Field capture of male oriental fruit flies (Diptera: Tephritidae) in traps baited with solid dispensers containing varying amounts of methyl eugenol

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The oriental fruit fly, *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae), is a major pest of fruits and vegetables worldwide (CABI 2019). Detection of this highly invasive species relies heavily on traps baited with the powerful male-specific lure methyl eugenol (Vargas et al. 2010). In southern California, Jackson traps baited with 5 mL of methyl eugenol are deployed at a density of 5 traps per square mile (= 1.61 km^2), and are monitored throughout the yr over 2,500 km^2 (IPRFFSP 2006). The lure is applied as a liquid (with 1% naled added) to a cotton wick held within a perforated basket positioned inside the trap above a sticky floor to retain the insects. Because methyl eugenol is a volatile compound, lure-bearing wicks are replaced every 6 wk.

High volatility enhances the attractiveness of the lure but simultaneously shortens its effective field longevity. One potential solution to extending the lure replacement interval, and reducing associated costs, involves the use of slow-release, solid dispensers. These dispensers, which are individually packaged, also decrease possible health risks associated with handling liquid methyl eugenol (National Toxicology Program 2000). One such dispenser, a rectangular wafer 'loaded' with 6 g of methyl eugenol, has proven effective for as long as 10 wk (Shelly et al. 2017). However, the wafer's large size (7.5 × 5.0 cm) makes it cumbersome, thus requiring extra handling time. The present study compared field captures of wild *B. dorsalis* males among Jackson traps baited with 6 mL of liquid methyl eugenol on a wick (standard protocol) and Jackson traps baited with polymeric plugs containing 3, 6, or 10 g of methyl eugenol. All plugs fit inside the same perforated baskets used for the methyl eugenol-bearing wicks and thus could be adopted without major change to the trapping system currently in use.

Field work was conducted on Hawaii Island (Big Island) and Oahu, Hawaii, USA. On the Big Island, a single trapping experiment (Experiment 1) was conducted from Jul to Oct 2019, at the edge of second-growth forest 10 km south of Hilo, Hawaii, USA (19.6326°N, 155.0912°W). Four treatments were tested: fresh liquid methyl eugenol (6 mL, 1% naled) on a cotton wick (added immediately before each trapping interval), and weathered plugs with 3, 6, or 10 g of methyl eugenol. Traps containing plugs also held a second perforated basket containing a dichlorvos square (2.54 cm^2, 0.09 g a.i.). Traps were placed 1.5 to 2.5 m aboveground in shaded locations between 7:00 and 10:00 AM. Treatments were positioned in repeating sequences along the forest edge, with neighboring traps separated by 50 m. For each trapping interval, 12 traps (replicates) were deployed for each of the 4 treatments. Traps were operated for 24 h, then collected and returned to the laboratory to count flies. After removing the sticky floor, plug-containing traps (with dichlovors squares also left in place) were suspended 2 m aboveground under a covered outdoor porch and left until the next trapping period. Trapping was conducted when plugs and dichlorvos strips were weathered for 0 (all treatments fresh), 6, 8, 10, and 12 wk.

On Oahu, a trapping experiment (Experiment 2) was conducted during May to Jul 2019, in a commercial coffee (*Coffea arabica* L.; Rubiaceae) field 10 km southeast of Haleiwa, Hawaii, USA (21.5599°N, 158.0666°W). This experiment tested the same 4 treatments and deployed the same number of traps per treatment as on the Big Island. Traps were placed on wind-break trees (Norfolk Island pines, *Araucaria heterophylla* (Salisb.) Franco; Araucariaceae) planted along the edge of the coffee field. Placement of traps followed the protocol given above for the Big Island. Traps were operated for 1 to 2 d, then collected and returned to the laboratory to count flies (captures were computed on a daily basis for analysis). Plugs and dichlorvos squares were weathered in the manner described above for the Big Island, and trapping was conducted when plugs and dichlorvos strips were weathered for 0 (all treatments fresh), 6, 8, and 10 wk.

Following $\log_{10}$ transformation, data met the assumption of normality in both Experiments 1 and 2; consequently 2-way ANOVA with treatment (lure/insecticide) and wk as main factors was used for analysis. Although variances were not equal among groups in these experiments, an ANOVA on ranked data (Conover & Iman 1981) yielded the same results as the analysis based on raw data. Therefore, parametric analysis of raw data was considered sufficiently robust to accommodate unequal variances. Where appropriate, the Tukey multiple comparisons test was used to identify pair wise differences. Statistical analysis was performed using SigmaPlot vers. 11 (Systat Software, San Jose, California, USA).

Despite following the same protocol, Experiments 1 and 2 yielded different results. For Experiment 1, there was a significant effect of wk on captures ($F_{4,220} = 22.1$; $P < 0.001$), but treatment had no significant effect ($F_{3,220} = 2.05$; $P = 0.11$; Fig. 1). Likewise, the wk × treatment interaction was not significant ($F_{12,220} = 0.83$; $P = 0.62$). For Experiment 2, on the other hand, both wk ($F_{3,176} = 79.9$; $P < 0.001$) and treatment ($F_{3,176} = 14.0$; $P < 0.001$) had significant effects (Fig. 2A). The interaction term was also significant ($F_{9,176} = 4.2$; $P < 0.001$). Based on the multiple comparisons test, trap captures in Experiment 2 did not vary among treatments for wk 0 or 6. However, captures for the fresh liquid lure were significantly greater than those for the 3 g plug at wk 8, and significantly greater than those for all plug sizes at wk 10.

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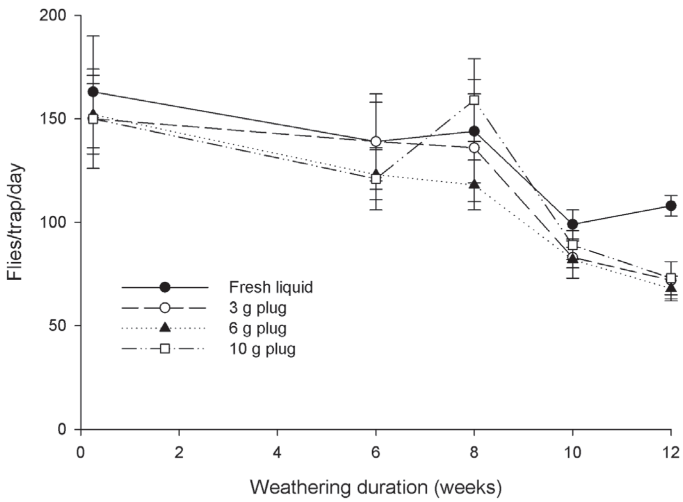

Fig. 1. Captures of *Bactrocera dorsalis* males on the Big Island, Hawaii, USA (Experiment 1) in Jackson traps baited with fresh liquid methyl eugenol or weathered, polymeric plugs containing 3, 6, or 10 g of methyl eugenol. Symbols represent means ± 1 SE; $n = 12$ in all cases.

Differences in weather conditions between the Big Island and Oahu sites may have accounted for the variable results between Experiments 1 and 2. Based on weather stations located near the respective sites and measurements taken over the entire course of the respective study periods, the average daily maximum temperatures varied between 30.5 to 32.2 °C on Oahu (National Oceanic and Atmospheric Administration, Wheeler Army Airfield, Wahiawa, Hawaii) compared to only 27.1 to 28.0 °C on the Big Island (National Oceanic and Atmospheric Administration, Keaau, Hawaii), whereas the average daily relative humidity was 62% to 65% on Oahu compared to 67% to 71% on the Big Island. Possibly owing to these differences, we observed that, whereas the dichlorvos squares were intact over the entire study period on the Big Island, the squares became brittle over time on Oahu, and in some instances began to "splinter" into smaller fragments. Consequently, we ran another experiment (Experiment 3) during Aug to Oct 2019, on Oahu that was identical to Experiment 2, except that only plugs were weathered, while dichlorvos squares were discarded after use, and new squares were placed inside the traps just prior to the next trapping period. Weather conditions during Experiment 3 were similar to those reported above for Experiment 2.

Two-way ANOVA on $\log_{10}$ transformed data showed that both wk ($F_{3,176} = 10.6$; $P < 0.001$) and treatment ($F_{3,176} = 9.1$; $P < 0.001$) had significant effects in Experiment 3 (Fig. 2B). The interaction term also was significant ($F_{9,176} = 2.2$; $P = 0.02$). Based on the Tukey test, trap captures in Experiment 3 did not vary among treatments for wk 0 or 6. For wk 8 and 10, captures for the fresh liquid lure were significantly greater than those for the 3 g plug but did not differ significantly from captures for traps with 6 or 10 g plugs.

Based on these results, we hypothesize that Jackson traps baited with methyl eugenol-bearing plugs and dichlorvos squares had lower field longevity on Oahu than on the Big Island, because the higher temperature and slightly lower humidity on Oahu limited the effectiveness of the dichlorvos squares to a greater degree than on the Big Island. This interpretation follows from the finding that, for experiments performed on Oahu, traps containing 6 or 10 g plugs weathered for 10 wk captured similar numbers of *B. dorsalis* males as traps baited with fresh liquid methyl eugenol (and naled) when dichlorvos squares were replaced for each 1 to 2 d trapping period (Experiment 3) but captured significantly fewer males when dichlorvos squares were weathered along with the lures (Experiment 2). While the 6 and 10 g plugs performed well for 10 wk on Oahu, the 3 g plugs tested there appeared to lose attractiveness more rapidly; even with replacement of the dichlorvos squares, traps baited with 3 g plugs captured significantly fewer flies than traps baited with fresh liquid methyl eugenol after 8 wk of weathering on Oahu. This suggests that, especially under warmer and drier conditions, the longevity of methyl eugenol-bearing plugs varies directly with the amount of lure contained in the plugs.

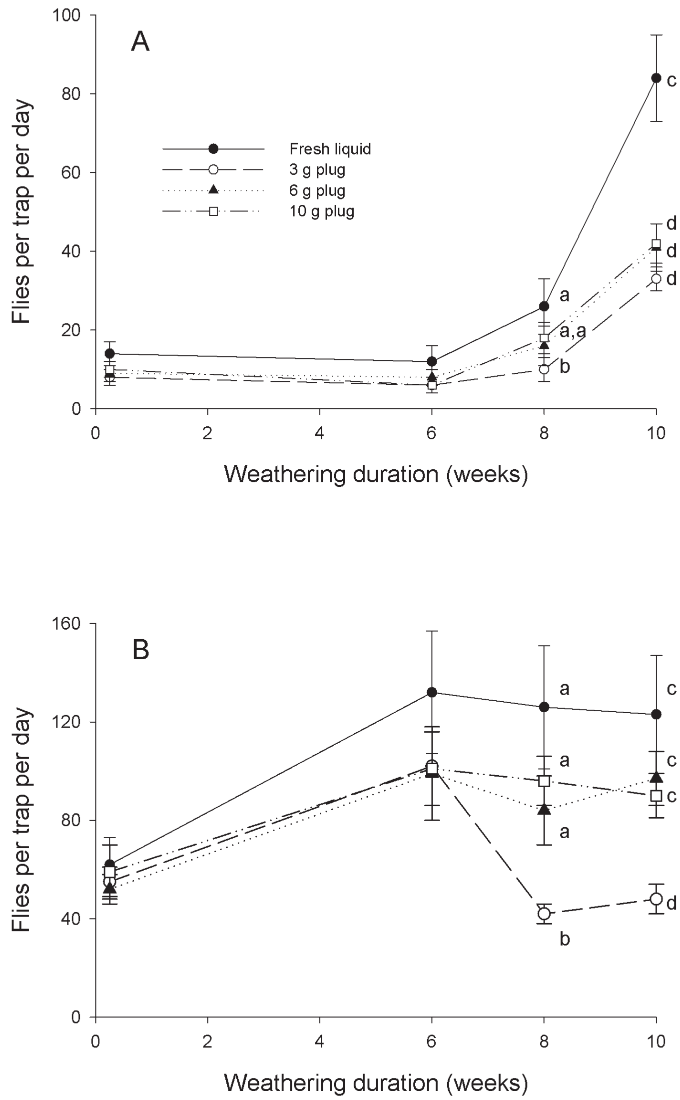

Fig. 2. Captures of *Bactrocera dorsalis* males on Oahu, Hawaii, USA, in Jackson traps baited with fresh liquid methyl eugenol or weathered, polymeric plugs containing 3, 6, or 10 g of methyl eugenol, where accompanying dichlorvos squares were either weathered (A, Experiment 2) or replaced prior to each trapping period (B, Experiment 3). Symbols represent means ± 1 SE; $n = 12$ in all cases. For a given trapping interval, means marked with different letters differed significantly ($P < 0.05$, Tukey test).

Summary

Detection of invasive populations of *Bactrocera dorsalis* relies on traps baited with the male-specific attractant methyl eugenol. Standard protocol involves applying 5 mL of liquid methyl eugenol (1% naled) to a cotton wick, which is then placed inside a Jackson trap. Because of the lure's high volatility, the lure is replaced every 6 wk.

Prolonging the lure's longevity would increase trap servicing intervals and reduce associated costs. Conducted at 2 sites in Hawaii, the present study investigated the performance of weathered solid dispensers containing 3, 6, or 10 g of methyl eugenol, deployed with solid insecticidal strips, relative to freshly baited liquid-bearing cotton wicks. At the cooler site, the solid lure/toxicant combination captured as many males as the fresh liquid formulation for as long as 12 wk. At the warmer site, the solid lure/toxicant system had shorter longevity, apparently owing to the reduced effectiveness of the insecticidal strip over time.

Key Words: *Bactrocera dorsalis*; invasive species; male lure; detection

Sumario

La detección de poblaciones invasoras de *Bactrocera dorsalis* se basa en trampas cebadas con el atrayente metil eugenol específico para los machos. El protocolo estándar implica la aplicación de 5 mL de metil eugenol líquido (naled al 1%) a una mecha de algodón, que luego se coloca dentro de una trampa Jackson. Se reemplaza el señuelo cada 6 semanas debido a la alta volatilidad del señuelo. Al prolongar la longevidad del señuelo aumentaría los intervalos de mantenimiento de las trampas y reduciría los costos asociados. Realizado en 2 sitios en Hawái, el presente estudio investigó el rendimiento de dispensadores de sólidos desgastados que contienen 3, 6, o 10 g de metil eugenol, desplegados con tiras insecticidas sólidas, en relación con mechas de algodón con líquido recién cebado. En el lugar más fresco, la combinación de señuelo sólido/tóxico capturó tantos machos como la formulación líquida fresca durante un período de hasta 12 semanas. En el sitio más cálido, el sistema de señuelo sólido/tóxico tuvo una longevidad más corta, aparentemente debido a la menor efectividad de la tira de insecticida con el tiempo.

Palabras Clave: *Bactrocera dorsalis*; especies invasivas; señuelo para machos; detección

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