EVALUATING PEAR-DERIVED KAIROMONE LURES FOR MONITORING *CYDIA POMONELLA* (L.) (LEPIDOPTERA: TORTRICIDAE) IN GRANNY SMITH APPLES UNDER MATING DISRUPTION

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Summary

Four sex pheromone lures and the DA2313 lure based on ethyl (2*E*, 4*Z*)-2,4-decadienoate, a pear-derived kairomone, were compared for their attraction to codling moth in a 7.3 ha apple orchard at Bathurst NSW. Plots (1190 m^2 or 1025 m^2) of Granny Smith with Jonathan pollinators (5:1), treated with the mating disruptant, Isomate C at 1000 dispensers ha^{-1} were used. Lures were placed in sticky traps mounted on poles just below the height of the tree canopy, in the middle of each plot. There were three lure change intervals over a 24 week period at 2, 4 and 8 weeks for Scenturion 10 mg sex pheromone lure and at 4, 8 and 12 weeks for BioLure, Mega Lure and Super Lure (the "Bubble") sex pheromone lures and the DA2313 lure. In 28 weeks from October 2002 to April 2003, DA2313 lure and the Bubble caught more male codling moths than Scenturion, BioLure and Mega Lure. DA2313 lure baited traps also caught 1.5x more females than males. There was no effect of lure change interval on catches of males for any of the lures. DA2313 lures in the field for 12 weeks without change caught more female moths than those changed at 4 or 8 week intervals over the same 24 week period.

Keywords: sex pheromone, monitoring traps, apple orchards, ethyl (2*E*, 4*Z*)-2,4-decadienoate, DA2313

INTRODUCTION

Codling moth, *Cydia pomonella* (L.), is a destructive insect pest of pome fruit (apples, pears, quinces) in most parts of the world where these fruits are grown. The pest's host crops are grown commercially in Australia below 28º S and include all States except the Northern Territory. Of these, only Western Australia remains free from *C. pomonella*.

Synthetic insecticides have generally provided good control of the pest since their introduction into pome fruit orchards in the late 1940s (Thwaite 1997). Azinphos-methyl, an organophosphate insecticide, was widely used in Australian pome fruit orchards for more than three decades for control of the pest. Resistance to azinphos-methyl in codling moth was first confirmed in Australia in 1991 (Thwaite *et al*. 1993). Since then, control of the pest through the use of insecticides has been less than satisfactory despite the introduction of new chemistry.

In 1993 mating disruption was introduced to pome fruit orchards in Australia as an alternative management tool for *C. pomonella*. Mating disruption was described by Vickers and Rothschild (1991) as *"a technique used to prevent or reduce mating of insect pests by modifying adult behaviour with synthetic pheromone"*. The first commercially available product was 'Isomate C' (Biocontrol Ltd. Mt Crosby, Queensland). If used alone for codling moth control, mating disruption could significantly reduce the use of insecticides in pome fruit orchards, a major industry priority in the 1990s (Thwaite 1997). However, Vickers *et al*. (1998) showed that mating disruption was only a viable alternative to insecticide control when the population of *C. pomonella* was low. Mating disruption often needs to be supplemented with application of insecticides to achieve satisfactory control of codling moth.

Pest monitoring is critical for managing *C. pomonella* using mating disruption. If the insect is present in other than low numbers then supplementary insecticides are usually required to avoid crop damage. Traps baited with 10 mg sex pheromone lures (Vickers *et al*. 1998) have become a widely used device for monitoring. However, there was ample evidence that the traps were unreliable (WG Thwaite unpubl.). Pome fruit growers who used mating disruption for codling moth control were urged to check trees for evidence of fruit infestation and not rely solely on catches of codling moth adults in traps baited with 10 mg sex pheromone lures for monitoring (Penrose *et al.* 2000).

Light *et al.* (2001) described a pear-derived kairomone, ethyl (2*E*, 4*Z*)-2,4-decadienoate, that attracted both male and female *C. pomonella*. The pear-derived kairomone has also been named DA2313 (Blomefield and Knight 2000). It is the attractant in lures which are now commercially available through Trécé Incorporated (Salinas, California USA). This paper describes a field trial that compared lures containing only DA2313 with four commercially available sex pheromone-based lures for monitoring codling moth in a Granny Smith apple orchard under mating disruption.

MATERIAL AND METHODS

Site

The orchard at Bathurst NSW was 7.3 ha of apple trees, 35 years old, planted in two sections (south 3.9 ha, north 3.4 ha) separated by a grassed waterway 15 m wide. There were 31 rows of apple trees, 6.6 m apart and orientated north-south, arranged as five rows of Granny Smiths then one row of Jonathans as pollinators. There were 50 trees at 4 m intervals in rows in the southern section and 42 trees per row in the northern section.

Mating disruption supplemented with insecticides was used in the block in 2000-01. A spring frost in 2001 removed most of the fruit so the grower chose not to treat the remaining crop with fungicides, insecticides or mating disruption in 2001-02.

'Isomate C' mating disruption dispensers were applied to the entire block in September 2002. The product consists of red opaque polyethylene dispensers loaded with 165 mg of *E,E*-8,10 dodecadien-1-ol (60%), dodecan-1-ol (32%) and tetradecanol (8%) (Biocontrol Technical Note c-020, June 2000).

The block was treated for diseases and pests as per commercial practice (Thwaite *et al.* 2002) except that application of insecticides for codling moth to supplement mating disruption was advised according to pest pressure as determined by monitoring.

Layout

Thirty plots were arranged in each of the southern and northern sections of the block. Plots were nine trees (36 m) x five rows (33 m) wide in the southern section and eight trees (32 m) by five rows wide in the northern section.

'Easiset' Delta Traps (AgriSense-BCS Limited, Pontypridd, Wales) which are triangular in cross-section (110 mm from base to apex) and made from white core-flute plastic were used for the trial. The traps were fitted with a removable cardboard base (190 mm x 190 mm) coated with Tanglefoot® Tangle Trap (The Tanglefoot Company, Grand Rapids, Michigan USA) or similar. Traps were mounted on plastic conduit poles with the wire, normally used to suspend the trap from a branch, shaped so that it held the trap in a horizontal position from the top of the pole. Poles were mounted in the centre of each plot so that the trap was within the top 0.5 m of tree canopy (southern section) or between two trees so that the trap was no higher than either tree (northern section). All traps were installed 4 October 2002 and placed so that none was closer than 0.3 m to an Isomate dispenser (Knight *et al.* 1999).

Treatments

A combination of lure types and change intervals were compared. The lures and their source were:

- Scenturion® – 10x red rubber septum, the lure extensively used in mating disruption blocks until 2001-02 (supplied by EE Muir, Orange NSW and IK Caldwell, Cobram, Victoria)
- BioLure® – Codling Moth 10x membrane (Suterra LLC, Bend, Oregon, USA)
- "The Bubble" – Codling Moth Super Lure, (Phero#Tech Inc, Delta, BC, Canada)
- Mega Lure – Pherocon® Cap, CM Mega Lure, grey halobutyl septum (Trécé Incorporated, Salinas, California, USA)
- DA2313 – Pherocon® Cap, CM/DA2313 - 3460, grey halobutyl septum (Trécé Incorporated, Salinas, California, USA)

The first four lures listed contained codling moth sex pheromone, 10 mg or greater, while the fifth lure, DA2313, was based on the pear-derived kairomone, ethyl (2*E*, 4*Z*)-2,4-decadienoate. Scenturion and the two Pherocon lures were placed in the centre of the trap's sticky base. BioLure was attached to the inside wall of the trap and the Bubble was suspended over the base from the trap apex using a pin.

Lures were replaced at three intervals, 2, 4 and 8 weeks for the Scenturion (two weeks recommended to apple growers by Penrose *et al.* 2000); 4, 8 and 12 weeks for the other four lure types. Sticky bases were replaced every four weeks. There were four replicates of each treatment in randomised blocks, two blocks (eastern and western) in each of the southern and northern sections of the orchard.

Six applications of micro-encapsulated parathion-methyl (Penncap-M®, Colin Campbell (Chemicals) Pty. Ltd. Sydney) were applied on the following dates to supplement mating disruption: 7 November 2002, 22 November 2002, 7 December 2002, 17 January 2003, 6 February 2003 and 25 February 2003.

Assessments

Moths caught in the traps were counted and removed weekly. Bases with moths from traps baited with DA2313 lures were exchanged with a clean, pre-used base. Male and female moths on the bases were sorted using a stereo-microscope. The experiment ran from 4 October 2002 to 17 April 2003. All lures were changed in error on 1 November 2002 (4 weeks) so the experiment was re-started on that date and ran for a further 24 weeks.

'Biofix', the start of sustained catches in sex pheromone traps, as determined at Bathurst Agricultural Research and Advisory Station (BARAS) was recorded. Degree-days (DD) were calculated from BARAS meteorological records using a sine wave transformation (Allen 1976) and the accumulated Celsius degree-days (ACDD) for the season determined. The end of each generation of *C. pomonella* was based on 560 DD per generation (Williams *et al*. 2000).

Statistical analysis

Weekly catches of male moths (only) were transformed using square root (x + 0.5) and the means analysed for differences at each date by ANOVA using Genstat Release 6.1 (Gensat 5 Committee). For all analyses, the treatment effect was separated into lure type and change interval within lure. There were five degrees of freedom (d.f.) for lure type, 12 d.f. for change interval within lure type and 51 d.f. for residual. Total catches for the 28 weeks from 4 October 2002 and total catches for the 24 weeks from 1 November 2002 were also transformed and analysed. For DA2313 lure totals, male and female *C. pomonella* were analysed separately.

RESULTS

Codling moth adults were caught in traps at Bathurst from early October 2002 ('Biofix' 8 October 2002) until the end of March 2003. No moths were trapped in April. Three generations were completed based on the DD accumulation in the six months to the end of March. The first generation ended on 15 December 2002 (561 ACDD), the second generation on 29 January 2003 (1115 ACDD) and the third on 1 April 2003 (1681 ACDD).

For male moths only, none of the change intervals within lure effects were significant at any date. Therefore, Table 1 presents the mean catch of male codling moths for each lure type at each date, combining the three lure change intervals. The three observations in April when no moths were caught are not included. The least significant difference, calculated on the transformed data for each date where there is a statistical difference, is also shown. Moths were caught in every week of the 25 weeks to the end of March (Table 1). There were significant differences in male moth catches between the lure types in ten of the 25 weeks and for these ten weeks, DA2313 lures was highest or shared the highest catch in seven and the Bubble in five of the weeks. BioLure and Scenturion shared the highest catch in three of the ten weeks only. Mega Lure never had the highest catch.

Total catches for the season for each lure type, combining the three change intervals, are given in Table 2. Catches of female moths taken in DA2313 lure baited traps are included separately. For male moth catches, DA2313 lures ranked equal with the Bubble on the season-long data. However, the DA2313 lure has the advantage over the sex pheromone lures in that it will also attract females. In our experiment, the female catch was 1.5x that of males caught in DA2313 lure traps based on the re-transformed data (Table 2).

Mean codling moth catches for each of the lures and lure change intervals, commencing after the accidental full lure change on 1 November 2002, are given in Table 3. The data show that the only significant difference was observed with the female catch in the DA2313 lures in which the 12 week change interval caught the most moths. The mean weekly catches across all change intervals for each lure for this 24 week period show that the DA2313 lures were superior to all others. Catches of males and females in traps baited with DA 2313 lures were not significantly different (Table 3).

DISCUSSION

The observation of three generations of codling moth based on ACDD calculations is consistent with 2002-03 being a hot, dry season. Two complete generations and a partial third are normally expected for Bathurst (Allman 1928). The higher moth catches for the three periods in Table 1, when the significant differences between lure types occur, coincide with each of the three generations.

Most moths were caught during the first generation that ended 15 December 2002 and in part reflected the carryover of *C. pomonella* from the previous season in which the severely reduced crop was left untreated. The high moth catches in the first generation prompted intervention with three applications of insecticide in November-December. *C. pomonella* larval infestation of fruit observed in early January 2003 led to a further three sprays against the second and third generations.

Table 1. Mean number[1] male *Cydia pomonella* captured in sticky traps baited with five lure types, three change intervals combined (n=12).

Date[2] traps checked	Lure type					
	Scenturion	**BioLure**	**Bubble**	**Mega Lure**	**DA2313**	**l.s.d.[3]**
11 Oct 02	0.750	0.750	0.793	0.793	0.707	ns
18 Oct 02	0.793 c	1.379 b	2.116 a	1.235 bc	1.375 b	0.520
25 Oct 02	2.420 a	1.280 c	1.700 abc	1.300 bc	2.050 ab	0.751
*1 Nov 02	1.668 ab	1.279 b	1.469 b	1.164 b	2.130 a	0.568
8 Nov 02	1.378 b	0.952 c	1.039 bc	0.909 c	1.954 a	0.364
15 Nov 02	0.793 ab	0.793 ab	0.923 a	0.707 b	0.707 b	0.133
22 Nov 02	0.880	0.890	1.122	0.984	0.890	ns
29 Nov 02	0.707	0.707	0.793	0.750	0.793	ns
6 Dec 02	0.750	0.707	0.707	0.750	0.707	ns
13 Dec 02	0.866	0.793	0.793	0.707	0.707	ns
20 Dec 02	1.098 b	0.923 b	1.460 a	0.952 b	0.933 b	0.337
27 Dec 02	0.866 bc	0.866 bc	1.182 ab	0.837 c	1.399 a	0.335
3 Jan 03	0.823 b	0.793 b	1.022 ab	0.823 b	1.249 a	0.339
10 Jan 03	0.750	0.793	0.793	0.793	0.780	ns
17 Jan 03	0.750	0.750	0.837	0.750	0.866	ns
*24 Jan 03	0.707	0.707	0.780	0.707	0.780	ns
31 Jan 03	0.750	0.880	0.707	0.750	0.837	ns
7 Feb 03	0.750	0.847	0.853	0.750	1.025	ns
14 Feb 03	0.707	0.823	0.793	0.793	0.990	ns
21 Feb 03	0.707 c	1.258 ab	0.963 bc	0.866 c	1.356 a	0.333
28 Feb 03	0.750 b	1.146 a	0.750 b	0.793 b	1.085 a	0.246
7 Mar 03	0.793	0.793	0.707	0.750	0.825	ns
14 Mar 03	0.750	0.707	0.707	0.750	0.823	ns
21 Mar 03	0.707	0.793	0.750	0.793	0.793	ns
28 Mar 03	0.750	0.707	0.707	0.707	0.707	ns

[1]Data transformed $\sqrt{(x+0.5)}$ prior to analysis.
[2]Catches are for the 7 d up to the date listed. All lures were changed on dates marked*. Data for the three weeks in April are omitted as no moths were caught.
[3]Least significant difference (l.s.d.) of means at $P<0.05$ is shown where applicable. Means in rows followed by the same letter are not significantly different.

Table 2. ***Cydia pomonella*** **adults per trap (n=12) for all lure change intervals, ranked in order of lure performance, 4 October 2002 to 17 April 2003 (28 weeks). Means followed by the same letter are not significantly different (P<0.05).**

Lure	Moths/trap	Re-transformed
DA2313 - females	5.90 a	34.3
DA2313 - males	4.85 b	23.0
Bubble	4.14 bc	16.6
Scenturion	3.60 c	12.5
BioLure	3.30 cd	10.4
Mega Lure	2.64 d	6.5

Table 3. ***Cydia pomonella*** **adult catches (moths/trap) for the 24 weeks, 1 November 2002 to 17 April 2003, for each lure and change interval.**

Change interval (weeks)	Lure[1]					
	Scenturion	BioLure	Bubble	Mega Lure	DA2313 (males)	DA2313 (females)
2	2.58 a	-	-	-	-	-
4	1.68 a	2.19 a	3.03 a	2.13 a	3.43 a	3.51 b
8	2.12 a	2.44 a	2.84 a	1.86 a	3.20 a	3.34 b
12	-	2.90 a	2.66 a	1.57 a	4.13 a	4.82 a
Lure mean[2]	2.12 cd	2.51 bc	2.84 b	1.85 d	3.59 a	3.89 a

[1]Means (n=4) followed by the same letter are not significantly different (P<0.05) within a column.
[2]Lure means (n=12) followed by the same letter are not significantly different (P<0.05) within the row.

The object of the experiment was to find the best lure/change interval combination as reflected by the highest moth catches as an indication of pest activity. We observed uneven distribution of moths across the large experimental site. This was attributed to the effects of the frost on fruit survival in the previous season. The large variation between trap catches meant that the statistical analyses were unable to detect consistent differences in the lure change intervals.

DA2313 lures caught similar numbers of male *C. pomonella* as did the best sex pheromone lure, the Bubble. Our experiments showed that both lures have a field life of at least 12 weeks. However, the DA2313 lures also attracted female *C. pomonella* and the combined catch of both sexes far exceeded the catch of the best sex pheromone lure. This adds greatly to the potential of the new lure as a tool for monitoring orchards under mating disruption. There is a need to confirm the superior performance of DA2313 lures in other situations, especially in other apple cultivars, before advocating their widespread use.

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