

**Development of
improved lures for
monitoring of codling
moth**

Graham Thwaite
NSW Agriculture

Project Number: AP02029

AP02029

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**DEVELOPMENT OF IMPROVED LURES
FOR MONITORING OF CODLING MOTH**

FINAL REPORT

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This report describes an investigation to improve monitoring of codling moth under mating disruption programs in apples. It evaluated four pheromone based lures and the DA or pear ester lure in a Granny Smith apple orchard at Bathurst NSW.

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MEDIA SUMMARY

A new lure based on a common flavouring agent may hold the key to successful control of a major insect pest of apples.

In a move away from reliance on pesticides for control of the destructive codling moth, many Australian apple and pear growers have adopted mating disruption as an alternative control method.

Mating disruption aims to saturate the air around trees in the orchard with a copy of the natural pheromone or scent used by female moths to attract a male to mate. Male moths then have trouble finding the female.

Egg laying is stopped or reduced so there are fewer grubs to attack the fruit.

Fruit growers using mating disruption for codling moth found they were “flying blind”. They were unable to use traditional monitoring methods of sticky traps baited with the female pheromone to follow the insect’s flight patterns during the growing season.

Researchers in the USA found that pear ester, sometimes used to flavour confectionery, was a useful attractant for codling moth.

They also found that the pear ester attracted both male and female moths, unlike the pheromone lures which draw in only males.

The new lure was tried out by NSW Agriculture staff in a Granny Smith apple orchard at Bathurst which was treated with Isomate C mating disruption dispensers.

Moth catches in sticky traps baited with either pear ester lure, also known as the DA lure, were compared with four types of high rate pheromone lures.

More than 1300 codling moths were caught in 60 traps in the 7 ha orchard. Pear ester lure attracted more moths than the four pheromone lures combined and more than half of the moths in the pear ester lure traps were females.

Another benefit of the DA or pear ester lures is that they worked in the field for at least three months. The 10x pheromone lure, used by growers trying to monitor under mating disruption, needed to be changed every two weeks.

Keeping tabs on codling moth in mating disruption blocks should now be more reliable and less costly as a result of the trials funded through Horticulture Australia.

TECHNICAL SUMMARY

Codling moth, *Cydia pomonella* (L.), management remains a challenge to pome fruit growers in mainland eastern Australia. Industry should no longer rely on one insecticide in a seasonal program to provide control. Development of resistance in codling moth to the current limited range of insecticide groups is an ever-present threat. Mating disruption based on the use of dispensers or other delivery systems to permeate the air space in the orchard with synthesised pheromone has been promoted as an alternative management technique.

Monitoring codling moth under mating disruption was initially based on the use of sticky traps baited with septa charged with high load (10 mg or 10x) pheromone. It proved notoriously unreliable. Development in the USA of DA lures containing pear ester, a synthesised kairomone, as the active ingredient was an important advance. Septa containing this compound were shown to attract female as well as male moths, unlike pheromone which attracted only males. There were some varietal/fruit type differences in the effectiveness of DA lures in pome fruit orchards in the USA.

A replicated field trial was completed in 2002/03 in a 7 ha Granny Smith apple orchard at Bathurst NSW. Over a 28 week period (early October to mid April), delta-shaped sticky traps baited with septa charged with pear ester (DA lures) caught more male moths (0.89 moths/trap/week) than four types of pheromone lures, Super Lure Bubble (0.66), Scenturion, (0.54), BioLure 10x (0.39) and Mega Lure (0.28). In addition, DA lure baited traps caught 1.31 female moths/trap/week. There was no evidence of the catches in DA lure traps declining relative to other types as fruit reached maturity.

Half of the 60 traps were placed within the tree canopy in plots each 1170 m² containing 45 trees and the other half between two trees in smaller (1040 m²) 40-tree plots. Traps in both positions caught 0.5 moths/tree, suggesting that positioning of the trap inside or outside the tree canopy had no effect on trap efficiency.

Three lure change intervals were compared for each type. For Scenturion, intervals were 2 weeks (industry standard for this lure) 4 and 8 weeks, while for all other types the intervals were 4, 8 and 12 weeks. Catches in all but DA and BioLure declined as the change interval increased.

DA lures have the potential to replace pheromone lures for use in sticky traps to monitor codling moth in orchards under mating disruption. This investigation demonstrated their effectiveness in a Granny Smith apple orchard. Information from the USA suggests that the lures might not work as well with other fruit types (e.g. pears) or with some varieties of apples. Evaluation of DA lures using other fruit types and varieties in Australia is the next logical step in developing the use of DA lure technology for the local pome fruit industry.

1. INTRODUCTION

Codling moth, *Cydia pomonella* (L.), is the most destructive pest of apples and pears in mainland eastern Australia. Uncontrolled, it can infest almost the entire crop. From the late 1940s until the 1980s, fruit growers controlled the pest using a schedule of insecticide sprays which protect the developing crop. Control, based on the organophosphate insecticide azinphos-methyl (e.g. Gusathion^{®1}), began to break down during the 1980s. Many growers increased the number of applications to achieve control. By 1991, resistance to azinphos-methyl was confirmed (Thwaite *et al.* 1993).

At the same time, research was in progress seeking alternatives to the regular use of “hard” insecticides for control of this key pest in apple production. “Softer” alternatives, which were registered in the early 1990s, included the insect growth regulator insecticide, fenoxycarb (Insegar[®]). The technique of mating disruption, based on the product Isomate-C[®], followed soon afterwards.

Vickers and Rothchild (1991) described mating disruption as “a technique used to prevent or reduce mating of insect pests by modifying adult behaviour with synthetic pheromone or with compounds known to suppress male catch at pheromone traps but which are not found in the pheromone”. The last mentioned compounds are inhibitors and antipheromones, but this report considers only the sex pheromone.

Mating disruption became the key component in a resistance management strategy developed under HRDC Project AP96022 (Thwaite and Hatley 1999). Practical guidelines for the adoption of mating disruption as an alternative control strategy for codling moth had previously been developed under HRDC Project AP201 (Vickers 1996) and summarised by Taylor (1996). There was rapid adoption of mating disruption by Australian apple and pear growers from the first commercial release of Isomate-C in 1994/95 until 1999/2000 when it reached about 5,000 ha (Thwaite 2001). This was estimated to be one third of the apples and pears grown in mainland eastern Australia. Colin Campbell Chemicals registered a second mating disruption product, Disrupt[®] CM, for the Australian market in 1998.

An unknown proportion of orchards under mating disruption also need to supplement the control of codling moth with insecticide applications, either as full cover sprays or by treatment of the orchard perimeter. Anecdotal evidence suggests that the proportion of mating disruption orchards receiving supplementary sprays is high.

Unfortunately, mating disruption did not always meet growers’ expectations. Some of the shortcomings were (anecdotal):

1. Expensive. One treatment costs the equivalent of a full insecticide program. Insecticide supplementation to mating disruption is an added cost.
2. Cost up front. The dispensers need to be purchased (around \$400/ha) and applied in September (application cost estimate \$95/ha). If the crop is lost or seriously reduced (frost, hail) the outlay will not be recovered. An insecticide program can be on a “PAYG” basis.
3. Secondary pests. Sometimes unexpected insect pests become a problem under the reduced pesticide regime. They have included harlequin bugs, apple leafhopper,

¹ [®] Registered trade name

Fullers rose weevil. While they can cause economic injury, control measures are either non-existent (no registration/efficacy data) or are disruptive to IPM.

4. Monitoring. Tree/crop examination is time consuming and therefore not done at all or not properly. Traps baited with 10x pheromone lures, while widely used on the advice of the companies selling the pheromone products, have been an unreliable guide in the field. UV light traps (Rivkina *et al.* 2000) have been evaluated in some orchards but are expensive to purchase and inconvenient to service.

The first five paragraphs of this introduction are reproduced from the Final Report for HAL Project AP01040 (Thwaite 2002). It went on to introduce DA lures based on pear ester, a synthesised kairomone developed in the United States of America (Light *et al.* 2001). The product was initially coded DA2313 and is now marketed through Trécé Incorporated. Background information on its development is given in Appendix 6 of the Final Report for project AP01040.

Recommendation 1 in that Report was to evaluate the DA lures under Australian Conditions. This document reports on that evaluation.

2. MATERIALS AND METHODS

Site

An orchard at Bathurst (“Appleton”, College Road) was used. The block is a total of 7.3 ha, cultivar ratio 5 Granny Smith:1 Jonathan. It was planted in the mid-1960s in two sections divided by a grassed waterway (Fig 1). This block has been used previously for codling moth related trials. Unfortunately it was frosted in spring 2001. Fruit which survived was mainly in the first few rows closest to College Road (western side) but the fruit was not treated for codling moth in 2001/02. This provided a carryover of the pest into 2002/03 which was concentrated in the western rows.

The trial site had last been treated with mating disruption for codling moth control in the 2000/01 season. In winter 2002, all old dispensers were removed from the trees.

Isomate C mating disruption dispensers (Biocontrol Limited, Brisbane) were applied to the block by 30 September 2002 at the recommended rate of 1000/ha. Care was taken to ensure that the dispensers were placed high in the canopy and distributed as evenly as possible.

Treatments

The trial was set up to compare the codling moth catches in delta shaped sex pheromone traps baited with the following lures:

- A - Scenturion[®] 10x pheromone red rubber septum
- B - Pherocon[®] Cap CM/DA lure (pear ester) grey halobutyl septum (Trécé USA)
- C - BioLure[®] codling moth 10x membrane (Suterra USA)
- D - Codling Moth Super Lure, “The Bubble” (PheroTech, Canada)
- E - Pherocon[®] Cap CM Mega Lure, grey septum (Técé USA).

All lures were sourced in September 2002 and stored in a domestic freezer until required. Scenturion and Pherocon Lures were placed directly onto the sticky base, the BioLure was stuck to the inside wall of the trap and the Super Lure was suspended from the apex of the trap using a pin.

There were three replacement intervals for each type, which varied between types depending on the known or perceived field life. The change intervals are in Table 1.

Table 1. Lure change intervals (weeks)

Lure Type	Interval 1	Interval 2	Interval 3
A – Scenturion 10x	2	4	8
B – Pherocon DA	4	8	12
C – BioLure 10x	4	8	12
D – Super Lure Bubble	4	8	12
E – Pherocon Mega Lure	4	8	12

Delta traps (AgriSense-BCS Limited, Wales, supplied by Crop Health Services, DNRE Victoria) were used for all treatments. The sticky bases were changed every four weeks.

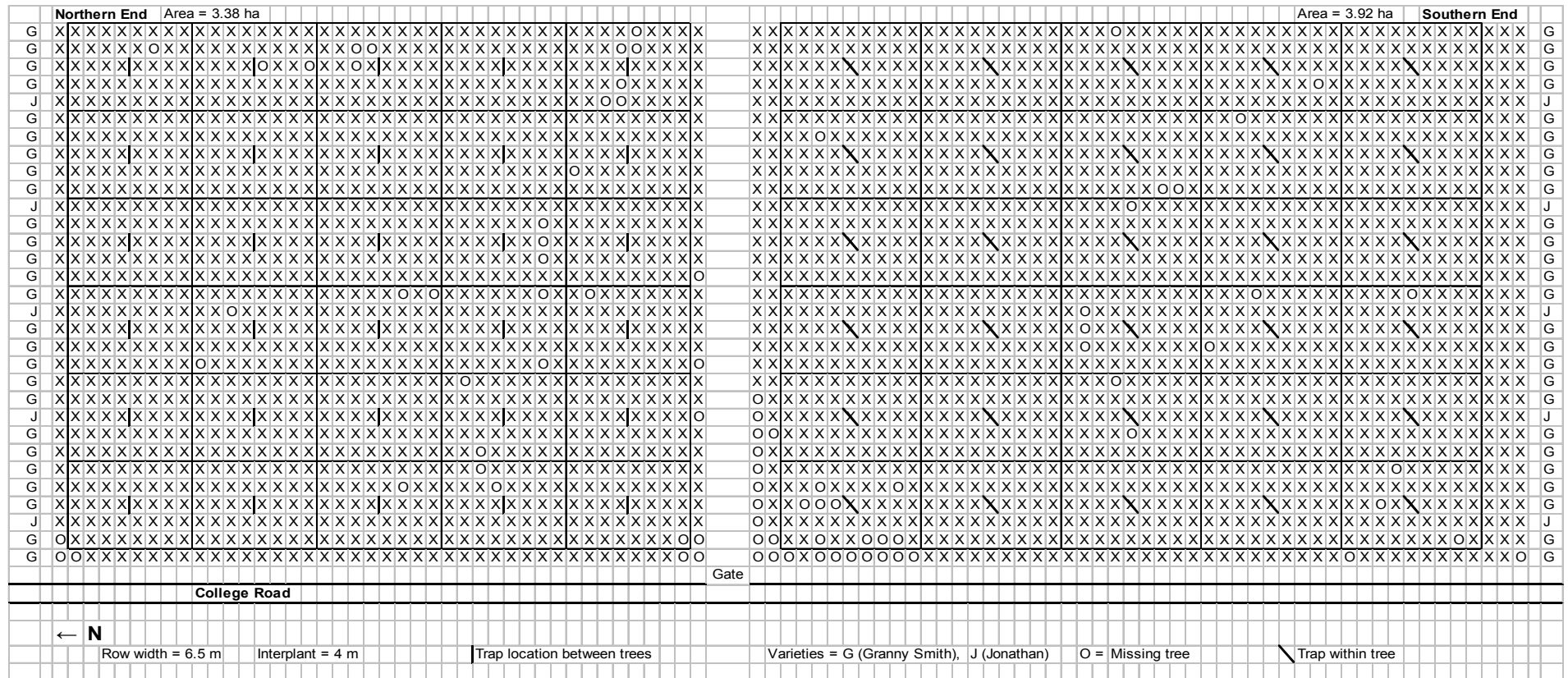


Figure 1. Layout of lure evaluation trial, “Appleton”, Bathurst. A grassed waterway separates the northern and southern sections. See Fig 4 for location of treatments.

When lures were changed, the old lure was removed from the block and discarded in land-fill.

Each trap was placed on a PVC pipe pole in the centre of each plot (Fig 1). They were intended to be located high in the canopy of the central tree (Fig 2) but not within 30 cm of a dispenser (Knight *et al.* 1999). However those in replicates 3 and 4 were inadvertently placed between two trees (Fig 3), literally in the centre of the plot.



Figure 2. Trap placement, reps 1 & 2 where the pole is within the tree.



Figure 3. Trap placement, reps 1 & 2 where the pole is in the tree row. See Fig 1.

Randomisation of the treatments within the four replicates is shown in Fig 4.

						East					
Replicate	Northern End					Southern End					Replicate
[3]	B8-3	B4-3	D12-3	B12-3	A4-3	A4-1	B12-1	E4-1	C8-1	A8-1	[1]
	A2-3	E4-3	C4-3	A8-3	D8-3	A2-1	E12-1	C12-1	D12-1	B4-1	
	D4-3	E12-3	E8-3	C8-3	C12-3	C4-1	D4-1	E8-1	D8-1	B8-1	
[4]	E12-4	A4-4	D12-4	D4-4	E4-4	D12-2	A2-2	A8-2	D8-2	B8-2	[2]
	B4-4	E8-4	A8-4	C8-4	C12-4	E4-2	E12-2	C4-2	C8-2	C12-2	
	C4-4	B8-4	A2-4	D8-4	B12-4	D4-2	B4-2	A4-2	E8-2	B12-2	
College Road											
						West					

Figure 4. Layout of lure comparison trial at Bathurst, 2002/03 – see also Fig 1. Southern end (reps 1 & 2) is 3.9 ha and the northern end (reps 3 & 4) is 3.4 ha. There were 45 trees in plots in reps 1 and 2, 40 in plots reps 3 and 4. The letter codes refer to lure types, the first number refers to the change interval (see Table 1) and the last number is the replicate.

Traps were checked every week for 28 weeks. Any codling moths caught were counted then removed from the sticky bases. Bases from traps baited with a DA lure (treatment B) were exchanged with a pre-used base and the base with moths returned to the laboratory so that the moths could be sexed.

3. RESULTS

The combined trap catches for the 28 weeks of the trial are shown in Figure 5. Degree-day accumulation from Biofix (commencement of sustained codling moth emergence, 8 October) at several points through the season is also indicated, as are the spray dates for micro-encapsulated parathion-methyl (PennCap-M[®]) and when outbreaks of CM damage were observed.

Moth catches, total for the four replicates for each trap type and change interval, are given in the Appendix.

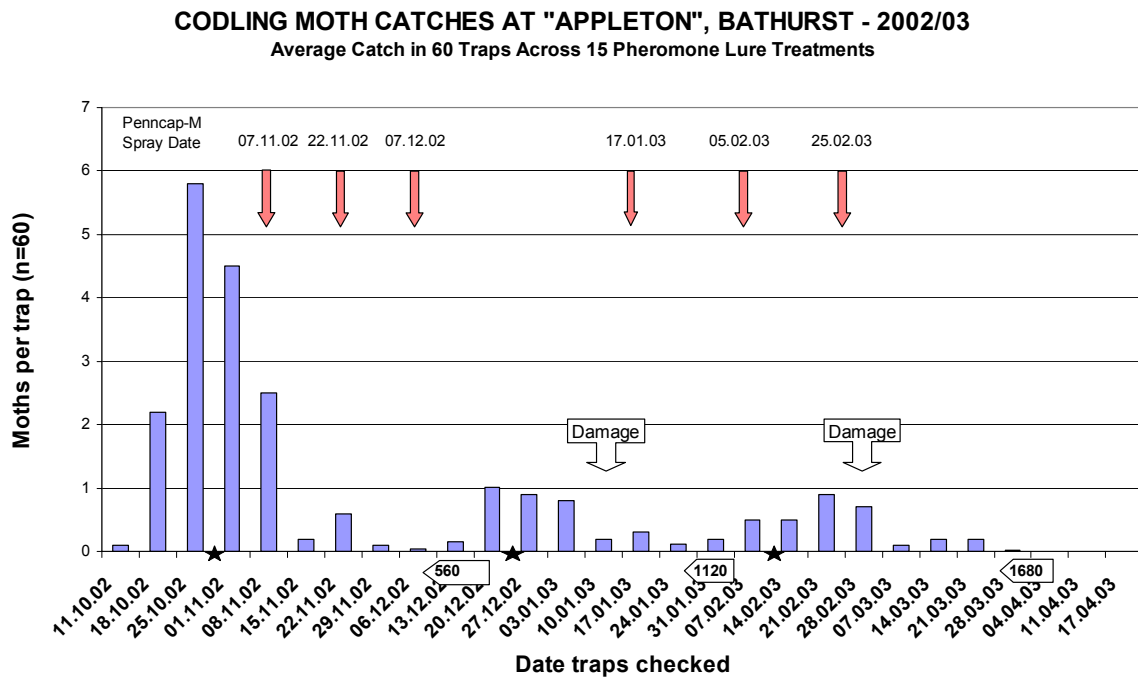


Figure 5. Codling moth population trends at Bathurst, 2002/03, all treatments and replicates combined for the 28 weeks of the investigation. Numbers between the date and the axis indicate DD accumulation from BIOFIX (08.10.02). The position of the numbers represents the end of the first, second, and third generations based on Williams *et al.* (2000). ★ - predicted egg hatch for each generation. Larval damage observations are indicated.

Evaluation was intended to run for 24 weeks from 04.10.02 to allow 2 x 12 week, 3 x 8 week and 6 x 4 week lure change intervals, but there was a lure change error at week 4, so the trial was re-started from 1 November 2002.

Some data outlined below will be for the 24 weeks of the direct comparisons, other results will include the full 28 weeks.

Lure Type

Mean trap catches across all change intervals are given in Table 2.

Table 2. Codling moths caught 04.10.02 to 17.04.03 (28 weeks) – mean moths/trap/week for all lure change intervals, ranked in order of lure performance.

Lure type	Mean catch (males)	Mean catch (females)
B. Pherocon DA lure	0.89	1.31
D. Super Lure bubble	0.66	-
A. Scenturion 10x	0.54	-
C. BioLure 10x	0.39	-
E. Pherocon Mega Lure	0.28	-

Change Interval

The mean number of moths/trap/week for each lure change interval (weeks 5-28) for all lure types are given in Table 3. Detailed data are given in the Appendix and specific data for DA lures are given in Table 4.

Table 3. Mean CM (both sexes for treatment B) caught/trap/week from 01.11.02 to 17.04.03 (weeks 5 to 28) for each lure change interval. For treatment code see Table 1.

Change interval	Treatment code				
	A	B	C	D	E
2 weeks	0.27	-	-	-	-
4 weeks	0.11	0.98	0.20	0.38	0.20
8 weeks	0.21	0.89	0.23	0.36	0.17
12 weeks	-	1.67	0.33	0.29	0.09

Table 4. Effect of lure change interval on trap catch (moths/trap/week) for DA lures for the period 01.11.02 to 17.04.03 (24 weeks), Bathurst 2002/03.

Change interval	Male	Female	Sex ratio (M:F)
4 weeks	0.48	0.50	0.96:1
8 weeks	0.44	0.45	0.98:1
12 weeks	0.71	0.96	0.74:1

Lure Efficiency

Figure 6 presents the data for the 4-week change interval (only) for 24 weeks from 04.10.02.

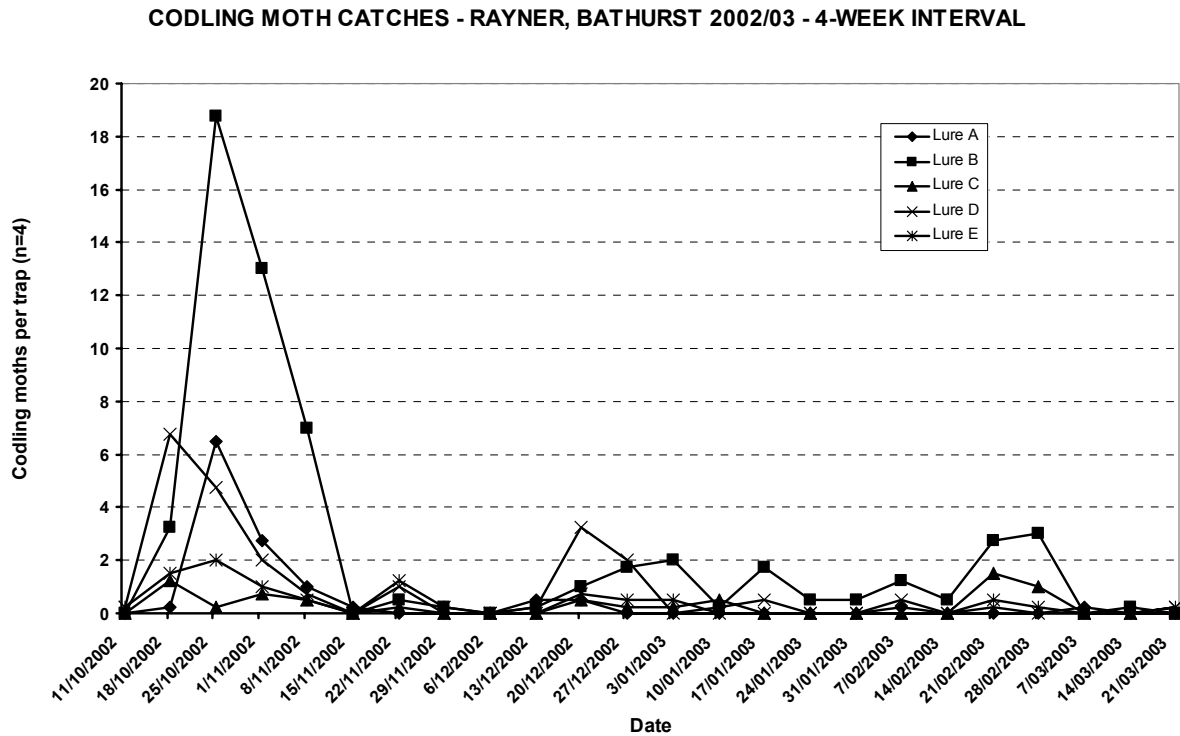


Figure 6. Codling moth catches in sticky traps baited with DA lure (B) and four pheromone-based lures (see Table 1), all changed at intervals of four weeks. Trapping commenced 04.10.02. Lure B data includes both male and female moths.

Sex Ratio

Mean catches for the 28 weeks in the DA lures (only traps to attract females) are given in Table 2. The sex ratio calculated from this was 0.68:1 male:female.

Table 5 presents the change in the sex ratio during the season according to the generation intervals indicated in Fig 5.

Table 5. Sex ratio (M:F) of moths captured in DA lure traps in all change intervals during generation 1 (04.10.02 to 13.12.02), 2 (14.12.02 to 31.01.03) and 3 (01.02.03 to 28.03.03).

Generation	Moths captured		Sex ratio (M:F)
	Males	Females	
1	195	328	0.59:1
2	54	49	1.10:1
3	49	64	0.77:1
Total	298	441	0.68:1

Trap Placement

Trap catches were analysed to determine if there was any effect on trap location i.e. placed within the tree (replicates 1 and 2, Fig 2) or between trees (replicates 3 and 4, Fig 3). Results are presented in Table 6.

Table 6. Effect of trap location on codling moth catches, 28 weeks 04.10.02 to 17.04.03.

	Replicates 1 & 2 (trap within tree)	Replicates 3 & 4 (trap between trees)
Plot area (m ²)	1170	1040
Number of plots	30	30
Trees per plot	45	40
Total trees	1350	1200
Total moths	732	634
Moths per tree	0.54	0.53

Replicate Position Effect

The distribution of codling moth catches over the trial site for the three generations indicated in Figure 5 are given in Table 7.

Table 7. Codling moth distribution (moths/plot) between the four replicates (see Fig 4), from 04.10.02 to 13.12.02 (generation 1), 14.12.02 to 31.01.03 (generation 2) and 01.02.03 to 28.03.03 (generation 3).

Replicate	Northern end			Southern end		
	Gen 1	Gen 2	Gen 3	Gen 1	Gen 2	Gen 3
Eastern	5.9	2.5	2.2	9.4	2.9	2.9
Western	23.3	4.8	3.6	25.8	4.1	3.8
Western÷Eastern	3.9	1.9	1.6	2.7	1.4	1.3

4. DISCUSSION

There were three complete generations of codling moth during the 2002/03 season as indicated by the accumulated Celsius degree days (Fig 5). Despite the application of Isomate C according to directions and a program of six supplementary sprays of parathion-methyl between early November and the end of February, damage from codling moth was observed. Infested fruit seen in January was removed from the orchard. Isomate C (1000 dispensers/ha) was deliberately chosen over the less labour-intensive Isomate CTT (500/ha) to maximise the number of point sources of pheromone in this codling moth infested block.

The three “peaks” of adult activity for each generation occurred 25.10.02, 20.12.02 and 21.02.03 respectively (Fig. 5). DA lures provided strongest evidence of the first and third peaks (Fig. 6) with good contributions from the “Super Bubble” in the second and BioLure for the third adult peaks. However, only the DA lures consistently attracted codling moth during the season (6 months).

When males only are considered, the DA lure was the best performer in the experiment, with a mean catch of 0.89 moths/trap/week over 28 weeks (Table 2). However, these traps also caught female moths and in this trial, more females than males were caught in the traps baited with DA lures. The sex ratio of catches changed during the trapping period (Table 5).

Codling Moth Distribution

Distribution of codling moth in 2002/03 was consistent with the observed residue of crop in 2001/02. Fruit left on the trees following the spring 2001 frost was concentrated in the few rows adjoining the College Road boundary fence (Fig 1). The orchard was unsprayed in 2001/02 and fruit became infested. Data in Table 7 clearly show that most of the overwintering codling moth occurred in the western (College Road) replicates, an average of 2.7 times more than the eastern replicates in the southern section and 3.9 times in the northern section. The difference declined with each subsequent generation with the proportion between western and eastern becoming progressively closer to 1.0 (the ideal). While this suggests that the pest population was becoming more evenly distributed, these data are also consistent with the known slow movement of codling moth in an orchard.

Beyond College Road was further orchard which has had a history of codling moth infestation and which the grower admitted was not controlled as well as it should be. The grower suspected that there might have been movement of moths from that area to the trial block. There is no evidence available to support or challenge this conjecture. I remain of the opinion that moths caught were from within the trial block.

Lure Change Interval

There was no consistent trend in the data in Table 3 to suggest that the longer the lure change interval, the lower the mean weekly catch. Only the Mega Lure (E) and “Bubble” (D) showed that pattern. Mega Lures changed at 12 weeks resulted in the lowest trap catches (Table 3) for any period during the investigation.

Scenturion 10x lures were widely used for monitoring in commercial orchards under mating disruption prior to this trial. It was recommended that the lures be changed at intervals of two weeks. Based on our results, that advice was justified – catches in traps in

which the lure was changed 2-weekly was 2.5 times those with a 4-weekly change frequency. Scenturion lures changed at intervals of 8 weeks caught more moths than those changed at 4 weeks, for which there is no obvious explanation.

Sex Ratio

Only male codling moths were expected to be captured in sex pheromone traps. Moths caught in those traps were not sexed.

All moths caught in traps baited with DA lures were sexed. Table 4 shows that for the traps in which lures were changed at 4 and 8 weeks, the sex ratio is close to the expected 1:1. For those changed at 12 weeks, there were more females than males taken in the traps.

From Table 2, the overall male:female ratio for the full 28 weeks was 0.68:1. The ratio changed during the season (Table 5) – from 0.59:1 in the first generation (all over wintered moths from shelter) to higher ratios for the second and third generations. There is no obvious explanation for the shift in sex ratio.

The data in Table 5 also document lower pest numbers in the second and third generations implying that despite some evidence of fruit injury (Fig 5) the population was suppressed by the control measures applied.

Trap Placement

It has generally been agreed by those who work with codling moth monitoring systems that traps work best when placed with the tree canopy. Under mating disruption, pheromone traps are recommended to be placed high in the tree, within the top 0.5 m (Knight and Christianson 1999).

Through a communication error, traps in this investigation were placed in two positions, within (Fig 2) and between (Fig 3) trees. When the moth catches were calculated on the basis of moths/tree (Table 6) there was no difference between trap catches within or between trees. There was no effect of position (east-west), lure type or change interval on these calculations as each of the factors were equally represented in the northern and southern sections of the block (Fig1, Fig 3).

Spraying Threshold

Warner (2003) quoted Dr Knight's proposed threshold using DA lures that if more than one female moth was caught in a DA lure baited trap, the grower should consider spraying. On this basis in the Bathurst orchard, the strong catch of females throughout the season would have required a full season supplementary spray program. The program of micro-encapsulated parathion-methyl used at "Appleton" (Fig 5) was only about two sprays short of a full program (Thwaite *et al.* 2002).

Conclusions

DA lures based on pear ester were shown to be the most effective attractant for male codling moth adults in this trial on Granny Smith apples. The traps baited with DA lures had the additional advantage that they also caught female moths.

The trial also demonstrated that there is no disadvantage in locating traps outside the tree canopy instead of within it. Our catches in 60 traps over 28 weeks showed that on a per tree basis, moth catches were unaffected by position in or outside the tree.

Based on this investigation, DA lures appear to be an ideal replacement for 10x pheromone lures for monitoring codling moth in orchards under mating disruption. It remains to be established if the lures are equally or more effective when used in other fruit types and varieties. If so, clear guidelines for use (action thresholds, positioning traps etc) are required.

DA lures were effective throughout the growing season (early October to end of March) and caught most moths under high population pressure (generation 1, to mid-December) and under the lower pest pressure of the subsequent generations. They remained effective for 12 weeks and based on this investigation, there was no justification for changing them more frequently.

5. TECHNOLOGY TRANSFER

Publications

- Thwaite, Graham. Monitoring mating disruption blocks. *FruitWise*, Spring 2002, No. 49, page 12.
- Thwaite, Graham. Monitoring with mating disruption. *Tree Fruit*, December 2002-January 2003, pages 18-19.
- Thwaite, Graham. Monitoring mating disruption blocks – some results. *FruitWise*, Winter 2003, No. 51, page 9-10.

Media

- Improving monitoring of codling moth under mating disruption – video segment prepared by Bernadette York, NSW Agriculture, April 2003. Used by Regional Television in New South Wales.
- Codling moth breakthrough. *The Rural*, April 18, 2003, page 5. Based on a press release prepared by Bernadette York.
- Female codling moth lures a first. *Agriculture Today*, May 2003, page 3. Author – Bernadette York.
- New tool for orchardists. *Western Advocate*, May 1, 2003, page 2. Based on a press release prepared by Bernadette York.
- Improved monitoring under mating disruption. Radio interview with Graham Thwaite, 2BS Bathurst, May 6, 2003.

Grower Meeting

- Managing mating disruption for codling moth in apple orchards. Presentation by Graham Thwaite at “Apple Growers Spring Technical Afternoon”, Batlow Fruit Cooperative and NSW Agriculture. Batlow, September 30, 2003.

6. RECOMMENDATIONS

DA lures are effective in Granny Smith apples under mating disruption. Personal communication with Dr Alexandre Il'ichev (DPI Victoria) and Mr Ron Gordon (Batlow Fruit Cooperative) indicated doubtful performance of DA lures in pears, nashi and some varieties of apples in trials conducted in Victoria in 2001/02 (Il'ichev *et al.* 2002) and 2002/03, and at Batlow in 2002/03.

A specially convened workshop at Tumut (14 May 2003) failed to establish any common grounds on which results from independent trials in Victoria and New South Wales could be compared. The workshop proposed a joint project in 2003/04 in which DA lures would be compared with the best available pheromone lures, BioLure 1 mg membrane for non-mating disruption blocks and Super Lure Bubbles for mating disruption sites. Four varieties of apples are to be included, as well as pears and nashi.

Recommended that the proposed trial proceed under HA Project FR01008, “Area-wide mating disruption for OFM and codling moth control in fruit”. DPI Victoria will remain as the lead agency and the specific trial will be coordinated by NSW Agriculture. Trial sites will be at Shepparton, Batlow, Bathurst and Orange.

Depending on the outcome of the 2003/04 investigation, the next step is to prepare clear guidelines for the use of DA lures by growers and develop action thresholds.

7. ACKNOWLEDGMENTS

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Anne Hatley (Technical Officer) and Marion Eslick (Technical Assistant) Entomology Unit, Orange Agricultural Institute prepared the site, set up the trial and carried out the routine observations. Helen Nicol, former Biometrician with NSW Agriculture, assisted with the trial design and provided statistical advice as required.

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8. BIBLIOGRAPHY

- Knight A, Christianson B. 1999. Using traps and lures in pheromone-treated orchards. *Good Fruit Grower* 50 (7): 45-51.
- Knight AL, Croft BA, Bloem KA. 1999. Effect of mating disruption dispenser placement on trap performance for monitoring codling moth (Lepidoptera: Tortricidae). *Journal of the Entomological Society of British Columbia*. 96: 95-102.
- Light DM, Knight AL, Henrick CA, Rajaparka D, Lingren B, Dickens JC, Reynolds KM, BATTERY RG, Merrill G, Roitman J, Campbell BC. 2001. A pear-derived kairomone with pheromonal potency that attracts male and female codling moth, *Cydia pomonella* (L). *Naturwissenschaften* 88: 333-338.
- Rivkina OG, Sexton SB, Il'ichev AL. 2000. The black light trap for monitoring of codling moth *Cydia pomonella* (Lepidoptera: Tortricidae) in pome fruit orchard under mating disruption. Abstract 1128. XXI International Congress of Entomology, Brazil. 284.
- Taylor R. 1996. Confusing the codling moth. *Rural Research* 169: 28-30.
- Thwaite WG. 2001. Codling moth and its control in Australia. *Good Fruit and Vegetables*. 12(2): 40-41.
- Thwaite WG. 2002. Final Report: Project AP01040. Visit to Australia by Entomologist, Dr Alan Knight – January 2002. Horticulture Australia Limited, Sydney.
- Thwaite WG, Williams DG, Hatley AM. 1993. Extent and significance of azinphos-methyl resistance in codling moth in Australia. Pest Control and Sustainable Agriculture. CSIRO Australia. 166-168.
- Thwaite WG, Hatley AM. 1999. Codling moth resistance management. Final Report, Project AP96022. Horticultural Research and Development Corporation, Sydney.
- Thwaite WG, Hetherington SD, Bright JD. 2002. Orchard Plant Protection Guide for Deciduous Fruits in NSW. 12th edn. NSW Agriculture.
- Vickers RA. 1996. Towards the integrated management of codling moth. Final Report Project AP 201. Horticultural Research and Development Corporation, Sydney.
- Vickers RA, Rothschild GHL. 1991. Use of sex pheromones for control of codling moth. *In* Tortricid Pests: Their Biology, Natural Enemies and Control. LPS van der Geest and HH Evenhuis (Eds). Elsevier. 339-354.
- Warner G. 2003. Pear ester trap works well with mating disruption. *Good Fruit Grower* 54 (4): 14.
- Williams D, Harrison G, James P, Washington W, Holmes R, Bates V, Nardi D, McFarlane P, Ranford T. 2000. Orchard Pest and Disease Handbook. 10th edition, 2000-2002. Deciduous Fruit Australia Inc.

9. APPENDIX

