Evaluation of lure dispensers for fruit fly surveillance in New Zealand

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Abstract

BACKGROUND: Fruit flies (Diptera: Tephritidae) represent a major biosecurity threat to the horticulture sector of New Zealand, which is entirely free of these invasive pests. A nationwide surveillance programme is conducted to ensure any incursion is detected as early as possible. A review of the lure dispensers used is reported here.

RESULTS: Lure dispenser emission trials found that the currently used lure plugs release lure more slowly under New Zealand subtropical to temperate climates than wafer dispensers. Subsequent trapping experiments at high altitude in Hawaii (as a mimic of New Zealand meteorological and expected fruit fly ecological conditions) compared Lynfield traps baited with the existing lure plug dispensers and newer wafer dispensers. Catches of wild Oriental fruit flies, Bactrocera dorsalis (Hendel), were 9.5-fold higher with methyl eugenol wafers than with the plugs. Recaptures of sterile melon flies, Bactrocera cucurbitae (Coquillet), were 2.6-fold higher with cuelure wafers than with the plugs. Recaptures of sterile Mediterranean fruit flies, Ceratitis capitata Weid., were not significantly higher with trimedlure wafers than with the plugs.

CONCLUSIONS: Release rate and trapping experiments found new lure dispensers differed in release rate characteristics from existing dispensers under temperate and subtropical conditions, and indicated some potential for improvement in surveillance efficacy.

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Keywords: Tephritidae; Bactrocera dorsalis; Bactrocera cucurbitae; Ceratitis capitata; lure dispensers

1 INTRODUCTION

Fruit flies (Diptera: Tephritidae) represent a major biosecurity threat to New Zealand’s horticulture sector, worth in excess of $NZ 2 billion in 2005.1 Over 250 species of fruit flies present varying degrees of risk to New Zealand,2 and the absence of fruit fly species represents an export market advantage that is highly valued. The Ministry of Agriculture and Forestry, Biosecurity New Zealand (MAFBNZ) operates a nationwide surveillance trapping programme, with about 7385 Lynfield traps3,4 deployed at 3518 sites that are checked fortnightly.5 Traps are deployed at a range of locations based on incursion risk profile,6 with the largest number (about 67%) in Auckland,3 and fewer than 18% of the traps in the South Island. Traps are placed near high-risk points of entry such as ports and international airports, areas with high levels of tourist activity and areas with significant horticultural production. The climatic suitability for many fruit fly species is greatest in northern New Zealand.7,8 The main target species include Mediterranean fruit fly, Ceratitis capitata Weid., Queensland fruit fly, Bactrocera tryoni Froggatt, melon fly, B. cucurbitae (Coquillet), Oriental fruit fly, B. dorsalis (Hendel) and other male lure responsive species. The lures used in fruit fly surveillance in New Zealand are the international standards trimedlure and cuelure, and methyl eugenol.9,10 This programme provides trading partners an auditable assurance that New Zealand remains free of fruit flies, and is designed to detect incursant fruit fly populations quickly so that they may be efficiently eradicated. This requires the operational use of the most sensitive lures available. However, surveillance in a cooler climate raises the question of whether lure performance may be different from operational performance in warmer environments.

Improvements in sensitivity from potentially useful new surveillance systems need to be evaluated periodically, and this project aimed to fulfil that need by assessment of lure dispenser performance under New Zealand conditions, and direct trapping experiments elsewhere in locations with key fruit flies present. The release rate (which determines
efficacy) and longevity (length of effective field life) of the surveillance plugs was unknown under New Zealand conditions, and the initial quantity of active ingredient (AI) present had not been independently assessed. The first part of this project sought to answer these questions with longevity trials and residual chemical analysis in New Zealand. A range of lure dispensers was evaluated, but only the most promising products were considered for field testing.

In the second part of the project, experiments used Lynfield traps in Hawaii for direct evaluation of the same current and potential new lures for three fruit fly species. It was not possible to undertake these experiments in New Zealand under the Hazardous Substances and New Organisms Act (1996), since these species are absent. Therefore, best endeavours were made to conduct trials in areas with a similar climate to Auckland, and with fly densities of up to ten flies per trap per day, a density that might be within the range expected during an incursion, as opposed to fully established populations. However, it was recognised that other factors that could influence trap performance, including relative humidity, precipitation, topography and landscape vegetation cover, could not be as readily matched. The objective was to maximise the potential sensitivity of New Zealand’s fruit fly surveillance with commercially available lure dispensers, and it is acknowledged that the comparison of a 2 g plug and a 4 g wafer is not a direct comparison of dispenser technologies.

2 MATERIALS AND METHODS

2.1 Field sites

2.1.1 Release rate and longevity trials: New Zealand sites

The longevity field trials were carried out simultaneously at the Biosecurity New Zealand Laboratory campuses at Lynfield, Auckland (36.93 °S, 174.72 °E), and Lincoln, Canterbury (43.65 °S, 172.48 °E). The trials ran for 17 weeks from 11 February to 10 June 2003 (i.e. mid-summer through to early winter), which was 5 weeks longer than the 12 week operational standard. The traps were hung in dappled light in available foliated trees, between 1.3 and 1.6 m above the ground, as per the New Zealand fruit fly trapping standard. The host trees and degree of exposure were selected to replicate home gardens, as used in the operational surveillance programme. Climate data were acquired from the National Institute for Water and Atmospheric Research (NIWA) for the trial period for the nearest Auckland site at Owairaka (36.89 °S, 174.72 °E), Auckland, and Lincoln, Canterbury, and used in the interpretation of the results. Six replicates of each experimental treatment were used. The replicates were grouped into randomised blocks, using a separate tree for each block.

2.1.2 Field trapping experiments – climate matching to target locations in New Zealand

The field trapping experiments were designed to compare the performance of the lures, measured by the capture rate of fruit flies under natural conditions, under climatic conditions as comparable as possible with those in New Zealand where traps are deployed for surveillance. Traps in New Zealand are deployed in a wide range of locations, covering a range of subtropical to cool temperate climatic conditions, latitudes 34–47 °S. Because 66% of fruit fly traps in New Zealand are deployed around Auckland (which is generally warmer than locations to the south), climate matching was focused on choosing a site occupied by the target species and with closest possible climate match to Auckland. Meteorological data (temperature and rainfall) were obtained from NIWA (2007) for Auckland, New Zealand, and from the Western Regional Climate Center (2007) for Kanalohuluhulu, Hawaii.

It was also essential that the trials were conducted in an area with appropriate fly populations present, in order to match the low population densities of flies that might be experienced in trapping in New Zealand, in the event of an incursion. A seasonal temperature match and population density comparison indicated that a site at 1066 m elevation on the island of Kaua‘i, Hawaii, USA, would offer a reasonable and practical solution to the need to find a temperate/subtropical climate, low fruit fly densities (less than ten flies per trap per day), with suitably qualified personnel available for data collection. Populations of wild *B. dorsalis* had been studied at this site previously, and releases of sterile *B. cucurbitae* and *C. capitata* were used because of the absence of reproducing populations of these species.

2.1.3 Site at Kaua‘i

A trapping experiment was set up for three species (*B. dorsalis*, *C. capitata* and *B. cucurbitae*) at Koke‘e State Park (22.04 °N, 159.60 °W, alt. 1066 m). The area was vegetated by forest cover dominated by the native koa tree (*Acacia koa* A. Gray) and ‘Ohi’a lehua (*Metrosideros polymorpha* Gaud.) trees, along with a range of other species, including strawberry guava (*Psidium cattleianum* Sab. var. *lucidum*), an invasive host of fruit flies. The mean annual temperature of 15.1 °C at this site is the same as the mean annual temperature at the Owairaka weather station in Auckland, New Zealand, although the seasonality is offset by 6 months (Fig. 1). Long-term rainfall records indicated a likelihood of higher rainfall in Hawaii than in Auckland during some parts of the year (Fig. 1) (compare offset Kanalohuluhulu site monthly mean rainfall with Auckland). *Ceratitis capitata* and *B. cucurbitae* were absent at the high altitude Kaua‘i site, so sterile flies of both species were released. Populations of wild *B. dorsalis* at this site were considerably higher than the nominal target range.
of ten flies per trap per day, but were expected to drop during the trial, based on previous phenology.14

2.2 Test products and traps

The specification for polymer plugs (Agrisense-BCS Ltd, Pontypridd, UK) is 2 g for the trimedlure (TML) (label) and 1 g ± 100 mg of cuelure and methyl eugenol (per plug) (Casagrande E, private communication, 2003). Two plugs of cuelure and methyl eugenol were used per trap to achieve the desired 2 g AI. The cylindrical plugs are approximately 18 mm high with a diameter of 14 mm. The plugs are suspended inside small clip-top baskets that are in turn hung by the small hole in a lug on the top edge of the basket. The wafers (FarmaTech Intl Corp., Fresno, CA) are claimed to contain 4 g AI of their respective materials (Cook J, private communication, 2003). The wafers measure 5 × 5 × 0.3 cm.

Lynfield traps were used in all experiments. These are non-sticky, vertical pot-type traps composed of an outer bucket-shaped, translucent plastic container with a clip-on lid, 100 mm high with a 105 mm diameter top and an 85 mm diameter base (Huhtamaki, Henderson Ltd, Auckland, NZ).15 The walls were perforated by four 27 mm diameter circular holes situated equidistant from each other in a ring around the trap where the top of each hole was about 18 mm below the top of the trap. A length of wire with a crook at the end was inserted through the centre of the lid, while the other end of the wire was hooked around the branch of a tree. For the bioassays only, each trap contained a 150 g kg⁻¹ dichlorvos strip in the bottom (Agrisense-BCS Ltd, Pontypridd, UK).

2.3 Experiment 1: release rate

This experiment compared the release rates of the wafers with the release rates of the plugs under New Zealand conditions at two sites – Lynfield, Auckland, and Lincoln, Canterbury. Six replicates of each test product were used at each location.

The initial (day 0) and final (week 17) active ingredient quantities present in the dispensers were determined by extraction and gas chromatography (Shimadzu GC17A chromatograph; Shimadzu Corp., Kyoto, Japan), using commercial liquid lures as standards. The operating conditions used with a BPX70 60 m column (0.25 mm ID, 0.25 μm film thickness) had a temperature programme with 140 °C held for 2 min, a ramp at 8 °C min⁻¹ to 275 °C, then held for 10 min. The injector temperature was 240 °C, and the detector temperature was 280 °C. Carrier flow was 1.0 mL min⁻¹, with a constant velocity programme at 29 cm s⁻¹. The injection volume was 1 μL, and split 50:1.

The test products (n = 6) were individually weighed at the start of the test (day 0) and subsequently reweighed on days 3 and 7, and then weekly for the following 16 weeks (17 weeks in total). At the end of the trial, the lures were removed, weighed, securely sealed in foil (with tape) and stored at ambient temperature before final extraction and analysis.

The active ingredient quantities between the measured initial and final values were estimated by interpolation from the measured weights, assuming no other losses. This assumption was checked with an additional set of internal controls of each treatment trialled under identical conditions at one location (Lincoln) until week 3, followed by weighing, extraction and analysis. Additional control sets of three new (sealed) lures of each treatment were extracted and analysed at the beginning of the trial, at 3 weeks and at the end of the trial (i.e. each time AI was analysed). Regression of release rate (g day⁻¹) was performed with time, temperature and rainfall.

2.4 Experiment 3: field bioassays

2.4.1 Experiment 2: Trapping trials in Hawaii for Bactrocera dorsalis, Ceratitis capitata and Bactrocera cucurbitae, comparing the plug and wafer dispensers

A trapping trial was conducted using Lynfield traps on Kaua‘i to compare two dispensers (the standard polymer plugs and a new formulation of wafers) of each of three types of lure: methyl eugenol, cuelure and trimedlure (TML), each compared with a blank control (ten replicates of each). The lure loadings were 2 g of plug dispensers held in baskets and 4 g of wafers (hung from a wire hook), with blank controls (containing neither wafers nor plugs), with the traps placed in a randomised block design, suspended from trees at ca 1.5 m. Traps baited with plugs or wafers were ca 30–40 m apart, on either side of the release point. Insecticide strips were replaced every 6 weeks, but the lures remained in the field for 14 weeks. Traps were checked fortnightly for 14 weeks (28 September 2005 to 4 January 2006), and all flies were counted and sexed at each date. In the absence of a wild population, and because recapture rates could also be estimated, sterile insects were released fortnightly for C. capitata (4500 per release, 31 500 total) and B. cucurbitae (2480 per release, 17 360 total). The release points were ca 20 m from traps. This enabled a comparison between...
recapture rates for the two species. Only wild *B. dorsalis* were trapped.

2.5 Data analysis

2.5.1 Release rate experiments

The active ingredient values were interpolated from the mean raw weights of the dispensers on the basis of the known initial and final active ingredient gas chromatography values based on the change in weight. It was assumed that the changes in weight were related to changes in active ingredient. To test whether the release profiles were weather dependent, correlation coefficients were generated for the weekly mean values for temperature and AI weight change per week over weeks 3 to 12, (the period of both the most demanding climate and lure change activity). The correlation coefficients were compared with Pearson’s critical values to determine significance.

2.5.2 Field experiments

The trap catch data were transformed by \(\sqrt{\text{catch}} + 0.5\) before analysis to stabilise the variance. Analysis was run by Minitab version 14.0 (Minitab, Coventry, UK). The effect of dispenser on male trap captures was analysed by *t*-test, in the absence of any control catches. Correlation analysis was used to compare catches by trap occasion between lure types to investigate the potential impact of factors such as weather. Mean flies per trap per day are presented ± SEM. Average daily average temperature was calculated using the formula

\[
\text{Daily average temperature} = \frac{(\text{daily max}T + \text{daily min}T)}{2}
\]

The average daily temperatures and the total precipitation were calculated for each trapping period.

3 RESULTS

3.1 Release rate experiments

3.1.1 Methyl eugenol

The amount of methyl eugenol released from the wafers at Lincoln over 17 weeks was 2.298 g compared with 2.915 g at Lynfield (ca 58 and 75% AI depleted respectively). Initial loadings were 1.847 ± 0.007 g for each plug and 3.988 ± 0.047 g for wafers. Methyl eugenol release rate was faster from the wafers than from the plugs, but measurement errors led to some anomalous values based on fluctuating weights (Fig. 1). The methyl eugenol release rate was positively correlated with date and mean weekly temperature, but not rainfall (not shown) (Table 1). The release rate of the methyl eugenol plugs at Lincoln was correlated with mean weekly relative humidity (\(P < 0.05\); correlation coefficient \(r = -0.703\)), but this was the only significant correlation of RH with any active ingredient or dispenser. Comparison of regression statistics for the dispensers and locations showed a more rapid release rate from the wafers. The wafers at Lynfield showed a steady decay until about week 12, whereas at Lincoln release rates reduced from week 7 (data not shown). Over the trial period, the methyl eugenol plug released approximately 25% of the total methyl eugenol present in the lures (0.414 and 0.467 g released at Lincoln and Lynfield respectively), to end at ca 1.4 g. The release rate exhibited a slow decline from weeks 1 to 7, followed by limited further release (data not shown).

3.1.2 Cuelure

Initial loadings were 1.288 ± 0.07 g for each plug and 4.368 ± 0.07 g for wafers. The wafers released 2.8 and 10.3 times more cuelure than the plugs at Lincoln and Lynfield respectively. The cuelure plugs released very slowly over the trial period, with a maximum of 0.095 g (7%) cuelure loss at Lincoln, to end at 1.193 g (per pair of plugs). The release of cuelure from the wafers was also slow – the total release was 0.563 g (13%) over 17 weeks at Lynfield. The inconsistencies observed in apparent release rate between weeks suggest that the weight of cuelure dispensers varied owing to environmental conditions. There was a negative correlation with mean weekly rainfall at Lynfield (\(P < 0.5\)), suggesting some absorption of water. The release of cuelure from the two products was not dependent on climate variables measured and did not show a significant change over time (Table 1), so has not been presented in Fig. 1.

3.1.3 Trimedlure

Initial loadings were 1.929 ± 0.009 g for each plug and 4.2688 ± 0.077 g for wafers. The trimedlure (TML) wafers had a higher release rate than the plugs, with 95% of TML released at Lynfield and 75% at Lincoln by week 17. In contrast, the trimedlure plug at Lynfield released a total of 75% of the TML present, and at Lincoln 50% of the TML present by week 17. The
trumedlure plugs followed a linear release rate from weeks 3 to 12, while the wafers followed first-order release kinetics (Fig. 1, Table 1). Both dispensers released more trimedlure under the warmer conditions at Lynfield than at Lincoln. The release rate of the trimedlure plug was correlated with the mean weekly temperature at both sites, while the wafer was only at Lynfield than at Lincoln. The release rate of the wafers followed first-order b∗∗∗ a Mean release rate over the first 12 weeks, from weekly readings. y

# Table 1. Amount of lure released (g day⁻¹) over time (days) for methyl eugenol, cuelure and trimedlure from plugs and wafers at two sites in New Zealand, and correlation of weekly mean temperature with release rate (g day⁻¹)

<table>
<thead>
<tr>
<th>Lure</th>
<th>Site</th>
<th>Lure dispenser</th>
<th>Estimated average release rate (g day⁻¹)</th>
<th>Regression equation</th>
<th>R² Release rate × days</th>
<th>R² Release rate × mean temperature</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methyl eugenol</td>
<td>Lincoln</td>
<td>Plug</td>
<td>0.0059</td>
<td>y = 0.0283 – 0.00633 ln(x)</td>
<td>0.731</td>
<td>*** 0.6724</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>Lynfield</td>
<td>Plug</td>
<td>0.0077</td>
<td>y = 0.0393 – 0.00898 ln(x)</td>
<td>0.712</td>
<td>*** 0.4032</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Lincoln</td>
<td>Wafer</td>
<td>0.0279</td>
<td>y = 0.0843 – 0.0167 ln(x)</td>
<td>0.403</td>
<td>** 0.6593</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>Lynfield</td>
<td>Wafer</td>
<td>0.0339</td>
<td>y = 0.0887 – 0.0166 ln(x)</td>
<td>0.378</td>
<td>** 0.4556</td>
<td>*</td>
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<tr>
<td>Cuelure</td>
<td>Lincoln</td>
<td>Plug</td>
<td>0.0018</td>
<td>y = 0.0077 – 0.00176 ln(x)</td>
<td>0.52</td>
<td>NS 0.0204</td>
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<td>Plug</td>
<td>0.0004</td>
<td>y = 0.0011 – 0.000166 ln(x)</td>
<td>0.54</td>
<td>NS 0.0156</td>
<td>NS</td>
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<td>0.0074</td>
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<td>0.06</td>
<td>NS 0.0003</td>
<td>NS</td>
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<td>Wafer</td>
<td>0.0031</td>
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<td>0.11</td>
<td>NS 0.0139</td>
<td>NS</td>
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<tr>
<td>Trimedlure</td>
<td>Lincoln</td>
<td>plug</td>
<td>0.0108</td>
<td>y = 0.0348 – 0.00691 ln(x)</td>
<td>0.540</td>
<td>*** 0.7006</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>Lynfield</td>
<td>Plug</td>
<td>0.0158</td>
<td>y = 0.0402 – 0.00718 ln(x)</td>
<td>0.747</td>
<td>*** 0.7797</td>
<td>**</td>
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<tr>
<td></td>
<td>Lincoln</td>
<td>Wafer</td>
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<td>*** 0.6432</td>
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<td>Wafer</td>
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<td>0.697</td>
<td>*** 0.2591</td>
<td>NS</td>
</tr>
</tbody>
</table>

a Mean release rate over the first 12 weeks, from weekly readings.

b *** <0.1% ** 1% significance; * 5% significance.

table 1. Amount of lure released (g day⁻¹) over time (days) for methyl eugenol, cuelure and trimedlure from plugs and wafers at two sites in New Zealand, and correlation of weekly mean temperature with release rate (g day⁻¹)

3.2 Field bioassay results

3.2.1 Trapping trials in Hawaii for Bactrocera dorsalis, Ceratitis capitata and Bactrocera cucurbitae, comparing the plug and wafer dispensers

The Kaua’i site approximated the temperate conditions in New Zealand as intended, with a mean daily temperature during the trapping period (14.5 °C) slightly below the annual mean for Auckland (15.9 °C) (Fig. 2).

Catches of wild B. dorsalis in traps containing the wafers releasing methyl eugenol dominated the dataset, with a total catch of 35 279 wild flies (Table 2). It is unlikely that the increased volume per se of methyl eugenol in the wafers would give higher catches. However, it is assumed that the 5–10 times higher estimated release rate of wafers over the plugs under these conditions (for weeks 3 to 14) would be a significant determinant in the relative efficacy of the two products. The greater catch of wild B. dorsalis by methyl eugenol presented in wafers compared with plugs (9.5-fold higher) was consistent over time (Fig. 3), and would represent a major improvement in sensitivity at detecting incipient populations in a surveillance programme. The catches of wild B. dorsalis with the standard lures were in the desired range of up to ten flies per trap per day, although the daily catch was much higher with the wafer dispenser. This difference in catch between the two lures highlights the limitations of designing an experiment to target a certain catch range in the population – the standard dispenser of plugs operating in the target range indicated a much lower density than was actually present, as detected by another dispenser. Catches of males in untreated control traps were close to zero throughout the trial, for all three species. Catches of 1–2 females in traps in all the treatments occurred occasionally, as a random by-catch.

Recaptures of sterile C. capitata and B. cucurbitae (Fig. 3) were also sufficient to provide data for a comparison of the two dispensers of lures in Lynfield traps (Table 2). Catches of the sterile B. cucurbitae and C. capitata males were in the range desired to simulate potential trapping conditions in Auckland, in the event of an incursion. Recaptures of 6608 sterile B. cucurbitae were 2.6-fold higher with cuelure wafers (P < 0.01) than with the existing standard plugs (Table 2).

Recaptures of 3048 sterile C. capitata were 1.4-fold (not significantly) higher with trimedlure in wafers.
Figure 3. Catch per trap per day of (A) wild Oriental fruit flies Bactrocera dorsalis in Lynfield traps baited with methyl eugenol (ME), (B) released sterile melon flies Bactrocera cucurbitae in Lynfield traps baited with cuelure and (C) released sterile Mediterranean fruit flies Ceratitis capitata in Lynfield traps baited with trimedlure (TML) in wafer or plug formulations of lures in Hawaii, over 14 weeks, 28 September 2005 to 4 January 2006, together with (D) total precipitation (bars) and range of daily average temperatures (box plots) in Kanalohuluhulu during the same period.
than with the existing standard plugs, representing no improvement.

The recapture rates for *B. cucurbitae* were up to 75% per release with the wafer (Table 3) in a given week, and averaged 19% across the releases for both lures.

The recapture rates for *C. capitata* were above 10% on two occasions with the wafer, and averaged 4.8% across the releases for both lures. Catches were low at the first reading, and again at weeks 10 and 12. The higher recapture in the last week indicates that the lures remained attractive.

The correlation between the catches of flies with the two lure types on each date was significant for all three species ($r^2 > 95\%$ in each case), indicating that weather or other biweekly factors generally influenced both lure types equally. Mean recapture rates for melon fly were higher than for *C. capitata* (Table 3), indicating a probable difference in surveillance efficiency of the two species.

### 4 DISCUSSION

New lure dispensers (wafers) have been compared with the standard lures (plugs) used in New Zealand for fruit fly surveillance. The fruit fly lures and traps used for surveillance in New Zealand have not been experimentally re-examined for an extended period. Improvements in trapping efficacy with more recent lure dispensers have reportedly been achieved, but it was necessary to examine the performance of the lures using Lynfield traps before considering changes to the current operational surveillance protocols, in the event of any trap–factor interactions. New Zealand has a unique position with freedom from fruit flies. The risks from an incursion are significant because of extensive areas of host availability, suitable climate and limited resources available for surveillance. The severe economic impact of even a temporary establishment of fruit flies means that a strategy for early detection is likely to offer considerable economic benefits over time, but changes to operational procedures must be made with caution to avoid losing sensitivity.

The field trials of release rate demonstrated that cuelure and methyl eugenol plugs had slower release rates than expected from the manufacturer’s information for operation in warmer countries, resulting in a field life well beyond 12 weeks under New Zealand climatic conditions. This raised concerns that the low amount of active ingredient released by these plugs may be limiting surveillance sensitivity. In contrast, the single wafers have twice the initial active ingredient of the two plugs used per trap, and under temperate New Zealand conditions the wafers were found to give off significantly more methyl eugenol and cuelure than the plugs, at both Lynfield and Lincoln.

It is likely that emission rate is a significant determinant of the efficacy of the candidate products, which is supported by the significantly higher catches in Hawaii to the wafers. A change to the wafers based on technical performance appears to be warranted. The overriding abundance of *B. dorsalis* showed that even a cool climate location was supporting significant populations of this species. Catches were low at the first reading, suggesting a possible problem with initial product release rate (although neither dispenser would be expected to suffer from this, based on the chemical analysis). Low catches at weeks 10 and 12 could be a result of the heavy rainfall during that time.

No literature was found that directly addresses the relationships between cuelure release rate and attractancy; although a correlation has been observed (Jang E, unpublished data). This study confirms this relationship, with the larger amounts of cuelure released by the wafers over the plugs yielding 2.6-fold higher catches of *B. cucurbitae*.

The 2 g trimedlure dose has been the international standard in monitoring programmes since the recommendations of Leonhardt *et al.* in 1989, who adopted the 2 g dose from cotton wick dispensers into solid plug technology as an interim standard, expecting a 4 g dispenser to supersede the 2 g plug. The 4 g plug was superior to the 2 g plug, as it lasted longer and catches were similar to fresh cotton wicks (cf. lower catches with 2 g plug). They showed that reports regarding repellency at 4 g were unsubstantiated. Repellency could result from a high emission rate rather than loading, and/or the repellent effect in Steiner traps could be due to high emission rates from cotton roll wicks producing high local concentrations of trimedlure at the entrances of enclosed traps, which might discourage flies from entering the traps. The high local concentration of trimedlure at the entrances of the traps is potentially an issue for Lynfield traps; however, doses greater than the 2 g maximum initial loading are unlikely to be repellant with controlled release from these modern lure dispensers. The trimedlure wafer should provide significantly higher sensitivity than the plug, as the wafer had an average estimated emission rate of 68.6 mg day$^{-1}$ for 8 weeks and 51.6 mg day$^{-1}$ over 12 weeks at Lynfield and 56.4 mg day$^{-1}$ for 8 weeks and 43.1 mg day$^{-1}$ over 12 weeks at Lincoln. These values are close to the reference emission rates of 61–63 mg day$^{-1}$ for cotton wicks given by Leonhardt *et al.*

The average estimated emission rates of trimedlure plugs were 15.8 mg day$^{-1}$ over 12 weeks at Lynfield and 10.8 mg day$^{-1}$ over 12 weeks at Lincoln. Leonhardt *et al.* demonstrated that an emission rate
of approximately 52 mg day\(^{-1}\) caught similar numbers of \(C.\) capitata to fresh wicks, and 15 mg day\(^{-1}\) caught roughly 50% of fresh wicks. However, in the trial in Hawaii there was no significant difference in total catch of \(C.\) capitata between the two trimedlure dispensers, and there was no evidence from the trapping results to support a change to the trimedlure wafer dispenser, although mean catches in six of seven trapping intervals were slightly higher using the wafers. The bioassay results could be due to differences in the temperature profile of the bioassay site and the field ageing performed in New Zealand, or the differences in the attractiveness of trimedlure under cooler temperatures not leading to higher captures in spite of the higher emission. The technical challenges of the early detection of \(C.\) capitata in cool or temperate climates, along with the limitations of trimedlure in detecting spring and early summer populations in temperate/seasonal climates, have been discussed previously.\(^{32}\)

Surveillance trapping in a grid or other layout relies on attraction of the target organism to the trap vicinity, and then local capture of the highest proportion of insects present. The performance of traps in a grid and therefore overall grid efficacy are subject to a range of factors, some of which are generic, while others are species specific. Trapping programmes should ideally be designed from principles of risk management, with knowledge of probability of capture of organisms that might be present within the grid. Design of grids for certain performance standards is possible, for example at certain spacings and temporal frequency of assessment, if information is available about trap efficacy.

In the case of fruit flies, the previous detection of incursions of \(C.\) capitata and other species in New Zealand using Lynfield traps, albeit with cotton dental wicks as the substrate,\(^{3}\) provides some comfort that the surveillance system being used now would again detect such incursions. However, it is not clear how quickly after arrival the incursion would be detected, and whether there are operational improvements that can cost-effectively improve current practice. The practical difficulty in achieving an assessment of grid efficacy that would apply to the New Zealand surveillance programme for exotic fruit fly species is clear. It may be possible to use the recapture information reported here in a first step to improve current understanding of the surveillance programme for \(C.\) capitata and \(B.\) cucurbitae, taking into account dispersal and other parameters.

This type of validation work is useful because it provides confidence that Biosecurity NZ has access to the best possible attractants and trapping systems for surveillance. These studies have shown that relatively simple improvements in New Zealand cool climate fruit fly surveillance are immediately available without incurring substantially greater costs.

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REFERENCES

16 Leonhardt BA, Cunningham RT, Rice RE, Harte EM and Hendricks J, Design, effectiveness, and performance criteria of dispenser formulations of trimedlure, an attractant of the


