CHAPTER 12

FIELD TRAPPING WITH SYNTHETIC PHEROMONES

12.1. Introduction

Five synthetic blends of the pheromone compounds found in *M. convecta* females were tested in the wind tunnel (Chapter 11). Of these, two blends (3 and 5) were found to be comparable with, if not better than, calling females. Males flown to these blends exhibited high levels of approach and close-range sexual behaviours such as landing and clasper extrusion with copulatory attempt. Thus, these two blends were considered for testing in the field.

Blend 1 (the CSIRO blend) was also tested in the field although it did not work well for *M. convecta* males in the wind tunnel. Tests were conducted to repeat the preliminary field trials done with this blend. CSIRO provided the lures for Blend 1 used in these experiments.

12.2. Materials and methods

12.2.1. Experimental sites and designs

Field experiments were conducted at three sites in NSW - Kootingal (31° 02' S, 151° 03' E), Armidale (30° 30' S, 151° 39' E) and Boggabri (30° 41' S, 150° 01' E), and three sites in Victoria - Swan Hill (35° 18' S, 143° 34' E), Dookie (36° 19' S, 145° 43' E) and Rutherglen (36° 02' S, 146° 29' E) (Fig. 12.1).

Most experiments were designed as Latin Squares, with three factors, location, treatment (trap type or pheromone blend), and time (trap rotation interval). Perry *et al.* (1980) reviewed the use of Latin Square designs in pheromone research, and concluded that they have many advantages. As applied to trapping studies, Latin Square experiments have equal numbers of trapping locations, trapping occasions, and treatments. The treatments are rotated through the locations so that each treatment occurs once at each location and on each occasion (Fig. 12.2).

The advantage of this design is that it allows the computation of sums of squares for occasions, locations and treatments independently, because interactions can be neglected. Perry *et al.* (1980) present a worked analysis of variance to illustrate the method.

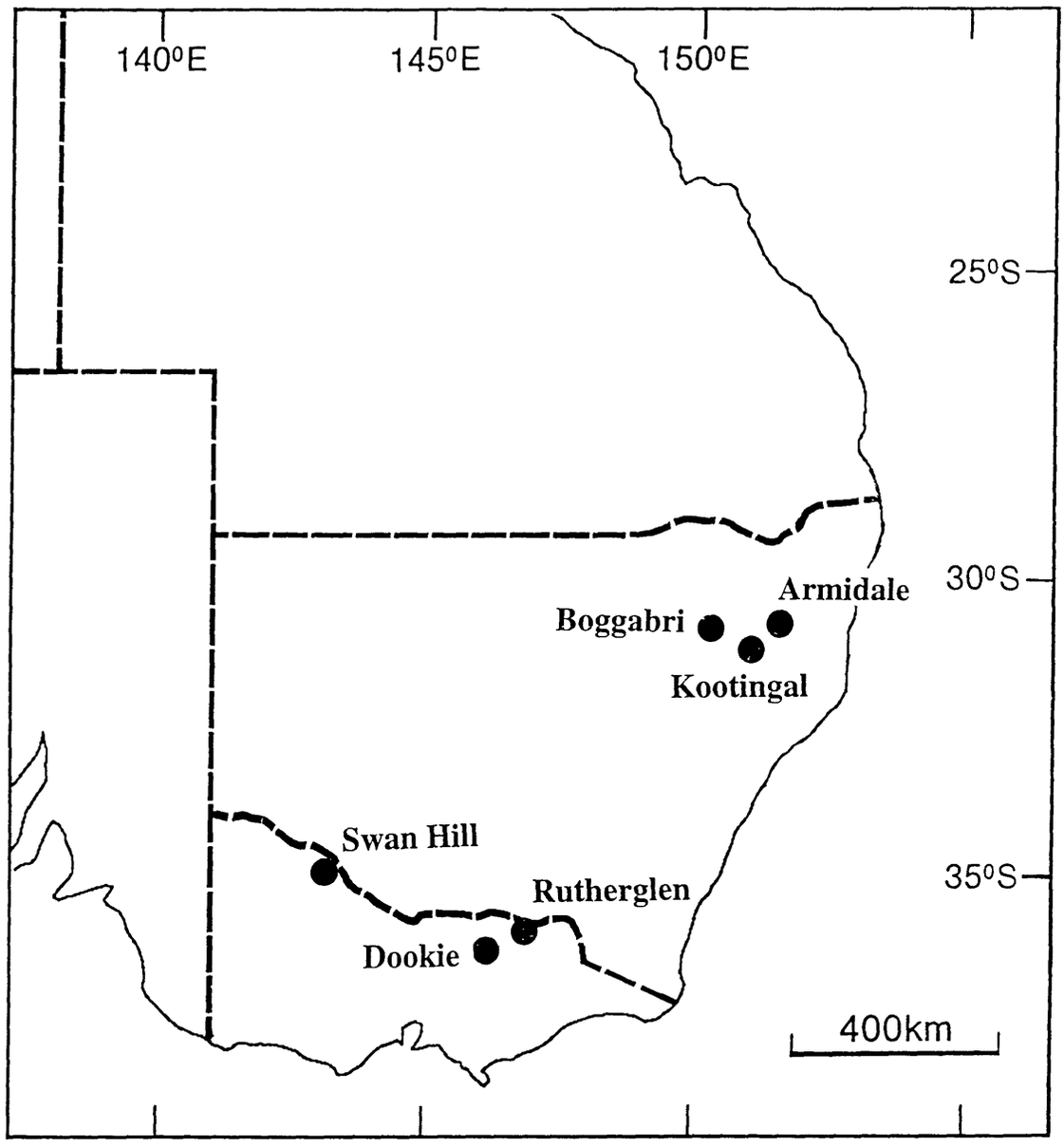

Fig. 12.1. Locations of field experiments to test *M. convecta* synthetic pheromones.

	Site			
Occasion	I	II	III	IV
1	A	B	C	D
2	D	A	B	C
3	C	D	A	B
4	B	C	D	A

Fig. 12.2. A 4 x 4 Latin Square pheromone trapping experiment. A, B, C and D are different treatments (e.g., pheromone blends). Modified from Perry *et al.* (1980).

In these experiments, Latin Squares were used whenever labour constraints made them feasible. "Occasions" were the trap rotation intervals, which ranged from 1-6 days, depending on the catch size, but were constant within each experiment. Some experiments were replicated either in space or time. The replicates were analysed as separate Latin Squares.

For the Victorian experiments, Latin Squares could not be used because labour to rotate the traps was not available. Consideration of the analyses must therefore include the possibility of confounding effects of trap locations for the Victorian results.

Experiment 1 - Blend 1 using different types of traps, Kootingal and Armidale

The experiment aimed to test Blend 1 using different trap types. It was conducted at two sites, Kootingal (Experiment 1a) and Armidale (Experiment 1b). The experiment was a 4 x 4 Latin Square, with 4 rotation periods, 4 trap locations and 4 trap types - fermentation (FE) trap, Texas trap, AgriSense funnel trap and Hara trap. Details of trap designs are given in section 12.2.2.

At Kootingal, the experiment was done on a paddock of clover, ryegrass and lucerne from 13 November to 15 December 1991. The traps, located at 50-m spacings, were cleared and rotated every 4 days (Fig. 12.3a). At Armidale, the site was planted to a mixture of pasture and cereal crops and field legumes. The experiment was conducted from 24 December 1991 to 4 February 1992. The traps, located 100 m from each other, were cleared and rotated every 6 days (Fig. 12.3b). At both sites, each Latin Square experiment was replicated twice in time.

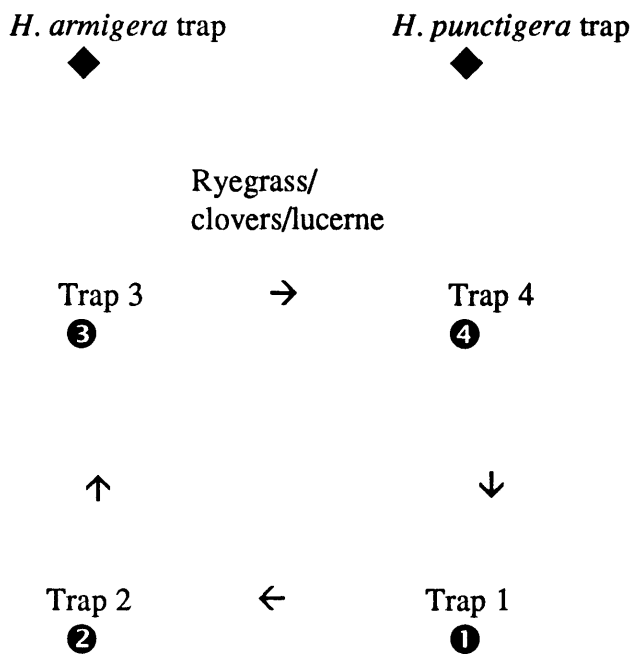

Fig. 12.3a. Experiment 1a. Lay-out of traps (●) at Kootingal. Traps were rotated in the direction of the arrows every 4 days. Trap 1 - FE trap; Trap 2 - Texas trap with Blend 1; Trap 3 - AgriSense trap with Blend 1; and Trap 4 - Hara trap with Blend 1. Dry funnel traps of *H. punctigera* and *H. armigera* (◆) using commercial lures were used as sentinel traps outside the main experiment. The traps were spaced at 50 m. The experiment was a 4 x 4 Latin Square replicated twice in time.

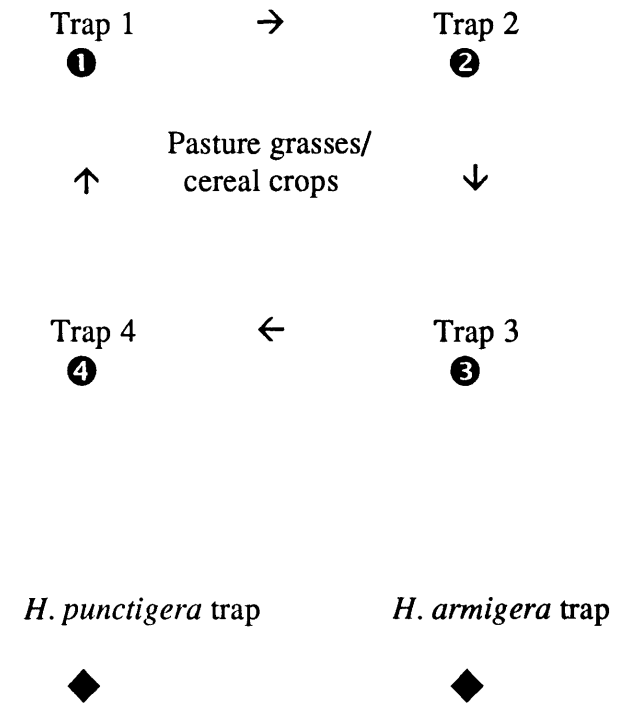

Fig. 12.3b. Experiment 1b. Lay-out of traps (●) at Armidale. Traps were rotated in the direction of the arrows every 6 days. Trap 1 - FE trap; Trap 2 - Texas trap with Blend 1; Trap 3 - AgriSense trap with Blend 1; and Trap 4 - Hara trap with Blend 1. Dry funnel traps of *H. punctigera* and *H. armigera* (◆) using commercial lures were used as sentinel traps outside the main experiment. The traps were spaced at 100 m. The experiment was a 4 x 4 Latin Square replicated twice in time.

Dry funnel traps using the commercial lures for the native budworm, *H. punctigera* and the cotton bollworm, *H. armigera* were operated as sentinel traps outside the main experiment. These traps were not rotated but were cleared at the same periods as the experimental traps.

Experiment 2 - Blend 1 and *Helicoverpa* commercial lures using Texas traps, Kootingal

Experiment 1 showed that Blend 1 caught large numbers of *H. punctigera.* This was further tested in this experiment, conducted from 5 to 10 January 1992. The experiment was designed as a single 6 x 6 Latin Square with 6 rotation periods, 6 trap locations and 6 treatments (lure type). Texas traps were located at 50-m spacings and were cleared and rotated daily (Fig. 12.4). The lure types used were FE lure, *M. convecta* females, Blend 1, *H. punctigera* commercial lure, *H. armigera* commercial lure. An empty or blank Texas trap was also included in the experiment.

Experiment 3 - Blend 3 using different types of traps, Boggabri

Two experiments were conducted on an area adjacent to an oats paddock to test Blend 3 using different trap types. The first experiment (Experiment 3a) was conducted from 23 to 30 April, 1993 and the second one (Experiment 3b), from 1 to 8 May 1993. Each experiment was a 4 x 4 Latin Square, with 4 rotation periods, 4 trap locations and 4 treatments (trap type), replicated thrice in space. The traps used were Texas trap with Blend 3, AgriSense funnel trap with Blend 3, FE trap and an empty or blank Texas trap. These traps, located 50 m from each other, were rotated and cleared every 2 days (Fig. 12.5).

Experiment 4 - Blends 3 and 5 using Texas traps, Boggabri

The experiment aimed to compare Blends 3 and 5, using Texas traps. Two sets of experiments (Experiments 4a and 4b) were conducted 10 days apart, on a wheat paddock (Figs. 12.6a and 12.6b). Each experiment was a 3 x 3 Latin Square, with 3 rotation periods, 3 locations and 3 treatments (lure type) - Blend 3, Blend 5 and FE lure. The traps were located 50 m from each other. In Experiment 4a, traps were cleared and rotated every 3 days. In Experiment 4b, trap clearing and rotation were done every two days. Each experiment was replicated thrice in space.

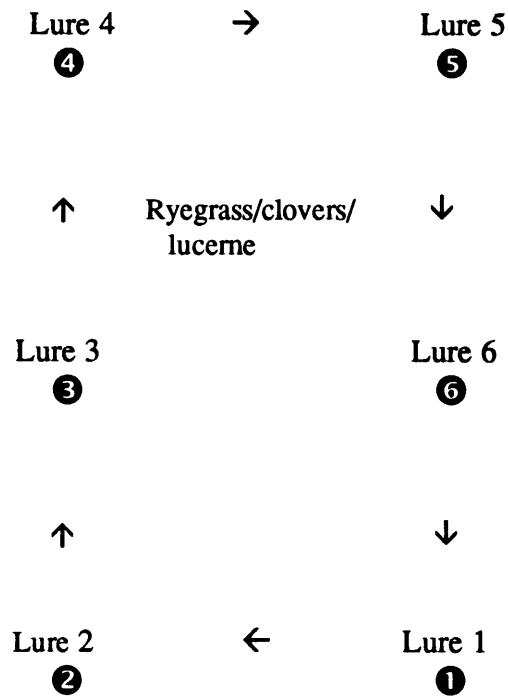

Fig. 12.4. Experiment 2. Lay-out of Texas traps (●) at Kootingal. Traps were rotated daily in the direction of the arrows. Lure 1 - FE lure; Lure 2 - *M. convecta* females; Lure 3 - Blend 1; Lure 4 - *H. punctigera* commercial lure; Lure 5 - *H. armigera* commercial lure; and Lure 6 - blank trap. The traps were spaced at 50 m. The experiment was a single 6 x 6 Latin Square.

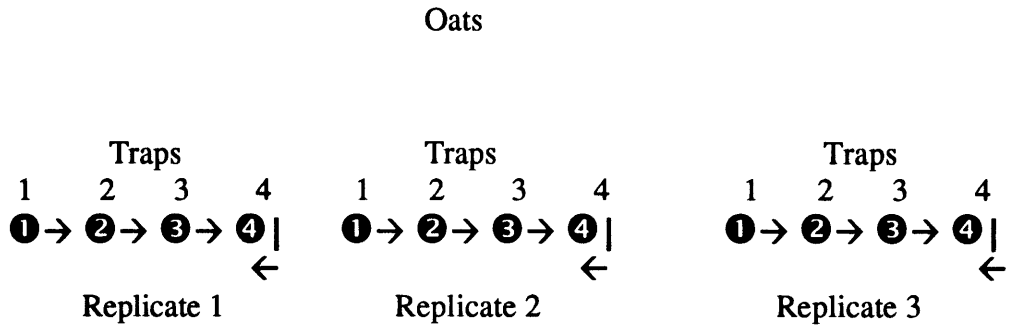

Fig. 12.5. Experiments 3a and 3b. Lay-out of traps (●) at Boggabri. Traps were rotated in the direction of the arrows every 2 days. Trap 1 - Texas trap with Blend 3; Trap 2 - AgriSense funnel trap with Blend 3; Trap 3 - FE trap; and Trap 4 - blank trap. The traps were spaced at 50 m. The experiment was a 4 x 4 Latin Square replicated thrice in space.

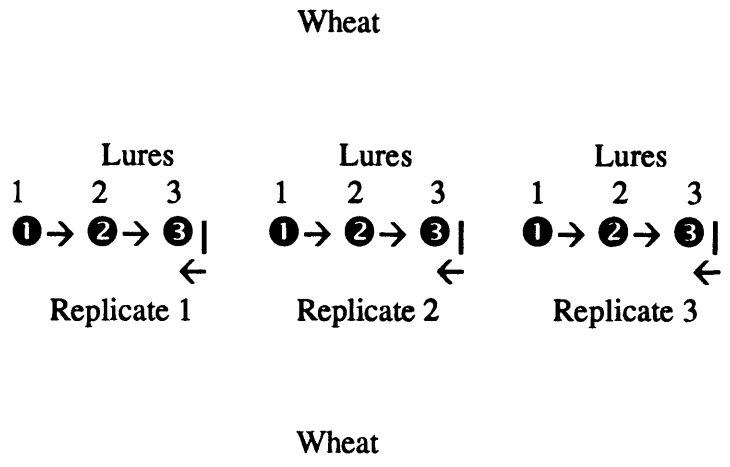

Fig. 12.6. Experiments 4a and 4b. Lay-out of Texas traps (●) at Boggabri. Traps were rotated in the direction of the arrows every 3 days. Lure 1 - Blend 3; Lure 2 - Blend 5; and Lure 3 - FE lure. Traps were spaced at 50 m. The experiment was a 3 x 3 Latin Square replicated thrice in space.

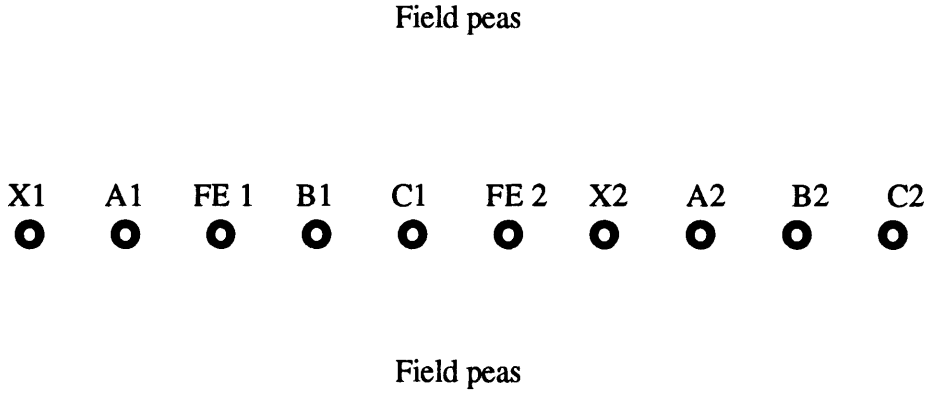

Fig. 12.7a. Experiment 5. Lay-out of AgriSense traps (O) at Swan Hill. Traps were not rotated. Traps A1 and A2 were baited with Blend 1; traps B1 and B2 with Blend 3 and traps C1 and C2 with Blend 5. Two FE traps (FE 1 and FE 2) and two blank traps (X1 and X2) were also operated. Traps were spaced at 50 m.

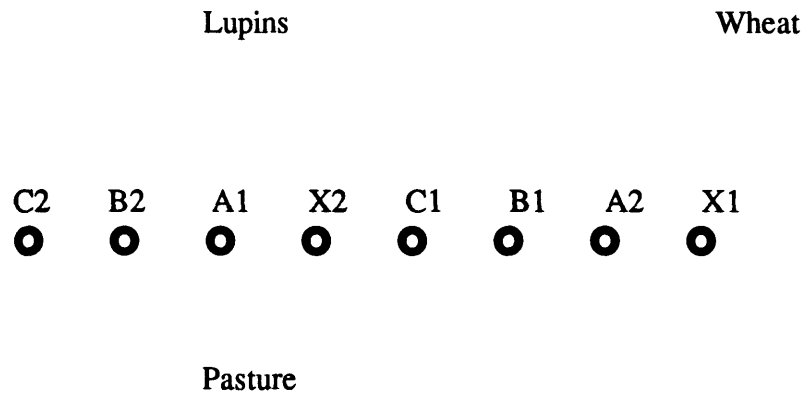

Fig. 12.7b. Experiment 5. Lay-out of AgriSense traps (O) at Dookie. Traps were not rotated. Traps A1 and A2 were baited with Blend 1; traps B1 and B2 with Blend 3 and traps C1 and C2 with Blend 5. Two blank traps (X1 and X2) were also operated. Traps were spaced at 50 m.

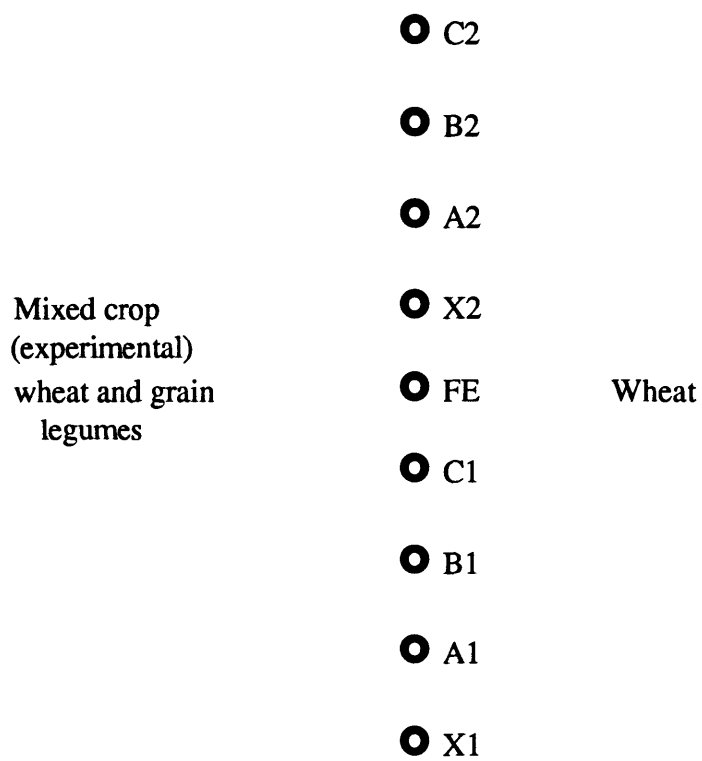

Fig. 12.7c. Experiment 5. Lay-out of AgriSense traps (O) at Rutherglen. Traps were not rotated. Traps A1 and A2 were baited with Blend 1; traps B1 and B2 with Blend 3 and traps C1 and C2 with Blend 5. One FE trap and two blank traps (X1 and X2) were also operated. Traps were spaced at 50 cm.

Experiment 5 - Blends 1, 3 and 5 using AgriSense traps, Swan Hill, Dookie and Rutherglen

The objective of this experiment was to test Blends 1, 3 and 5 using AgriSense funnel traps. The experiments were conducted at three sites in Victoria, in collaboration with Dr. G. McDonald of the Victorian Department of Agriculture (Figs. 12.7a, 12.7b and 12.7c). Due to the distance of the sites and lack of permanent staff to service the traps, traps were not rotated and were cleared at approximately weekly intervals. Moths were posted to the University of New England for sorting and dissection. The traps were spaced at 50 m from each other. FE traps were also operated at Swan Hill and Rutherglen. At Swan Hill, the site was planted to field peas. The site at Dookie was a lupin paddock adjacent to a wheat paddock. At Rutherglen, the traps were located on a wheat paddock. The experiments were run at Swan Hill from 1 September to 22 November, at Dookie from 8 September to 19 October, and at Rutherglen from 23 October to 11 November 1993.

12.2.2. Trap designs and lures

Different types of traps were used in the experiments. The Texas trap (Plate 12.1) is a cone trap with a skirt, with outer rim and inner skirt diameters of 75:50 cm. It is similar to the Texas trap used for trapping *Helicoverpa* spp. (Gregg & Wilson, 1991). The Texas traps here were made of green shadecloth instead of white plastic mesh. The AgriSense funnel trap (Plate 12.2) is similar to the International Pheromones dry funnel trap for *Helicoverpa* spp. described by Gregg & Wilson (1991). The Canadian-made Hara insect trap (Plate 12.3) consists of two white plastic cones (outer and inner rim diameters of 12:9 cm and length of 9 cm) joint together, with the outer rims meshed. The fermentation (FE) trap (Plate 12.4) is similar to the Texas trap using a fermented lure made up of 10% port wine and 15% brown sugar (McDonald, 1990). FE traps were included in the experiments to provide an index of *M. convecta* population in the area. They catch female as well as male moths, and are not specific to *M. convecta*. The dry funnel trap (Plate 12.5) for *Helicoverpa* spp. (Gregg & Wilson, 1991) consists of a funnel and a canister provided with a dry killing agent.

Plate 12.1. Texas trap

Plate 12.2. AgriSense funnel trap

Plate 12.3. Hara insect trap

Plate 12.4. Fermentation (FE) trap

Plate 12.5. Dry funnel trap

Pheromone blends are described in Chapter 11. The dosage of each blend was 1000 µg of the major component, Z11:16 Ald (plus corresponding amounts of other components), with toluene as the solvent. An antioxidant, topanol, provided by CSIRO, was added to the blend at a rate of 5% of total pheromone load (T. Bellas, pers. comm., 1992). Pheromone lures were dispensed in rubber tubing (Chapter 3.4). The lures were changed every week. Commercial *H. punctigera* and *H. armigera* lures were obtained from AgriSense (Fresno, California, USA). Their contents were believed to be as described in Gregg & Wilson (1991).

12.2.3. Statistical Analyses

Data on trap catches for each experiment are provided in the sub-directory A:\CHAP12 of the floppy disk. Means and standard errors of trap catches presented in tables (section 12.3) were calculated from the raw data using the MINITAB package (Ryan *et al.*, 1992). Differences between overall means were tested using the least significance difference (LSD) method (Snedecor & Cochran, 1967).

For the Latin Square analyses of variance for each experiment, the method of Perry *et al.* (1980) was employed, using the GLM routine in MINITAB. Data were first transformed logarithmically ($\log_{10}$ (X + 1)). For overall analyses, combining replicates, one-way analyses of variance were used. The possibilities of confounding effects of rotation interval and location can be assessed by examination of the analyses for individual replicates, for which the Latin Square design applied.

12.3. Results and discussion

Experiment 1 - Blend 1 using different types of traps, Kootingal and Armidale

Experiment 1 tested Blend 1 in 3 trap types - Texas, AgriSense funnel and Hara traps. An FE trap was also included in the experiment. Two experiments of this type were conducted at Kootingal (Experiment 1a) and Armidale (Experiment 1b). Results from the Kootingal experiment are given in Tables 12.1 and 12.2.

Blend 1 did not catch any *M. convecta*. Only the FE trap caught *M. convecta* moths. Large numbers of *H. punctigera* were caught in all trap types baited with Blend 1 lures. The Texas trap caught significantly more *H. punctigera* than the AgriSense or the Hara traps. One *H. armigera* male was caught with Blend 1 in the AgriSense trap and one in the FE trap.

	FE trap	Texas trap	AgriSense trap	Hara trap
Replicate 1				
M. convecta				
male	4.2 ± 0.8	0	0	0
female	2.0 ± 0.4	0	0	0
H. punctigera	34.2 ± 15.6	538 ± 201	246.5 ± 24.5	53.7 ± 12.5
H. armigera	0	0	0.2 ± 0.2	0
Replicate 2				
M. convecta				
male	11.2 ± 5.8	0	0	0
female	15.7 ± 10.5	0	0	0
H. punctigera	12.5 ± 1.6	422.2 ± 73	69.5 ± 20.8	20.2 ± 6.7
H. armigera	0.2 ± 0.2	0	0	0
Overall				
M. convecta				
male	7.8 ± 3.0	0	0	0
female	8.9 ± 5.5	0	0	0
H. punctigera	23.4 ± 8.4	480 ± 101	158 ± 36.6	37 ± 9.1
H. armigera	0.1 ± 0.1	0	0.1 ± 0.1	0

Table 12.1. Experiment 1a. Mean (± s.e.) catches of *M. convecta, H. punctigera* and *H. armigera* per rotation interval (4 days) in the different traps at Kootingal. Texas, AgriSense funnel and Hara traps were baited with Blend 1. Overall $LSD_{.05}$ for *H. punctigera* = 157.2.

The analyses of variance (Table 12.2) showed that in both replicates, trap rotation and location were not significant for *M. convecta* and *H. armigera.* Rotation was significant in both replicates, and location in the second replicate, for *H. punctigera.* In both replicates, however, trap type was the most significant factor, and overall, it was the only factor significantly influencing *M. convecta* and *H. punctigera* catches.

	Rotation	Location	Treatment
Replicate 1			
M. convecta	n.s.	n.s.	$F_{3,6} = 76.5$***
H. punctigera	$F_{3,6} = 26.8$***	$F_{3,6} = 17.6$***	$F_{3,6} = 159.3$***
H. armigera	n.s.	n.s.	n.s.
Replicate 2			
M. convecta	n.s.	n.s.	$F_{3,6} = 13.2$***
H. punctigera	$F_{3,6} = 6.4$*	n.s.	$F_{3,6} = 76.5$***
H. armigera	n.s.	n.s.	n.s.
Overall			
M. convecta	n.s.	n.s.	$F_{3,22} = 45.6$***
H. punctigera	n.s.	n.s.	$F_{3,22} = 25.5$***
H. armigera	n.s.	n.s.	n.s.

Table 12.2 Experiment 1a. Summary of results of analyses of variance for *M. convecta, H. punctigera* and *H. armigera* males at Kootingal. The number of * indicates level of significance and n.s., non-significance.

During the experiment it became apparent that large numbers of *H. punctigera* were being caught with Blend 1. It was therefore decided to run *Helicoverpa* dry funnel traps using the commercial lures, simultaneously with the remainder of the experiment, to serve as sentinel traps. These traps, however, were not set up until after two rotation periods, and were not rotated in the subsequent two periods. Catches of *Helicoverpa* spp. from these traps were compared with those caught in the three traps using Blend 1 (i.e., only during the same period when the commercial lures were used). Higher numbers of *H. punctigera* were caught with Blend 1 than with the commercial lure (Table 12.3).

Trap type	Lure type	*H. punctigera*	*H. armigera*
FE	fermented lure	26.5 ± 10.9	0.2 ± 0.2
Texas	Blend 1	577 ± 108	0
AgriSense	Blend 1	122.3 ± 38.3	0.2 ± 0.2
Hara	Blend 1	30.0 ± 9.3	0
Dry funnel	*H. armigera* lure	0	3.2 ± 1.1
Dry funnel	*H. punctigera* lure	3.8 ± 1.2	0

Table 12.3. Mean (± s.e.) catches of *H. punctigera* and *H. armigera* with different lure types at Kootingal. Dry funnel traps for the two species used the commercial lures.

Similar results were obtained in the experiment at Armidale (Table 12.4). *M. convecta* moths were not caught with Blend 1, but were caught only in the FE trap. The three traps baited with Blend 1 caught only *H. punctigera* males, with the Texas trap catching the highest number and the Hara trap catching the least number. Results from the analyses of variance showed that in both replicates, trap rotation and location did not significantly influence trap catches (Table 12.5). Trap type was significant for *H. punctigera* but not for *M. convecta*. Overall, rotation and location were not significant but trap type was, for both species.

	FE trap	Texas trap	AgriSense trap	Hara trap
Replicate 1				
M. convecta				
male	0.5 ± 0.5	0	0	0
female	0.2 ± 0.2	0	0	0
H. punctigera	0	30.5 ± 7.4	32.5 ± 13.8	11.2 ± 6.9
Replicate 2				
M. convecta				
male	6.2 ± 4.1	0	0	0
female	1.5 ± 0.9	0	0	0
H. punctigera	0	40.8 ± 20.7	14.5 ± 6.1	5.0 ± 1.1
Overall				
M. convecta				
male	3.4 ± 2.2	0	0	0
female	0.9 ± 0.5	0	0	0
H. punctigera	0	35.6 ± 10.4	23.2 ± 7.7	8.1 ± 3.5

Table 12.4. Experiment 1b. Mean (± s.e.) catches of *M. convecta* and *H. punctigera* per rotation interval (6 days) in the different traps at Armidale. Texas, AgriSense funnel and Hara traps were baited with Blend 1. Overall $LSD_{.05}$ for *H. punctigera* = 19.4.

	Rotation	Location	Treatment
Replicate 1			
M. convecta	n.s.	n.s.	n.s.
H. punctigera	n.s.	n.s.	$F_{3,6} = 16.8$**
Replicate 2			
M. convecta	n.s.	n.s.	n.s.
H. punctigera	n.s.	n.s.	$F_{3,6} = 15.5$**
Overall			
M. convecta	n.s.	n.s.	$F_{3,22} = 4.6$**
H. punctigera	n.s.	n.s.	$F_{3,22} = 30.0$***

Table 12.5 Experiment 1b. Summary of results of analyses of variance for *M. convecta* and *H. punctigera* males at Armidale. The number of * indicates level of significance and n.s., non-significance.

As in Experiment 1a, the dry funnel traps for *Helicoverpa* spp. were set up as sentinel traps at Armidale. Again, similar results were obtained. In comparison with the numbers caught with Blend 1 (Table 12.4), the commercial lures caught 19.1 ± 8.2 *H. punctigera* and 1.2 ± 0.6 *H. armigera*. The trap type most closely resembling the dry funnel trap is the AgriSense trap. Comparisons of these types using commercial *H. punctigera* lures indicate that their efficiencies for this species are comparable (P.C. Gregg, pers. comm., 1993). Thus, estimates of the relative attractiveness of Blend 1 compared to the commercial lure are 32.2 (122.3/3.8) at Kootingal and 1.2 (23.2/19.1)

at Armidale. These comparisons are not statistically rigorous, because the commercial lures were included as sentinel traps rather than integral parts of the Latin Square design. There may have been confounding effects of location. However, the most likely explanation of the results is that Blend 1 was at least as attractive as the commercial lure in the Armidale experiments, and much more so at Kootingal. Thus, the attractiveness of Blend 1 to *H. punctigera* was further investigated in another experiment at Kootingal.

Experiment 2 - Blend 1 and *Helicoverpa* commercial lures using Texas traps, Kootingal

Experiments 1a and 1b suggested that Blend 1 was more attractive to *H. punctigera* than the commercial lure. In these experiments, however, different trap designs were used and the dry funnel traps were not included in the main experiment but only as sentinel traps. Experiment 2 was conducted to specifically compare Blend 1 with the commercial lures for the two *Helicoverpa* spp. Only Texas traps were used. Results from Experiment 1 showed that this type was more efficient for *H. punctigera* than the AgriSense or the Hara traps.

In addition to three lure types (Blend 1, *H. punctigera* and *H. armigera* commercial lures), two other lures, the FE lure and live *M. convecta* females were also used. Three virgin females, aged 4 days and older, were held in a meshed cage suspended under the Texas trap. Any female which died was replaced with a new one of similar age. A blank or empty Texas trap was also included in the experiment. Results are presented in Tables 12.6 and 12.7.

	FE lure	Female	Blend 1	*H.p.* lure	*H.a.* lure	Blank
M. convecta						
male	2.5 ± 1.7	0.2 ± 0.2	0	0	0	0
female	0.5 ± 0.5	0	0	0	0	0
H. punctigera	0.7 ± 0.3	0.3 ± 0.2	49.2 ± 18.6	12.5 ± 5.0	0	0
H. armigera	0	0	0	0	1.0 ± 0.4	0

Table 12.6. Experiment 2. Mean (± s.e.) catches of *M. convecta*, *H. punctigera* and *H. armigera* per rotation interval (1 day) in Texas traps baited with FE lure, *M. convecta* females, Blend 1 and commercial lures for *H. punctigera* (*H.p.*) and *H. armigera* (*H.a.*) at Kootingal. Blank trap was an empty Texas trap. $LSD_{.05}$ for *M. convecta* male = 2.0 and *H. punctigera* = 22.7.

M. convecta males were caught only with the FE lure and live females. The number caught in the FE trap was significantly higher than the trap with live females, which caught only 1 male during the whole experiment. Only the commercial lure (*H.a.* lure) caught *H. armigera*. Blend 1 was significantly better for *H. punctigera* than the commercial *H. punctigera* lure. The number of *H. punctigera* caught with Blend 1 was 3.9 times greater than with the commercial lure.

The analyses of variance yielded non-significant effects of trap rotation and location but highly significant effects of lure type for *M. convecta*, *H. armigera* and *H. punctigera* males (Table 12.7).

	Rotation	Location	Treatment
M. convecta	n.s.	n.s.	$F_{5,20} = 5.0^{**}$
H. punctigera	n.s.	n.s.	$F_{3,20} = 30.4^{***}$
H. armigera	n.s.	n.s.	$F_{3,20} = 8.7^{***}$

Table 12.7 Experiment 2. Summary of results of analyses of variance for *M. convecta*, *H. punctigera* and *H. armigera* males at Kootingal. The number of * indicates level of significance and n.s., non-significance.

Experiment 3 - Blend 3 using different types of traps, Boggabri

Two experiments were conducted to test Blend 3 using different trap types. Mean trap catches of *M. convecta* in the different traps in Experiment 3a and a summary of the analyses of variance are given in Tables 12.8 and 12.9.

	Texas trap	AgriSense trap	FE trap	Blank trap
Replicate 1				
male	0.8 ± 0.5	0.2 ± 0.2	2.5 ± 1.5	0
female	0	0	4.5 ± 2.1	0
Replicate 2				
male	2.5 ± 2.2	0.2 ± 0.2	3.0 ± 1.5	0
female	0	0	3.2 ± 1.4	0
Replicate 3				
male	0.2 ± 0.2	0.2 ± 0.2	0.5 ± 0.3	0
female	0	0	1.0 ± 0.4	0
Overall				
male	1.2 ± 0.7	0.2 ± 0.1	2.0 ± 0.7	0
female	0	0	2.9 ± 0.9	0

Table 12.8. Experiment 3a. Mean (± s.e.) catches of *M. convecta* males and females per rotation interval (2 days) in the different traps at Boggabri. Texas and AgriSense funnel traps were baited with Blend 3 and FE trap with a fermented lure. The blank traps were Texas traps without any lure. Overall $LSD_{.05}$ for male = 0.5.

	Rotation	Location	Treatment
Replicate 1	n.s.	n.s.	n.s.
Replicate 2	n.s.	n.s.	n.s.
Replicate 3	n.s.	n.s.	n.s.
Overall	n.s.	n.s.	$F_{3,44} = 4.6^{**}$

Table 12.9. Experiment 3a. Summary of results of analyses of variance for *M. convecta* male at Boggabri. The number of * indicates level of significance and n.s., non-significance.

Both the Texas and AgriSense funnel traps baited with Blend 3 caught *M. convecta* males. The Texas trap caught significantly more *M. convecta* (6 times) than the AgriSense trap, indicating that the former is more efficient than the latter. The FE trap caught *M. convecta* of both sexes. There were more *M. convecta* males in the FE trap than in the Texas or AgriSense traps with Blend 3. For each replicate, rotation, location and trap type were not significant. Overall, however, the trap type was a significant factor influencing *M. convecta* catches.

In Experiment 3b, similar results with the Texas and AgriSense traps were obtained (Table 12.10). The Texas trap caught significantly higher *M. convecta* males than the AgriSense trap. The numbers of males in the FE trap and the Texas traps were not significantly different. The FE trap caught approximately twice as many females as males. The low numbers of male and female *M. convecta* moths caught in the blank trap might have been only accidental, that is, they blundered into the trap during flight.

	Texas trap	AgriSense trap	FE trap	Blank trap
Replicate 1				
male	2.0 ± 1.7	0	3.2 ± 1.2	0.2 ± 0.2
female	0	0	6.2 ± 1.6	0
Replicate 2				
male	3.5 ± 2.2	0	1.8 ± 1.1	0
female	0	0	6.2 ± 3.4	0.2 ± 0.2
Replicate 3				
male	3.0 ± 1.2	0.5 ± 0.5	2.5 ± 1.3	0
female	0.2 ± 0.2	0	5.2 ± 2.1	0
Overall				
male	2.8 ± 0.9	0.2 ± 0.1	2.5 ± 0.7	0.1 ± 0.1
female	0.1 ± 0.1	0	5.9 ± 1.3	0.1 ± 0.1

Table 12.10. Experiment 3b. Mean (± s.e.) catches of *M. convecta* males and females per rotation interval (2 days) in the different traps at Boggabri. Texas and AgriSense funnel traps were baited with Blend 3 and FE trap with a fermented lure. The blank traps were Texas traps without any lure. Overall $LSD_{.05}$ for male = 0.5 and for female = 0.6.

Results of the analyses of variance for Experiment 3b are given in Table 12.11. In all replicates, trap type was significant, and in replicate 3, trap rotation was also significant. Overall, both trap rotation and treatment significantly influenced *M. convecta* male catches.

	Rotation	Location	Treatment
Replicate 1	n.s.	n.s.	$F_{3,6} = 5.2^{*}$
Replicate 2	n.s.	n.s.	$F_{3,6} = 7.2^{**}$
Replicate 3	$F_{3,6} = 6.1^{*}$	n.s.	$F_{3,6} = 7.7^{**}$
Overall	$F_{3,44} = 5.2^{**}$	n.s.	$F_{3,44} = 10.4^{***}$

Table 12.11. Experiment 3b. Summary of results of analyses of variance for *M. convecta* male at Boggabri. The number of * indicates level of significance and n.s., non-significance.

These experiments clearly demonstrated that Blend 3 was attractive to *M. convecta* males. During the course of the two experiments a total of 54 moths were trapped in all the Blend 3 traps combined. All except 1 were males. Moreover, the overall numbers of males caught in the Texas traps (48) were similar to those caught in the FE trap (54). *H. punctigera* moths were not caught in any of the traps, probably because populations were very low, which is typical of the season (autumn) when the experiment was conducted (Gregg *et al.*, 1994, in press).

Between Experiments 3a and 3b, the traps were left in the paddock (without changing the lures) and checked after a week (9 to 15 May 1993). The Texas trap caught a total of 14 males and 1 female, the AgriSense traps, 3 males, and the FE traps, 1 male and 7 *M. convecta* females. Again, these results indicate that Blend 3 caught *M. convecta* males and that the Texas trap was more efficient than the AgriSense trap.

Experiment 4 - Blends 3 and 5 using Texas traps, Boggabri

In Experiment 3, the Texas trap appeared to be more efficient than the AgriSense trap for *M. convecta*. Thus, in Experiment 4, only Texas traps were used to test Blends 3 and 5. Two sets of experiments (4a and 4b), 10 days apart, were conducted. The experiments were 3 x 3 Latin Squares. When analyses are performed according to the method of Perry *et al.* (1980), 3 x 3 Latin Squares are too small because of insufficient degrees of freedom in the error term. However, the design is still appropriate to minimise confounding interactions.

Mean catches of *M. convecta* and *H. punctigera* and results of analyses of variance in Experiment 4a are shown in Tables 12.12 and 12.13. Both *M. convecta* and *H. punctigera* males were caught with Blends 3 and 5. The numbers of *M. convecta* did not significantly differ between the two blends but the numbers of *H. punctigera* did. Blend 5 caught about 8 times more *H. punctigera* than Blend 3. The numbers of *M. convecta* males caught with both blends were significantly higher than those caught in the FE trap.

	Blend 3	Blend 5	FE lure
Replicate 1			
M. convecta			
male	3.0 ± 1.5	3.3 ± 2.3	0
female	0	0	0
H. punctigera	2.7 ± 2.7	15.0 ± 2.1	0
Replicate 2			
M. convecta			
male	3.7 ± 0.9	1.7 ± 1.2	0.3 ± 0.3
female	0	0	0
H. punctigera	2.3 ± 1.4	10.3 ± 4.7	5.3 ± 5.3
Replicate 3			
M. convecta			
male	0.7 ± 0.3	3.7 ± 0.9	0.3 ± 0.3
female	0	0	1.7 ± 1.7
H. punctigera	0.3 ± 0.3	17.7 ± 9.7	0.7 ± 0.7
Overall			
M. convecta			
male	2.4 ± 0.7	2.9 ± 0.9	0.1 ± 0.1
female	0	0	0.6 ± 0.6
H. punctigera	1.8 ± 1.0	14.3 ± 3.4	2.0 ± 1.8

Table 12.12. Experiment 4a. Mean (± s.e.) catches of *M. convecta* and *H. punctigera* per rotation interval (3 days) in Texas traps baited with Blends 3 and 5 and FE lure at Boggabri. Overall $LSD_{.05}$ for *M. convecta* males = 1.91 and for *H. punctigera* = 6.6.

The analyses of variance showed that in the 3 replicates, rotation and location did not significantly influence *M. convecta* and *H. punctigera* catches. The lure type was significant for *M. convecta* in replicate 3 and for *H. punctigera* in replicate 1. Overall, for both species, only the lure type significantly affected trap catches.

	Rotation	Location	Treatment
Replicate 1			
M. convecta	n.s.	n.s.	n.s.
H. punctigera	n.s.	n.s.	n.s.
Replicate 2			
M. convecta	n.s.	n.s.	n.s.
H. punctigera	n.s.	n.s.	$F_{2,6} = 11.0^{**}$
Replicate 3			
M. convecta	n.s.	n.s.	$F_{2,6} = 10.1^{**}$
H. punctigera	n.s.	n.s.	n.s.
Overall			
M. convecta	n.s.	n.s.	$F_{2,24} = 8.5^{***}$
H. punctigera	n.s.	n.s	$F_{2,24} = 13.6^{***}$

Table 12.13. Experiment 4a. Summary of results of analyses of variance for *M. convecta* and *H. punctigera* males at Boggabri. The number of * indicates level of significance and n.s., non-significance.

In Experiment 4b (Table 12.14), the numbers of *M. convecta* males caught with both Blends 3 and 5 were significantly less than that in the FE trap. As in Experiment 4a, the numbers of *M. convecta* males caught with the two blends were not significantly different. With *H. punctigera* males, similar results to those in Experiment 4a were obtained. Blend 5 caught significantly more *H. punctigera* than Blend 3 or the FE trap. Results from the two experiments indicate that both Blends 3 and 5 are attractive to *H. punctigera* when this species is abundant, as it usually is in the season (spring) when these experiments were conducted (Gregg *et al.*, 1994, in press). However, Blend 5 caught significantly higher numbers than Blend 3.

The analyses of variance (Table 12.15) showed that for *H. punctigera,* the lure type was significant in all the replicates whereas for *M. convecta* lure type was significant in replicate 3. As in Experiment 4a, overall, only the lure type significantly influenced trap catches of both species.

	Blend 3	Blend 5	FE lure
Replicate 1			
M. convecta			
male	3.7 ± 2.7	0.3 ± 0.3	4.7 ± 1.2
female	0	0	0.7 ± 0.3
H. punctigera			
male	3.3 ± 1.8	19.3 ± 2.9	0.3 ± 0.3
female	0	0	1.3 ± 0.7
Replicate 2			
M. convecta			
male	2.0 ± 1.0	0.3 ± 0.3	13.0 ± 6.5
female	0.3 ± 0.3	0	7.7 ± 5.2
H. punctigera			
male	2.7 ± 1.4	20.7 ± 6.5	0.3 ± 0.3
female	0	0	1.3 ± 0.9
Replicate 3			
M. convecta			
male	2.3 ± 0.9	1.0 ± 1.0	5.0 ± 0.6
female	0	0	6.3 ± 3.3
H. punctigera			
male	2.7 ± 1.2	29.3 ± 12.2	0.3 ± 0.3
female	0	0	0.7 ± 0.7
Overall			
M. convecta			
male	2.7 ± 0.9	0.6 ± 0.3	7.6 ± 2.4
female	0.1 ± 0.1	0	4.9 ± 2.1
H. punctigera			
male	2.9 ± 0.8	23.1 ± 4.4	0.3 ± 0.2
female	0	0	1.1 ± 0.4

Table 12.14. Experiment 4b. Mean (± s.e.) catches of *M. convecta* and *H. punctigera* per rotation interval (2 days) in Texas traps baited with Blends 3 and 5, and FE lure at Boggabri. Overall $LSD_{.05}$ for *M. convecta* male = 4.3, for *M. convecta* female = 3.5, for *H. punctigera* male = 7.5.

During the period of 10 days between the two experiments, the traps were left in the paddock and checked after 9 days. The numbers of *M. convecta* and *H. punctigera* caught are given in Table 12.16. Similar results to those in the two experiments were obtained. Blend 3 caught more *M. convecta* than Blend 5, whereas Blend 5 caught more *H. punctigera* than Blend 3. One-way analyses of variance yielded significant effects of lure type on catches of both *M. convecta* ($F_{2,6} = 5.1^{*}$) and *H. punctigera* males ($F_{2,6} = 27.4^{***}$).

	Rotation	Location	Treatment
Replicate 1			
M. convecta	n.s.	n.s.	n.s.
H. punctigera	n.s.	n.s.	$F_{2,6} = 13.5^{**}$
Replicate 2			
M. convecta	n.s.	n.s.	$F_{2,6} = 8.5^{**}$
H. punctigera	n.s.	n.s.	$F_{2,6} = 13.7^{**}$
Replicate 3			
M. convecta	n.s.	n.s.	n.s.
H. punctigera	n.s.	n.s.	$F_{2,6} = 11.0^{**}$
Overall			
M. convecta	n.s.	n.s.	$F_{2,24} = 16.9^{***}$
H. punctigera	n.s.	n.s	$F_{2,24} = 49.8^{***}$

Table 12.15. Experiment 4b. Summary of results of analyses of variance for *M. convecta* and *H. punctigera* males at Boggabri. The number of * indicates level of significance and n.s., non-significance.

	Blend 3	Blend 5	FE trap
M. convecta			
male	13.0 ± 2.5	7.7 ± 5.8	0.3 ± 0.3
female	0	0.3 ± 0.3	1.7 ± 1.2
H. punctigera	4.7 ± 0.7	15.7 ± 2.2	0.7 ± 0.7

Table 12.16. Mean (± s.e.) catches of *M. convecta* and *H. punctigera* during the 9-day period between Experiments 4a and 4b at Boggabri.

Experiment 5 - Blends 1, 3 and 5 using AgriSense traps, Swan Hill, Dookie and Rutherglen

Mean catches of *M. convecta* and *H. punctigera* with Blends 1, 3 and 5 at the three sites in Victoria are shown in Table 12.17. At all sites, Blend 1 did not catch any *M. convecta* but did catch *H. punctigera*. At Swan Hill, *M. convecta* males were caught with Blend 5 while *H. punctigera* males were caught with both Blends 3 and 5. On one occasion at Swan Hill, 1 *H. armigera* male was caught with Blend 5. At Dookie, only *H. punctigera* males were caught with the two blends. At Rutherglen, Blend 3 caught only *M. convecta* and Blend 5 caught both species. At all sites, Blend 5 caught more *H. punctigera* than Blend 3.

Two blank traps at each site were also run. At Swan Hill and Rutherglen, these traps did not catch any *M. convecta* or *H. punctigera*. At Rutherglen, 1 *H. punctigera* was caught in one blank trap.

	Blend 1	Blend 3	Blend 5
Swan Hill			
M. convecta	0	0	0.03 ± 0.02
H. punctigera	15.8 ± 2.3	0.05 ± 0.02	7.2 ± 1.2
Dookie			
M. convecta	0	0	0
H. punctigera	2.9 ± 0.4	0.02 ± 0.02	0.4 ± 0.1
Rutherglen			
M. convecta	0	0.05 ± 0.05	0.02 ± 0.02
H. punctigera	0.8 ± 0.5	0	0.12 ± 0.9

Table 12.17. Experiment 5. Mean (± s.e.) catches/day of *M. convecta* and *H. punctigera* in AgriSense traps with Blends 1, 3 and 5 at three sites in Victoria. Traps were not rotated and were cleared at least once a week. The traps ran for 82 days at Swan Hill, 41 days at Dookie and 19 days at Rutherglen.

Analyses of covariance were done to test the significance of the main factor, lure type (blend) as well as the covariate time, measured by the successive intervals (approximately 1 week) when the traps were cleared, and the interaction between these factors (Table 12.18). At Swan Hill and Dookie, lure type was significant for *H. punctigera*. The significance was due to differences in the catches which followed patterns similar to those observed in earlier experiments, i.e., Blend 1 > Blend 5 > Blend 3. The significance of time and the interaction for *M. convecta* at Swan Hill was due to the fact that all moths trapped were caught near the end of the experiment, and all were caught with the one blend (Blend 5). However, the numbers involved were small. At Dookie, time and the interaction between lure type and time were significant for *H. punctigera*. Catches with Blend 1 significantly increased over time while those with Blends 3 and 5 did not. The reason for this interaction was not clear, but the numbers involved were small compared with Swan Hill where no such interaction was observed. At Rutherglen, no significant effects were obtained.

	Blend	Interval	Blend x Interval
Swan Hill			
M. convecta	n.s.	$F_{1,60} = 6.18^{*}$	$F_{2,60} = 6.18^{**}$
H. punctigera	$F_{2,60} = 25.38^{***}$	n.s.	n.s.
Dookie			
M. convecta	-	-	-
H. punctigera	$F_{2,24} = 4.92^{*}$	$F_{1,24} = 8.55^{**}$	$F_{2,24} = 8.81^{**}$
Rutherglen			
M. convecta	n.s.	n.s.	n.s.
H. punctigera	n.s.	n.s.	n.s.

Table 12.18. Experiment 5. Summary of results of analyses of variance for *M. convecta* and *H. punctigera* males at three sites in Victoria. The number of * indicates level of significance and n.s., non-significance. No *M. convecta* moths were caught at Dookie.

During the experimental period, *H. punctigera* populations appeared to be high at Swan Hill, and low to moderate at the other sites. The Swan Hill traps collected 92% of the overall total of 4145 *H. punctigera* caught during the experiments. *M. convecta* populations were very low, as indicated by the FE traps at Swan Hill and Rutherglen. At Swan Hill, a total of 15 *M. convecta* males and 35 females were caught from two FE traps, compared with 6 males with Blend 5. At Rutherglen, 6 *M. convecta* females were caught from one FE trap, compared with 2 males with Blend 3, and 1 male with Blend 5. The low catches of *M. convecta* in all traps suggest that the Victorian experiments may not be good indicators of the relative attractiveness of the blends to this species. The results, however, were similar to the Boggabri experiments. Both Blends 3 and 5 caught *M. convecta* and *H. punctigera,* and catches of the latter were greater with Blend 5 than with Blend 3. Across all sites, Blend 1 caught a total of 2831 *H. punctigera*, while Blend 5 caught 1302 and Blend 3 caught only 12.

The specificity of the pheromone is influenced by the population of the target species relative to that of the non-target species having similar pheromone components (Byers & Struble, 1987). This was demonstrated in the experiments with Blends 3 and 5 at Boggabri and Swan Hill during spring when *H. punctigera* populations were high and *M. convecta* populations were low. Catches of the non-target species, (i.e., *H. punctigera*) were greater than those of the target species (i.e., *M. convecta*). Catches of *H. punctigera* in the traps baited with Blends 3 and 5 can be explained by the presence of Z11:16 Ald as the major component in the two blends as well as in the commercial *H. punctigera* lure.

12.3.1. Blends 1 and 5 as *H. punctigera* lures

The experiments showed that *H. punctigera* moths were caught with all three blends tested. Blend 1 was highly specific to *H. punctigera*, catching higher numbers than the commercial lure, and no *M. convecta.* Between Blends 3 and 5, the latter caught significantly more *H. punctigera* than the former, but both also caught *M. convecta.*

The current Australian blend for *H. punctigera* (Gregg & Wilson, 1991) is a 50:50:1 mixture of Z-11-hexadecenal (Z11:16 Ald), Z-11-hexadecenyl acetate (Z11:16 Ac) and Z-9-tetradecenal (Z-9:14 Ald) (Rothschild *et al.*, 1982b). Ovipositor extracts from *H. punctigera* females indicated the presence of Z11:16 Ald, Z11:16 Ac, Z11:16 OH, and 16 Ald (Rothschild *et al.*, 1982b). Blend 1 and the *H. punctigera* commercial lure have two common components, Z11:16 Ald and Z9:14 Ald. The difference between these two lures is Z9:16 Ald in Blend 1. This compound is also the only

difference between Blends 3 and 5 (Chapter 11.2.1). The higher numbers of *H. punctigera* caught with Blend 5 than with Blend 3 suggest that Z9:16 Ald could be an attractive component to this species. Rothschild *et al.* (1982b) did not positively identify Z9:16 Ald in the pheromone of *H. punctigera.* However, they found small amounts of a substance they thought might be either Z9: or Z7:16 Ald. The results in this thesis strongly suggest that their unknown substance may have been Z9:16 Ald.

If Z9:16 Ald is attractive to *H. punctigera,* this contrasts with the situation in *M. convecta* where Z9:16 Ald elicited close-range behaviours but not more approach, and not higher trap catches. In turn, this suggests that in the hierarchal model, *H. punctigera* is using Z9:16 Ald earlier in the sequence (Chapter 11.3.3). These results suggest that a better commercial lure for *H. punctigera* might be developed by modifying either Blend 1 or the currently used lure, through the inclusion of Z9:16 Ald. Such an addition is unlikely to cause problems with contamination of the catch by *M. convecta.* However, the specificity of the lure with regard to *H. armigera* would require further investigation, as it was not tested when populations of this species were high.

An improved *H. punctigera* lure would be useful in several ways. One is in detecting spring immigrations into the grain legume areas in the south-eastern and western parts of Australia. *H. punctigera* is a serious pest of grain legumes such as field peas and beans in Victoria (Ridland *et al.,* 1993) and lupins in Western Australia (Walden, 1992). Gregg *et al.* (1993) reported that *Helicoverpa* spp., particularly *H. punctigera,* breed in winter in inland Australia if sufficient autumn rains occur to provide lush growth of host plants in these areas. In Western Australia, winter breeding of this species has been found to the north or north-east of the lupin-growing areas (Walden, 1992). Spring immigrations to these cropping areas are common, and the progeny of the spring immigrants can cause economic damage to these crops. Pheromone and light traps are being used in Victoria and Western Australia to monitor *Helicoverpa* spp. populations (Ridland *et al.,* 1993; Walden, 1992). Pheromone traps with the improved lures for *H. punctigera* that catch up to 3.9x than the current commercial lure (as was the case with Blend 1 at Kootingal), would provide more reliable monitoring tools.

In line with the resistance management strategy for *H. armigera* in cotton, species discrimination of *Helicoverpa* eggs and young larvae is necessary before spray decisions are made (Forrester *et al.,* 1993). However, catches from pheromone traps using the commercial *Helicoverpa* lures were poor indicators of species composition

of eggs laid in the fields adjacent to traps (Daly & Fitt, 1993). On the other hand, studies by Wilson & Morton (1989) suggested that pheromone traps can be useful to determine the relative abundance of *Helicoverpa* spp. provided cone traps are used, and are placed 40 m within, rather than on, the edges of the crop. Although a field identification kit to distinguish *H. armigera* from *H. punctigera* has been developed (Trowell *et al.*, 1993), *H. punctigera* pheromone traps with lures more effective than the currently used lures might still be useful in quantitative studies to determine species composition. Logistical requirements for operating pheromone traps would probably be less than those for the identification kit, which is expensive and can only be used once.

Pheromone traps are useful tools in forecasting outbreak or non-outbreak seasons of insect pests. *Helicoverpa* forecasts in eastern Australia made by the *Helicoverpa* Inland Research Group (HIRG), a collaborative research group studying the population dynamics of *Helicoverpa* spp. in inland Australia, were based on inland surveys and pheromone and light trapping programme (Dale *et al.*, 1992). Again, pheromone traps using improved lures for *H. punctigera* might be more reliable monitoring tools for this purpose.

12.3.2. Prospects for the development of a pheromone trap for *M. convecta*

A desirable pheromone trap for *M. convecta* is one that is highly specific for this species. Trap catches should be correlated with female oviposition to be a reliable predictor of potential damage. The trap should be cheap, simple to operate and easily serviced.

Two lures (Blends 3 and 5) were shown to catch *M. convecta* in numbers comparable to the previous best method, i.e., the FE trap. These blends, however, were not tested under high *M. convecta* populations or in outbreak conditions, hence how well they will work in the field still needs further investigation. The field experiments were conducted when most of eastern Australia experienced drought conditions which affected the quantity and quality of available hosts for this species. Average FE trap catches of *M. convecta* during the experiments ranged from 0.3/day at Dookie to 4.2/day at Kootingal. By contrast, in 1988 (when conditions were more favourable) Del Socorro (1991) frequently recorded catches of 50-125 *M. convecta* per day in FE traps in the Armidale area.

Comparisons of *M. convecta* catches between FE and Blend 3 or Blend 5 pheromones yielded variable results. Across all experiments, the general impression

was that the FE and pheromone lures were about equally attractive. However, there were occasions (Experiments 3a and 4b at Boggabri, and possibly Swan Hill) when FE catches were higher than pheromone catches. On other occasions (Experiment 4a, and the interval between Experiments 4a and 4b) the reverse was true. This suggests that food lures such as the FE and pheromones might be more or less attractive in different circumstances (such as when moths are at different stages of reproductive development). Further investigation of this phenomenon might help in the interpretation of pheromone trap catches.

The two blends were not entirely specific for *M. convecta*. They also caught *H. punctigera*, especially Blend 5. This is a problem, because *H. punctigera* is sympatric with *M. convecta* over wide areas of Australia. The two species migrate at similar times (Gregg *et al.*, 1994, in press; McDonald, 1994, in press). To entomologists, the species are readily distinguishable, but they might be confused by farmers, especially if specimens were battered, as they often are in pheromone traps. *H. punctigera* is not a cereal pest. Although it has been previously recorded on rice, forage sorghum, wheat and maize, it is unlikely that larvae would survive on these hosts (Zalucki *et al.*, 1986). Thus, misidentification of *H. punctigera* caught in *M. convecta* pheromone traps might lead to false alarms.

Further studies aimed at improving the attractiveness and specificity of the lures are therefore needed, starting with Blend 3 as a base. Blend 3 caught more *M. convecta* and less *H. punctigera* than Blend 5. The four unknown minor substances found in the gland and air samples from *M. convecta* females (Chapter 10) should be identified, and their functional role investigated. Further testing of synthetic equivalents in the wind tunnel and in field trapping experiments is needed.

If a better lure was developed, the type of trap that would suit the purpose has been determined by the studies in this thesis. The experiments reported here have shown that Texas traps were more efficient for both *H. punctigera* and *M. convecta* than the other designs. These traps also proved to be the most efficient for another *Helicoverpa* species, *H. armigera* (Sage & Gregg, 1985). This suggests that the behavioural response of *M. convecta* to traps is similar to *Helicoverpa* spp. Once a moth approaches the trap and enters the skirt, its tendency is to climb upward and thus, it ends up in the collecting bag (Sage & Gregg, 1985). However, the AgriSense dry funnel traps are cheaper and easier to operate (the catch is killed) than the Texas traps, so this type probably would be more practical and advantageous as the commercial type for *M. convecta*.

CHAPTER 13

SUMMARY AND CONCLUSIONS

Initial attempts to characterise the components found in the pheromone glands of *M. convecta* were done by T. Bellas and C. Whittle of CSIRO. They identified five compounds. These were Z-11-hexadecenal (Z11:16 Ald), Z-11-hexadecen-1-ol (Z11:16 OH), n-hexadecanal (16 Ald), Z-9-hexadecenal (Z9:16 Ald) and Z-9-tetradecenal (Z9:14 Ald), with a ratio of 1:0.17:0.15:0.05:0.005. Field testing of this blend, however, was unsuccessful.

Further attempts to identify the pheromone components of *M. convecta* were conducted by pheromone gland washing and collection of airborne volatiles from calling females. Pheromone analyses were done by gas-chromatography using six compounds as standards. These compounds were the five substances identified by CSIRO and Z-11-hexadecenyl acetate (Z11:16 Ac), the major component of another armyworm species, *P. unipuncta*. In both samples, Z11:16 Ald was the major component, which was consistent with the CSIRO study. Two compounds, Z9:14 Ald and Z11:16 Ac were not detected in either the gland or air samples. Four unknown minor components were found in both the gland and air samples.

Three of the components (Z11:16 Ald, 16 Ald and Z11:16 OH) found in the *M. convecta* pheromone comprise the blend of a closely related species, *M. separata*. Similarities between these species in morphology and pheromone components raise questions about their reproductive isolation. Electrophoretic studies to determine the extent of genetic differences between them might help resolve this.

Five synthetic pheromone blends, with Z11:16 Ald as the major component, were tested in the wind tunnel at various dosages. Blend 1 was the CSIRO blend consisting of Z11:16 Ald, Z11:16 OH, 16 Ald, Z9:16 Ald and Z9:14 Ald. Blend 2 was similar to blend 1 but excluding the smallest minor component, Z9:14 Ald. Blend 3 was equivalent to the *M. separata* blend with three components, Z11:16 Ald, 16 Ald and Z11:16 OH. Blend 4 also consisted of the same three components found in Blend 3, but with an altered ratio of Z11:16 OH to 16 Ald. Blend 5 had the same three components of the same ratios as in Blend 3, but had a fourth minor component, Z9:16 Ald.

Blends 1, 2 and 3 were tested at 0.01, 0.1, 10 and 100 μg; Blend 4 at 0.1 μg only and Blend 5 at 0.1 and 10 μg doses. Males were scored for take off, upwind flight, approach, landing, clasper extrusion and baulking. Baulking behaviour was not observed with the blank source or live females. Baulking males flew upwind to about 20-30 cm from the source then quickly backed-off from the source. Since male approach to calling females was shown to be dependent on the time of the scotophase at which males were released in the wind tunnel, male responses (designated by approach behaviour) to these various blends and doses were compared with the response that would have been expected if males were flown to females at similar times.

One- and 2-day-old males did not exhibit approach, landing, clasper extrusion or baulking, suggesting that reproductive maturation did not occur until after 2 days. Blends 1, 2 and 4 elicited low levels of approach and variable levels of baulking. Landing and clasper extrusion were not observed with these blends. On the other hand, Blends 3 and 5 gave higher levels of approach. Close-range behaviours such as landing and clasper extrusion were observed and baulking did not occur with these blends. In Blends 3 and 5, the amount of 16 Ald was greater than Z11:16 OH, whereas in Blends 1, 2 and 4, the amount of Z11:16 OH was greater than 16 Ald. The blends that were comparable to, if not significantly better than calling females, were Blends 3 and 5. Between these blends, landing and clasper extrusion with copulatory attempt were greater with Blend 5.

A hierarchy of sequential responses of *M. convecta* males to individual pheromone components was proposed. The major component, Z11:16 Ald mediates long-range attraction and upwind flight to the source. Once upwind, close approach or baulking may be due to either Z11:16 OH or 16 Ald, or the ratio between them. Z9:16 Ald appeared to be important in eliciting close-range behaviours such as landing and copulatory attempt. These behaviours were greater with Blend 5 which had Z9:16 Ald, compared with Blend 3 which did not have this minor component. The possible role of the four unknown minor components in each stage of the sequence is not understood.

The study showed that male responsiveness to the sex pheromone depended on a "response window". In comparison with female calling, however, the male window appeared to be slightly narrower. A possible explanation concerns energy expenditure and risk of predation on the part of the male. A male flying to locate a female uses

much energy and may be vulnerable to nocturnal birds or bats, whereas a female can call from a protected position.

Three synthetic blends (1, 3 and 5) were tested in the field. Experiments were conducted at Armidale, Kootingal and Boggabri in NSW and Swan Hill, Dookie and Rutherglen in Victoria. Fermentation (FE) traps were also operated to provide an index of the presence or absence of *M. convecta* moths in the area.

In NSW, Blend 1 was tested at Armidale and Kootingal using different trap designs. This blend did not catch *M. convecta* but did catch large numbers of *Helicoverpa punctigera.* The Texas trap was more efficient in catching *H. punctigera* than the AgriSense or Hara traps. The relative attractiveness of Blend 1 to the commercial *Helicoverpa* lures was estimated to be 3.9 times at Kootingal. Blends 3 and 5 were tested at Boggabri. In the first experiment, Blend 3 was tested using Texas, Agrisense and Hara traps. Blend 3 caught *M. convecta* males, the numbers of which, were comparable to the numbers caught in the FE trap. This blend did not catch *H. punctigera* in any of the traps, but *H. punctigera* numbers were thought to be low at the time of the experiment. The numbers of *M. convecta* caught were higher in the Texas traps than in the other designs. Two experiments were done later, testing both Blends 3 and 5 and using Texas traps only. The *H. punctigera* population at this time was high, as indicated by the catches with the commercial lure, while *M. convecta* numbers were low. *M. convecta* and *H. punctigera* were caught with both blends. In both experiments, Blend 3 caught about equal numbers of *M. convecta* and *H. punctigera*, whereas Blend 5 caught many more *H. punctigera* than *M. convecta.*

In Victoria, Blends 1, 3 and 5 were tested using AgriSense traps at Swan Hill, Dookie and Rutherglen. During the experiments, *H. punctigera* populations were very high at Swan Hill, while *M. convecta* populations were very low at Swan Hill and Rutherglen as indicated by the FE traps. Blend 1 caught the largest numbers of *H. punctigera* but no *M. convecta.* Blends 3 and 5 caught a few *M. convecta.* Blend 3 caught only a few *H. punctigera*, while Blend 5 caught about half the *H. punctigera* that Blend 1 did.

Blend 1 was highly specific to *H. punctigera* and did not catch any *M. convecta.* This blend appeared to be more effective than the commercial *H. punctigera* lure. Blends 3 and 5 catch *M. convecta,* but also catch *H. punctigera,* particularly when this species is abundant. Blend 5 caught more *H. punctigera* than Blend 3. These results suggest that both Blends 1 and 5 are potential *H. punctigera* lures.

Z9:16 Ald was previously thought to be a minor component in the *H. punctigera* pheromone and this compound is found in Blends 1 and 5 but not in Blend 3. A better commercial lure for this species might be possible by modifying Blend 1 or by including Z9:16 Ald in the currently used commercial lure.

Blend 3 offers more potential for development as a commercial pheromone for *M. convecta* than Blend 5. However, this blend was not entirely specific for *M. convecta.* The experiments were conducted when *M. convecta* populations were low compared with previous years. Thus, this blend needs to be tested under high *M. convecta* populations. Of the different traps tested, Texas traps appeared to be more efficient than the AgriSense or Hara traps. However, AgriSense traps are cheaper and easier to operate than Texas traps. Thus, this type might be more practical for commercial purposes.

The study was the initial attempt to investigate the calling behaviour of *M. convecta* females and behavioural responses of males to the natural sex pheromone as well as to various synthetic blends. There are still many aspects that need to be examined in order to fully understand the pheromone biology of this species, such as the relationship between calling and ovarian development to clarify the reproduction-flight syndrome, the relationship between calling and pheromone titre, and the effects of other exogenous factors on calling. Potential pheromone lures for *M. convecta* have been tested in the field. Further studies to improve the specificity should be done starting with Blend 3 as the base. Likewise, the four unknown minor substances should be identified. Electroantennogram assays would be useful to determine what substances are detected by males.

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