 0.4711$. *B. dorsalis* (replicate 1): Treatment: $F = 2.31$; $df = 2, 8.56$; $P = 0.1573$; week: $F = 3.49$; $df = 15, 122$; $P < 0.0001$; treatment × week interaction: $F = 0.79$; $df = 30, 119$; $P = 0.7706$. *B. dorsalis* (replicate 2): Treatment: $F = 16.43$; $df = 2, 11.9$; $P = 0.0004$; week: $F = 1.25$; $df = 13, 99.1$; $P = 0.2539$; treatment × week interaction: $F = 1.06$; $df = 26, 97$; $P = 0.3973$.

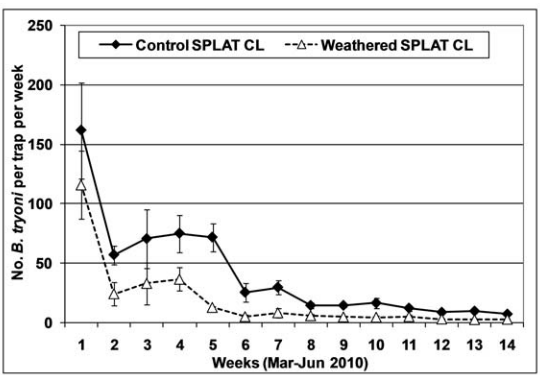


Fig. 1. Captures (mean ± SEM flies/trap/week) of male *B. tryoni* in traps with fresh or weathered SPLAT C-L treatments, evaluated weekly from 10 Mar to 9 Jun 2010.

[Footnote to Fig. 1]: PROC GLMMIX (SAS Institute 2009). Treatment: $F = 84.79$, $df = 1, 83$; $P < 0.0001$; week: $F = 20.56$; $df = 13, 83$; $P < 0.0001$; treatment × week interaction: $F = 0.85$; $df = 13, 83$; $P = 0.6115$

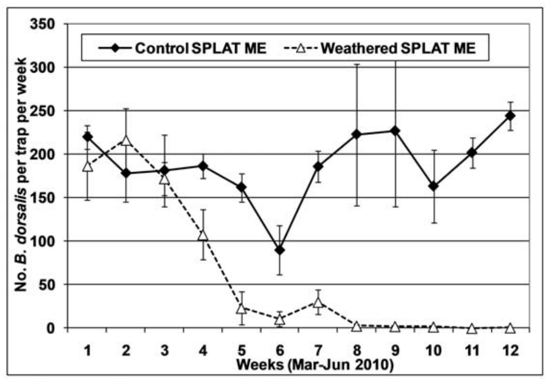


Fig. 2. Captures (mean ± SEM flies/trap/week) of male *B. dorsalis* in traps with fresh or weathered SPLAT ME treatments weekly from 10 Mar to 26 May 2010.

[Footnote to Fig. 2]: PROC GLMMIX (SAS Institute 2009). Treatment: $F = 151.16$; $df = 1, 6$; $P < 0.0001$; week: $F = 13.17$; $df = 11, 66$; $P < 0.0001$; treatment × week interaction: $F = 12.39$; $df = 11, 66$; $P < 0.0001$.

4.54 for weathered stations, respectively. Captures of *B. dorsalis* in fresh and weathered SPLAT ME traps over the 12 wk test differed significantly by treatment and wk, as well as their interaction (Fig. 2). Attraction of *B. dorsalis* to SPLAT ME was drastically reduced past 4 wk of weathering. Overall mean (±SEM) captures were 188.2 ± 12.0 for fresh and 62.7 ± 12.7 for weathered stations, respectively.

## DISCUSSION

Previous results in Hawaii suggested that against *B. cucurbitae* over 8 weeks, Jackson traps or Hawaii Area Wide Pest Management (AWPM) traps (Vargas et al. 2003) baited with Mallet C-L wafers impregnated with DDVP performed as well as standard Jackson traps that were baited with liquid C-L and naled in a wick (Vargas et al. 2009b, 2010a). In the present study, captures of another C-L-responding fly, *B. tryoni,* in traps baited with the Mallet C-L wafer were comparable to traps baited with liquid C-L plus malathion in a wick only during the first 8 weeks, but subsequently captures with the Mallet C-L wafer much lower than with the liquid C-L formulation.

However, captures with the Mallet MC wafer containing RK were similar to those with the standard liquid C-L plus malathion wick over the entire 16 weeks period, and higher than the Mallet C-L wafers. This suggests that the RK formulation (Mallet MC) may be superior to C-L formulations over long (>8 weeks) trapping periods. Also the SPLAT C-L and BactroMAT C-L formulations, using the slow acting spinosad and fipronil insecticides respectively, compared favorably with the quick knockdown malathion and DDVP. This may have been due to the small hole sizes in Tahitian traps, likely reducing the ability of flies to escape, in contrast with the larger hole sizes (3 cm) of the bucket traps used in Hawaii.

Standard Jackson traps or AWPM bucket traps with Mallet ME wafers impregnated with DDVP performed as well as the standard Jackson trap with liquid ME and naled against *B. dorsalis* in Hawaii (Vargas et al. 2010a). In the present study, the Mallet ME wafer outperformed all other dispensers, including the liquid ME standard, in both experiments. This superior performance may be due in part to the higher ME content of the Mallet ME dispenser (4.7g), yet it outperformed the wick and BactroMAT dispensers, both containing 4g of ME. The proprietary constitution of the Mallet support may help retard evaporation of ME.

Previously when testing liquid ME and C-L mixed together in varying proportions on the same wicks, Vargas et al. (2000) found that reducing the proportions of C-L incorporated into the wick did not reduce *B. cucurbitae* captures, whereas reducing proportion of ME incorporated into the wick reduced the captures of *B. dorsalis* over time. In the Tahiti tests, the new Mallet MC dispensers used in a single trap performed as well as two individual traps with separate Mallet C-L wafers or the standard liquid C-L or ME + malathion on wicks, but the Mallet MC wafer did not perform as well as the Mallet ME wafer. Numerically, in experiment 2, the captures by the ME and C-L liquid formulation traps were only 1.03 and 1.65 times greater, respectively, than the MC traps. For detection purposes, using both lures in a single MC dispenser could reduce trap numbers and labor requirements by 50%. In places such as California and Florida, where approximately 30,000 ME traps and 20,000 C-L traps are deployed for detection purposes, the savings would be significant.

Weathering of the new sprayable SPLAT-MAT ME and C-L lure and kill formulations with the reduced risk insecticide spinosad was also evaluated in Hawaii (Vargas et al. 2008b) and California (Vargas et al. 2010b). Research has focused on SPLAT ME and C-L as replacement for Min-U-Gel ME and C-L, both using the toxic naled insecticide (Vargas et al. 2008b, 2009a, 2010b). In trials conducted in California, chemical analyses of the weathered SPLAT formulation suggested a more rapid loss of ME than C-L from different dispensers (R. I. Vargas, unpublished). Our results in French Polynesia also suggested that SPLAT C-L lasted longer in the field than SPLAT ME.

The Hawaii fruit fly AWPM program has promoted registration and adoption of reduced-risk alternatives to organophosphates. The BactroMAT C-L fipronil stations and a sprayable SPLAT-MAT ME formulation were licensed for use in Hawaii (Vargas et al. 2005, 2008b, Mau et al. 2007), and work is continuing on the development of a SPLAT C-L product. The improvements were also driven by the reluctance on the part of workers to mix lures with restricted insecticides in monitoring traps. The replacement of liquid naled with DDVP (Vapor Tape®, Hercon Environmental, Emingsville, Pennsylvania) strips represents an important improvement from a worker safety viewpoint. Likewise, there has been a trend toward replacement of liquid lures with solid formulations without insecticide (e.g., Sentry ME cones and C-L plugs, Boseman, MT). The prepackaged Mallet wafer with a solid formulation of ME or C-L impregnated with DDVP is a novel dispenser that performed as well as liquid formulations in bucket and delta traps in Hawaii (Vargas et al. 2009b, 2010a). The development of these less toxic and more user-friendly alternatives also has important applications to detection and monitoring of fruit flies beyond Hawaii and French Polynesia, as in California, Florida, throughout the south and western Pacific islands, Australia, tropical Asia, Africa, and South America, where species of *Bactrocera* and *Dacus* are serious economic pests.

In summary, the Farma Tech Mallet ME and MC wafers are promising substitutes to traditional trapping using liquid lures that are mixed with naled or malathion for detection of fruit flies. These products should be further tested in Florida and California for the development of environmentally-friendly area-wide IPM procedures for early detection of accidental introductions of fruit flies into the U.S. mainland. The Mallet MC wafers also hold the promise of being used in a single trap in place of two separate ME and C-L detection traps. Finally, the Farma Tech wafers and SPLAT ME or C-L formulations could be used effectively as a reduced risk male annihilation technologies in Hawaii and French Polynesia AWPM programs, in conjunction with protein bait sprays and sanitation, and on the U.S. mainland for eradication of accidental fruit fly introductions.

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