Male Lures and the Detection of *Bactrocera* Fruit Flies (Diptera: Tephritidae): Performance of Solid Dispensers with Separate Insecticidal Strips Relative to Standard Liquid Lures

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Abstract. Detection of pestiferous *Bactrocera* fruit flies (Diptera: Tephritidae) relies largely on deployment of traps baited with male-specific attractants. Two species in particular, *B. dorsalis* (Hendel) and *B. cucurbitae* (Coquillett), pose serious threats to US agriculture, and males of these species are attracted to methyl eugenol (ME) and cue lure (CL), respectively. At present, these lures are applied as liquids (with naled added as an insecticide) to cotton wicks placed inside Jackson traps, a procedure that entails considerable handling time and potential health risk owing to inadvertent contact with the chemicals. Recent studies have demonstrated that solid dispensers containing male lures and the toxicant DDVP (dichlorvos) capture as many or more *B. dorsalis* and *B. cucurbitae* males as the standard liquid formulation. Owing to registration requirements, deployment of solid dispensers requires the lure and the killing agent be presented in separate devices. The goal of this study was to compare capture of *Bactrocera* males between traps baited with the liquid formulation (lure and naled mixed) versus traps baited with solid lure-bearing plugs or wafers and separate DDVP strips (lure and DDVP separate). Field trapping was conducted in various areas of Oahu, Hawaii, using variable amounts of DDVP (0.09 – 0.295 g) in the traps with the solid dispensers. In general, for both *B. cucurbitae* and *B. dorsalis*, traps with wafers performed as well as traps with liquids regardless of lure age (fresh or aged 6 weeks), DDVP dose, test location, or lure presentation (ME and CL presented singly or combined). Traps with aged plugs also performed as well as aged liquids for both *Bactrocera* species under nearly all test conditions. However, in a large proportion of tests, fresh plugs captured significantly fewer males of both species than fresh liquids over the full range of DDVP doses tested. The implications of these findings for *Bactrocera* detection are discussed.

Introduction

The genus *Bactrocera* (Diptera: Tephritidae) contains approximately 500 species, most of which inhabit forested regions of tropical Asia (Drew and Hancock 2000). While most of these species are not economically important, approximately 70 *Bactrocera* species pose a serious threat to fruit and vegetable production worldwide (White and Elson-Harris 1992). Two of these species, *B. dorsalis* (Hendel) and *B. cucurbitae* (Coquillett), are invasive threats to US agriculture, and states such as California, Florida, Hawaii, and Texas maintain continuous trapping programs to detect incipient infestations (IPRFFSP 2006). Detection relies primarily on male-specific attractants, namely methyl eugenol (hereafter ME) for *B. dorsalis* and cue lure (hereafter CL) for *B. cucurbitae*,

and in present practice, these male lures (containing a small amount of insecticide, typically naled) 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). Consequently, there is considerable interest in the development and adoption of solid dispensers for *Bactrocera* detection that minimize handling time and exposure risk, and, in fact, a number of recent studies (Vargas et al. 2009, 2010; Leblanc et al. 2011; Shelly 2010; Shelly et al. 2011a, b) have demonstrated that traps baited with solid polymeric ME- or CL-containing plugs or wafers capture as many or more males as traps baited with the standard liquid lures (but see Wee and Shelly 2013).

Although these studies support the adoption of an alternative delivery system, the solid dispensers tested invariably contained an insecticide (either naled or DDVP) together with the male lure. At present, however, there are no EPA-registered products that contain both an insecticide and ME or CL and that are approved for USDA-APHIS fruit fly surveys (J. Crowe, pers. comm.). Consequently, there is a need to test the efficacy of traps containing solid dispensers containing lure only with separate insecticidal dispensers. The goal of this study was to compare capture of *Bactrocera* males between traps baited with the liquid formulation (lure and naled mixed) versus traps baited with solid lure-bearing devices (plugs or wafers) and separate DDVP strips (i.e., lure and DDVP separate).

Materials and Methods

Study sites. Field work was conducted between April and November, 2012, at four sites on Oahu, namely Waimanalo, Waialua, Mililani, and the Dole coffee field (*Coffea arabica* L.). The first two sites are coastal (< 30 m elevation), rural areas, while the Mililani site is at a higher elevation (200 m) in the center of the island within the Mililani Agricultural Park. At these three sites, host plants occurred either in small plots (< 1 ha) or were dispersed haphazardly throughout the habitat. Host plant availability varied somewhat among these three sites, but papaya (*Carica papaya* L.), mango (*Mangifera indica* L.), bitter melon (*Momordica charantia* L.), ivy gourd (*Coccinia grandis* (L.)), tomato (*Solanum lycopersicum* L.), and zucchini (*Cucurbita pepo* L.) were present in all three locations. The final site was a coffee field (≈ 65 ha; elevation 100 m) roughly midway between Mililani and Haleiwa, bordered by unmanaged gullies that contained various *Bactrocera* host plants, notably bitter melon, ivy gourd, papaya, and guava (*Psidium guajava* L.). Coffee is a host plant for *B. dorsalis* but not *B. cucurbitae*. However, by positioning traps toward the edges of the field (i.e., near the gullies), both species were collected in sufficient numbers for analysis. Over the study period for all sites, daily minimum and maximum temperatures ranged from approximately 16 to 21°C and 24 to 28°C, respectively, and rainfall varied from approximately 10 to 15 cm/month (Weather-warehouse.com).

Traps and lures. Jackson traps (Scentry Biologicals Inc., Billings, MT) were used exclusively. These 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 tree branches using a metal hanger, with a straight portion positioned under the "roof" along the apex of the trap.

Liquid ME and CL were obtained from Farma Tech International, North Bend, WA. In all tests, I applied 6 ml of each lure (1% naled for ME, 5 % naled for CL) to two cotton wicks (each 2.5 cm in length, 2 cm in diameter), which were then placed in a perforated, plastic basket. This basket, in turn, was fastened to the metal hanger and suspended in the middle of the Jackson trap directly above the sticky insert. In all tests, liquid ME and liquid CL were presented in separate traps, i.e., they were never applied as a blend to a cotton wick.

Two types of solid polymeric dispensers were tested, namely plugs (Scentry Biologicals Inc., Billings, MT) and wafers (Farma Tech International). In the initial experiments, each type of solid dispenser contained 6 g of a single lure (ME or CL). As the specific gravity of each of the lures is approximately 1.0, the amount of each lure contained in the solid dispensers was approximately the same as that contained in the liquid application. Plugs were cylindrical (2.5 x 1.5 cm), and wafers were rectangular (7.5 x 5.0 cm, 0.2 cm thick). In a second set of experiments, traps baited with liquid lures were compared with traps baited with plugs (5.0 x 1.5 cm) containing both ME and CL (6 g and 3 g, respectively) or wafers (7.5 x 5.0 cm, 0.3 cm thick) containing both ME and raspberry ketone (6 g and 2.3 g, respectively), the plant-borne product from which CL is produced (hereafter referred to as RK).

DDVP strips. DDVP strips were obtained from two sources, Hercon Environmental (Emigsville, PA) and Plato Industries Inc. (Houston, TX). Hercon strips (Vaportape II; 2.5 x 10 cm, 2 mm thick) contained 0.59 g DDVP, but in our tests we cut the original units and used only half (0.295 g DDVP) or quarter (0.1475 g DDVP) strips. Plato strips were of two sizes: 2.5 cm squares (0.09 g DDVP) or 2.5 x 5.0 rectangles (0.24 g DDVP; both strip sizes were 2 mm thick). In all traps with solid dispensers, DDVP strips were placed in perforated baskets, which were suspended next to the dispenser.

Field Trapping. Five experiments were conducted (note that an ancillary experiment with a slightly different design was also performed and is described after the main experiments). In all of them, liquid ME and CL were presented in separate traps as described above. For the solid dispensers in Experiments 1–3, ME and CL were presented in separate plugs and wafers, respectively, with different DDVP treatments, namely 0.295 g (½ Hercon strip), 0.1475 g (¼ Hercon strip), or 0.09 g (one Plato square), with the different DDVP doses corresponding to Experiments 1, 2, and 3, respectively. For the solid dispensers in Experiments 4–5, ME and CL were presented in the same plugs and ME and RK were presented in the same wafers with different DDVP treatments, namely 0.1475 g (¼ Hercon strip) or 0.09 g (one Plato square) in Experiments 4 and 5, respectively (i.e., the ½ Hercon strip treatment was not included in tests involving the combination plugs and wafers). In a given experiment, we established 15 stations for each dispenser type (i.e., liquid, plug, or wafer) separated by a minimum of 50 m. In Experiments 1–3, we placed two traps containing the same dispenser type at each station, one ME-baited and the other CL-baited. In Experiments 4–5, two traps were placed at the stations assigned the liquid/wick treatment, whereas only one trap (baited with a ME-CL or a ME-RK combination dispenser) was placed at the stations assigned plugs or wafers, respectively. In all cases except the coffee field, stations were non-host trees along roads in the sampling area, with the different dispenser types placed sequentially along the roads (i.e., adjacent stations contained different dispenser types). Traps were suspended 1–3 m above ground in shaded locations.

In the coffee field, traps were placed 1–2 m above ground in plants within 50 m of the edge of the field. As above, dispenser types were alternated between adjacent positions.

In all experiments, traps were operated for two days and then collected and returned to the laboratory; trap placement and collection occurred between 0900–1100 hrs. The sticky inserts were removed, the flies counted, and the traps (minus the insert) were suspended in a shaded area outside the laboratory for ageing. Traps were run with fresh lures (traps prepared immediately before field sampling) and again after the lures aged for 6 weeks.

Ancillary experiment. A final experiment was conducted, which while largely similar to Experiments 1–3 described above, differed in three key ways: (i) the liquid lures were not aged but were replaced with fresh liquid at each sampling interval, (ii) trap catch was compared when solid dispensers were fresh, aged 6 weeks, and aged 8 weeks, and (iii) a single DDVP loading was used for all solid dispensers (Plato rectangle, 2.5 x 5.0 cm, 0.24 g DDVP).

Data analysis. As shown below, all experiments were replicated in two locations, except Experiment 3, which was conducted in three locations. For a given experiment, captures in the different locations were analyzed separately, since the relative performance of the different trap presentations was being evaluated, not spatial variation in fly abundance. Moreover, within an experiment, captures with fresh and aged lures were analyzed separately, since without systematic monitoring of the wild populations we could not ascribe temporal variation in captures (between weeks 0 and 6 or between weeks 0, 6, and 8 in the ancillary experiment) to changes in fly abundance or the potency of the lures. Raw data were subject to a $\log_{10}(x + 1)$ transformation and a 1-way ANOVA, with lure dispenser as the main factor. Upon detection of significant variation, the Tukey multiple comparison test was used to identify significant pair wise differences.

Results

Main experiments. *Results for B. dorsalis.* In Experiments 1–3, ME and CL were presented in separate solid dispensers. Across all sites and DDVP doses and for both fresh and aged lures, traps containing wafers captured similar or significantly greater numbers of *B. dorsalis* males than traps baited with standard liquid lures (Table 1). The effectiveness of wafers was most evident for fresh lures: captures with fresh wafers were significantly greater than those with (i) fresh liquid lures in two of the seven trials (total over all doses and sites) or (ii) fresh plugs in five of seven trials. Conversely, the relative effectiveness of plugs differed markedly between fresh and aged plugs (Table 1). Captures of *B. dorsalis* in traps baited with aged plugs did not differ significantly from those in traps baited with aged liquid or aged wafers for any DDVP dose or at any location. In contrast, fresh plugs performed relatively poorly. Captures with fresh plugs were significantly lower than those (i) with fresh liquid in three of seven trials and (ii) those with fresh wafers in five of seven trials.

In Experiments 4–5, ME and CL were presented together in solid dispensers. Across all sites and DDVP doses and for both fresh and aged lures, traps containing wafers captured similar numbers of *B. dorsalis* males as traps baited with standard liquid lures (Table 2). Results for the plugs were similar to those described above for Experiments 1–3, i.e., aged plugs performed as well as aged liquids or aged wafers at both DDVP doses, but fresh plugs did not. In particular, for the lowest

Table 1. Captures of *B. dorsalis* and *B. cucurbitae* in Jackson traps baited with methyl eugenol or cue lure (i) applied as liquids to cotton wicks or embedded in polymeric (ii) plugs or (iii) wafers (Experiments 1–3). Values represent means (SE) of raw data, though data were $\log_{10}$ transformed for analysis. F values derived from 1-way ANOVA, with n = 15 traps per dispenser type and df = 2, 42 in all cases. F-test results: *** P < 0.001, ** P< 0.01, * P < 0.05, ns = no significant variation. Where significance was detected, values sharing a letter were not significantly different in Tukey test.

Expt.	DDVP (g)	Site[1]	Lure Age[2]	Captures (flies/trap/day) Liquid	Plug	Wafer	F
B. dorsalis							
1	0.295	MI	F	10.7^{A} (2.2)	3.8^{B} (1.4)	17.0^{A} (3.2)	10.9^{***}
			A	9.5 (1.5)	5.9 (1.2)	12.0 (3.4)	2.1^{ns}
1	0.295	WO	F	34.5^{A} (9.3)	10.2^{B} (3.8)	46.0^{A} (12.7)	4.3^{*}
			A	29.8 (7.1)	24.7 (6.8)	40.6 (12.1)	1.0^{ns}
2	0.1475	WA	F	83.2 (22.1)	77.9 (11.5)	90.2 (16.0)	1.5^{ns}
			A	151.4 (21.9)	160.0 (14.2)	183.1 (33.4)	0.7^{ns}
2	0.1475	WO	F	144.5^{B} (16.9)	119.6^{B} (9.6)	184.0^{A} (20.3)	5.7^{*}
			A	78.8 (10.1)	59.7 (13.3)	69.8 (7.6)	0.7^{ns}
3	0.09	MI	F	25.9^{A} (4.9)	12.1^{B} (2.3)	29.9^{A} (5.4)	6.5^{**}
			A	18.6 (4.2)	14.2 (3.2)	14.4 (2.3)	0.6^{ns}
3	0.09	WO	F	75.8 (16.1)	78.7 (18.3)	66.5 (10.6)	0.2^{ns}
			A	153.3 (17.9)	199.7 (13.7)	152.3 (16.3)	1.0^{ns}
3	0.09	WA	F	140.3^{B} (14.5)	136.8^{B} (14.8)	200.4^{A} (22.1)	5.6^{*}
			A	125.1 (17.9)	167.6 (26.1)	156.5 (20.8)	0.6^{ns}
B. cucurbitae							
1	0.295	MI	F	48.6 (20.2)	45.1 (12.1)	62.4 (17.4)	1.9^{ns}
			A	60.3 (12.5)	50.7 (13.8)	88.8 (23.4)	1.8^{ns}
1	0.295	WO	F	24.5 (6.6)	34.4 (13.8)	21.3 (9.7)	0.9^{ns}
			A	14.8 (4.1)	9.0 (3.6)	18.7 (6.5)	1.7^{ns}
2	0.1475	WA	F	31.5 (7.2)	29.0 (5.8)	22.6 (5.3)	1.8^{ns}
			A	9.1 (2.2)	8.8 (2.9)	12.0 (4.4)	1.1^{ns}
2	0.1475	WO	F	28.9 (9.3)	30.2 (5.0)	20.9 (7.0)	0.8^{ns}
			A	22.8 (8.4)	21.9 (6.6)	31.8 (12.5)	1.2^{ns}
3	0.09	MI	F	72.7 (29.5)	51.9 (11.0)	76.0 (202.2)	0.9^{ns}
			A	45.9 (11.0)	47.9 (14.1)	72.6 (15.2)	1.1^{ns}
3	0.09	WO	F	12.0 (4.1)	7.1 (1.9)	8.3 (4.5)	0.6^{ns}
			A	10.6 (5.2)	12.5 (5.9)	9.7 (3.9)	0.1^{ns}
3	0.09	WA	F	25.6 (6.6)	32.8 (8.6)	39.7 (10.1)	3.4^{ns}
			A	9.8 (3.0)	8.1 (2.2)	4.6 (1.4)	1.1^{ns}

[1]MI = Mililani; WO = Waimanalo; WA = Waialua

[2]F = fresh; A = aged 6 weeks

Table 2. Captures of *B. dorsalis* and *B. cucurbitae* in Jackson traps baited with i) methyl eugenol or cue lure applied as liquids to cotton wicks or (ii) methyl eugenol and cue lure embedded in combination in polymeric (ii) plugs or (iii) wafers (Experiments 4–5). Values represent means (SE) of raw data, though data were $\log_{10}$ transformed for analysis. F values derived from 1-way ANOVA, with n = 15 traps per dispenser type and df = 2, 42 in all cases. F-test results: *** P < 0.001, ** P< 0.01, * P < 0.05, ns = no significant variation. Where significance was detected, values sharing a letter were not significantly different in Tukey test.

Expt.	DDVP (g)	Site[1]	Lure Age[2]	Captures (flies/trap/day) Liquid	Plug	Wafer	F
B. dorsalis							
4	0.1475	MI	F	21.0 (3.6)	17.7 (5.5)	20.5 (3.9)	0.2^{ns}
			A	24.7 (4.3)	25.6 (5.0)	18.1 (4.4)	0.3^{ns}
4	0.1475	WA	F	145.5 (21.6)	129.6 (19.4)	159.7 (22.5)	0.9^{ns}
			A	157.6 (31.1)	129.7 (23.3)	162.3 (31.2)	1.1^{ns}
5	0.09	HA	F	$135.7^{A,B}$ (19.1)	102.3^{B} 18.9)	195.4^{A} (27.3)	5.3^{*}
			A	113.8 (28.2)	78.4 (13.7)	77.4 (18.4)	0.9^{ns}
5	0.09	WO	F	$197.8\ (19.5)^{A}$	$148.2\ (26.5)^{B}$	$209.3\ (28.1)^{A}$	5.5*
			A	100.0 (14.3)	75.2 (21.1)	118.3 (20.8)	1.6^{ns}
B. cucurbitae							
4	0.1475	MI	F	109.8 (23.1)	83.9 (15.2)	92.2 (19.0)	0.6^{ns}
			A	75.4 (21.3)	70.0 (12.8)	67.7 (20.4)	0.1^{ns}
4	0.1475	WO	F	18.5 (3.6)	17.1 (4.0)	11.5 (5.2)	0.7^{ns}
			A	22.2 (8.9)	16.7 (4.8)	21.0 (4.8)	0.4^{ns}
5	0.09	HA	F	$42.6\ (6.6)^{A}$	17.5^{B} (4.0)	16.5^{B} (3.7)	7.6**
			A	18.7 (5.0)	9.9 (2.7)	9.7 (3.7)	3.2^{ns}
5	0.09	WO	F	$33.7\ (9.6)^{A}$	$13.7\ (3.6)^{B}$	$12.8\ (2.5)^{B}$	9.8***
			A	5.8 (1.2)	3.3 (1.0)	7.3 (1.9)	1.1^{ns}

[1]HA = Haleiwa; MI = Mililani; WA = Waialua; WO = Waimanalo
[2]F = fresh; A = aged 6 weeks

DDVP dose of 0.09 g, traps with fresh plugs captured significantly fewer males than traps baited with fresh liquid lures or fresh wafers at one site (Waimanalo, WO) and captured significantly fewer males than traps containing fresh wafers at another site (Haleiwa, HA).

Results for B. cucurbitae. The results obtained for *B. cucurbitae* were uniform for Experiments 1–3: the numbers of captured males varied independently of dispenser type at any site or any DDVP dose (Table 1). Likewise, where ME and CL were presented in combination in the plugs and wafers and the DDVP dose was 0.1475 g, there was no significant variation in captures of *B. cucurbitae* males among dispensers at the two sites tested (Experiment 4; Table 2). However, at the lower dose (0.09 g; Experiment 5), traps baited with fresh liquid lures caught significantly more males than either traps baited with fresh plugs or fresh wafers at both test locations, whereas no differences were

Table 3. Captures of *B. dorsalis* and *B. cucurbitae* in Jackson traps baited with methyl eugenol or cue lure i) applied as liquids to cotton wicks or embedded in polymeric ii) plugs or iii) wafers. All traps with solid dispensers contained a strip with 0.24 g DDVP. Values represent means (SE) of raw data, though data were $\log_{10}$ transformed for analysis. F values derived from 1-way ANOVA, with n = 15 traps per dispenser type and df = 2, 42 in all cases. F-test results: *** P < 0.001, ** P< 0.01, * P < 0.05, ns = no significant variation. Where significance was detected, values sharing a letter were not significantly different in Tukey test.

		Captures (flies/trap/day)			
Site[1]	**Age[2]**	**Liquid**	**Plug**	**Wafer**	**F**
B. dorsalis					
HA	F	4.6 (0.8)	5.8 (1.2)	5.9 (1.3)	0.3^{ns}
	A-6	496.6^{B} (36.6)	518.5^{B} (45.3)	701.9^{A} (60.2)	4.8^{*}
	A-8	142.1 (22.4)	162.3 (26.3)	222.5 (31.7)	1.6^{ns}
WO	F	32.3 (18.6)	48.0 (29.9)	51.0 (25.2)	0.8^{ns}
	A-6	41.0 (11.7)	63.1 (20.4)	66.2 (14.2)	1.3^{ns}
	A-8	27.6 (5.5)	45.1 (9.9)	47.8 (11.4)	1.0^{ns}
B. cucurbitae					
HA	F	4.9 (1.2)	3.9 (0.8)	5.9 (1.1)	0.7^{ns}
	A-6	13.1^{A} (1.3)	8.5^{B} (1.2)	$11.7^{A,B}$ (1.2)	4.6^{*}
	A-8	3.7 (0.5)	3.7 (0.8)	2.4 (0.4)	1.5^{ns}
WO	F	10.2 (3.8)	7.1 (2.2)	8.0 (2.8)	0.1^{ns}
	A-6	12.2 (5.0)	7.9 (4.5)	6.8 (2.7)	0.8^{ns}
	A-8	6.1 (1.5)	3.0 (0.6)	4.1 (1.2)	1.4^{ns}

[1] HA = Haleiwa; WO = Waimanalo

[2]F = fresh; A-6 = aged 6 weeks; A-8 = aged 8 weeks; age designations refer to solid dispensers only as liquid lures were refreshed anew for each sampling period.

detected at the same DDVP dose with aged lures (Table 2).

Ancillary experiment. *Results for B. dorsalis*. Traps baited with plugs or wafers captured similar or greater numbers of *B. dorsalis* males than traps baited with liquid lures over all ageing categories and at both test sites (Table 3). In one instance (solid dispensers aged 6 weeks, Haleiwa), however, traps baited with plugs captured significantly fewer males than traps baited with wafers.

Results for B. cucurbitae. Traps baited with wafers captured similar numbers of *B. cucurbitae* males as traps baited with liquid lures over all ageing categories and at both test sites (Table 3). Traps baited with plugs captured similar numbers of males as traps baited with liquid lures in all instances, with one exception (aged 6 weeks, Haleiwa) where they captured significantly fewer males than traps baited with liquids.

Discussion

Relative to the standard liquid application of lures to cotton wicks, the solid dispensers—both plugs and wafers—gen-

erally captured equivalent numbers of *B. dorsalis* and *B. cucurbitae* males. There were no significant differences in the trap catch of male *B. dorsalis* or *B. cucurbitae* among aged liquids, plugs, or wafers over any of the DDVP loadings or at any of the study sites, and this result was obtained both when ME and CL were presented separately or in combination in solid dispensers. Regarding fresh lures, traps baited with fresh wafers containing ME only or ME and CL in combination captured similar or significantly greater numbers of *B. dorsalis* males than the ME liquid-baited traps in all trials (independent of dose or site). In contrast, traps baited with fresh plugs containing ME only or ME and CL in combination caught significantly fewer *B. dorsalis* males than traps baited with liquid ML in about half the trials (over all doses and sites). The relatively poor performance of fresh plugs was observed for experiments involving high (0.295 g) or low (0.09 g) DDVP loadings. For *B. cucurbitae*, both fresh plugs and wafers loaded with CL only performed as well as liquid CL. However, when CL was presented in combination with ME, both traps with the fresh plugs or wafers captured significantly fewer *B. cucurbitae* males than liquid CL at the 0.09 g loading of DDVP at the two sites included in this experiment. There were no significant differences in trap catch of *B. cucurbitae* males among fresh liquid, plugs, or wafers at the higher DDVP loading of 0.1475 g (again, considering solid dispensers containing both ME and CL).

In sum, both fresh and aged wafers containing ME or CL separately or in combination were as effective as liquid lures in attracting *B. dorsalis* and *B. cucurbitae* males at all DDVP doses, with only a single exception (*B. cucurbitae*, Experiment 5). On the other hand, while aged plugs containing ME or CL separately or in combination were as effective as liquid lures in attracting *B. dorsalis* and *B. cucurbitae* males, fresh plugs bearing ME (singly or with CL) appeared less attractive to *B. dorsalis* males than liquid ME. Traps baited with fresh plugs containing CL only caught similar numbers of *B. cucurbitae* males as traps baited with liquid CL at all DDVP loadings, but traps with fresh plugs containing CL and ME were less effective than liquid CL at a DDVP dose of 0.09 g. Based on these findings, it appears that wafers containing single lures with a separate insecticidal device holding 0.09–0.295 g DDVP would be effective as the liquid lure plus naled mixture currently in use.

As part of a larger series of experiments, Jang et al. (2013) reported no significant difference in trap catch of *B. dorsalis* males in Jackson traps baited with liquid ME plus naled versus those baited with an ME-containing plug and a Hercon Vaportape II strip (0.59 g DDVP). Although no difference was detected over the entire 8-week sampling period, male captures in the traps containing the DDVP strip were low initially and then increased gradually over time. Citing results from an earlier study (Jang 2010), the authors suggest that Vaportape II strips suppress trap catch because of strong outgassing of DDVP. This phenomenon was not obvious in the present study as traps baited with fresh wafers and DDVP caught as many *B. dorsalis* and *B. cucurbitae* males as traps baited with fresh liquid lure and naled. It is possible that outgassing of DDVP accounted for the relatively poor performance of fresh plugs in attracting *B. dorsalis*, but this seems unlikely since fresh CL plugs with DDVP strips appeared to attract *B. cucurbitae* males as effectively as liquid CL plus naled. As noted, the insecticidal strips used by Jang et al. (2013) contained 2–6 times as much DDVP as the strips used in the present study, and hence any negative effect of the strips on trap capture

may have been negligible in the present study.

In conclusion, Vargas et al. (2009) demonstrated that traps containing a male lure but lacking an insecticide generally captured fewer *B. dorsalis* or *B. cucurbitae* males than traps containing a lure plus naled or a separate DDVP strip. Moreover, those authors also reported that the presentation of a male lure plus spinosad, a reduced risk pesticide, did not increase trap effectiveness above that observed for traps without an insecticide. It thus appears there is no viable substitute for organophosphate insecticides, and fruit fly surveillance programs will continue to use them to retain insects in the traps (but see Hiramoto et al. 2006 and Jang 2011 for data showing effectiveness of toxicant-free, one-way entrance traps). Given this constraint, the present data gain importance in showing that pre-packaged DDVP strips, which are easier and safer to handle than lure-naled solutions, may be as effective as these solutions in monitoring tephritid populations or detecting infestations.

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